طرح نگهداشت و افزایش تولید 27 مخزن

MECHANICAL CALCULATION BOOK FOR GLYCOL FLASH DRUM (V-120)

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

پروژه	بسته کاری	صادرکننده	تسهیلات	رشته	نوع مدرک	سریال	نسخه
BK	GCS	MF	120	ME	CN	0003	V00

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	X				
220	X				
221	X				
222	X				
223	X				
224	X				
225	X				
226	X				
227	X				
228	X				
229	X				
230	X				
231	X				
232	X				
233	X				
234	X				
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\V-120\V

Date of Analysis       : Dec 23,2024    4:29pm

PV Elite 2020, January 2020
```

ASME Code, Section VIII Division 1, 2019

Diameter Spec : 1100.000 mm. ID		
Vessel Design Length, Tangent to Tangent	3400.00	mm.
Specified Datum Line Distance	0.00	mm.
Internal Design Temperature	120	°C
Internal Design Pressure	8.000	bars
External Design Temperature	100	°C
External Design Pressure	1.034	bars
Maximum Allowable Working Pressure	8.574	bars
External Max. Allowable Working Pressure	1.968	bars
Hydrostatic Test Pressure	10.400	bars
Required Minimum Design Metal Temperature	5.0	°C
Warmest Computed Minimum Design Metal Temperature	-29.0	°C
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-516 70	...	...	K02700	No	No
Head	SA-516 70	...	...	K02700	No	No
Nozzle	SA-105	...	...	K03504	No	No
Nozzle	SA-516 70	...	...	K02700	No	No
Nozzle	SA-106 B	...	...	K03006	No	No
Re-Pad	SA-516 70	...	...	K02700	No	No
Nozzle Flg	SA-105	...	...	K03504	No	No
Rings	SA-516 70	...	...	K02700	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
Ellipse	8.056	1.03	10.000	6.0000	No	No
Cylinder	8.056	1.03	15.000	6.0000	N/A	No
Cylinder	8.056	1.03	15.000	6.0000	N/A	No
Ellipse	8.056	1.03	10.000	6.0000	No	No

Liquid Level: 550.00 mm. Dens.: 1019.530 kg/m³ Sp. Gr.: 1.020

Stiffener Ring Specifications:

Elevation mm.	Selected Type	User Description
1700.00	Bar 88.0 x 12.	Ring R1 Fr30

Element Types and Properties:

Element Type	"To" Elev mm.	Element Length mm.	Nominal Thickness mm.	Finished Thickness mm.	Reqd Thk Internal mm.	Reqd Thk External mm.	Long Eff	Circ Eff
Ellipse	50.0	50.0	12.0	10.0	9.2	...	1.00	1.00
Cylinder	1650.0	1600.0	...	12.0	9.3	...	1.00	1.00
Cylinder	3350.0	1700.0	...	12.0	9.3	...	1.00	1.00
Ellipse	3400.0	50.0	12.0	10.0	9.2	...	1.00	1.00

External Pressure Calculations:

From	To	External Actual T. mm.	External Required T. mm.	External Design Pressure bars	External M.A.W.P. bars
10	20	10	8.89963	1.034	1.96782
20	30	12	10.3799	1.034	2.29442
30	Ring	12	10.3799	1.034	2.29442
Ring	40	12	10.3799	1.034	2.29442
40	50	10	8.89963	1.034	1.96782

External Pressure Calculations:

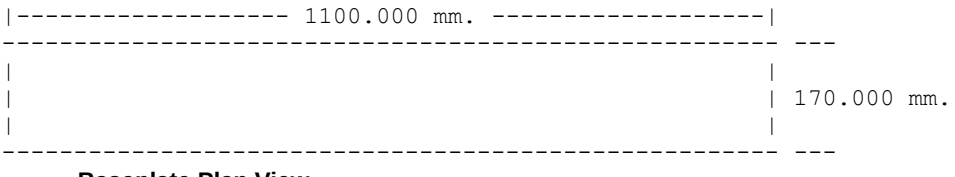
From	To	Actual Length Bet. Stiffeners mm.	Allowable Length Bet. Stiffeners mm.	Ring Inertia Required cm**4	Ring Inertia Available cm**4
10	20	No Calc	No Calc	No Calc	No Calc
20	30	1791.67	3830.13	No Calc	No Calc
30	Ring	1791.67	3830.13	No Calc	No Calc
Ring	40	1791.67	3830.13	18.0627	147.429
40	50	No Calc	No Calc	No Calc	No Calc

Saddle Parameters:

Saddle Width	150.000	mm.
Saddle Bearing Angle	120.000	deg.
Centerline Dimension	1200.000	mm.
Wear Pad Width	200.000	mm.
Wear Pad Thickness	12.000	mm.
Wear Pad Bearing Angle	135.000	deg.
Distance from Saddle to Tangent	300.000	mm.
Baseplate Length	1100.000	mm.
Baseplate Thickness	15.000	mm.
Baseplate Width	170.000	mm.

Number of Ribs (including outside ribs)	4	
Rib Thickness	15.000	mm.
Web Thickness	15.000	mm.
Height of Center Web	635.000	mm.
Number of Bolts in Baseplate	4	

Baseplate Sketch



Baseplate Plan View

Baseplate Side View

Maximum Tensile Bolt Load	0.	kN

Summary of Maximum Saddle Loads, Operating Case:

Maximum Vertical Saddle Load	39.29	kN
Maximum Transverse Saddle Shear Load	5.19	kN
Maximum Longitudinal Saddle Shear Load	10.39	kN

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

Maximum Vertical Saddle Load	47.35	kN
Maximum Transverse Saddle Shear Load	18.81	kN
Maximum Longitudinal Saddle Shear Load	14.84	kN

Summary of Maximum Saddle Loads, Hydrotest Case :

Maximum Vertical Saddle Load	33.75	kN
Maximum Transverse Saddle Shear Load	0.19	kN
Maximum Longitudinal Saddle Shear Load	0.21	kN

Weights:

Fabricated - Bare W/O Removable Internals	2785.3	kg.
Shop Test - Fabricated + Water (Full)	6363.3	kg.
Shipping - Fab. + Rem. Intls.+ Shipping App.	2887.5	kg.
Erected - Fab. + Rem. Intls.+ Insul. (etc)	2887.5	kg.
Empty - Fab. + Intls. + Details + Wghts.	2887.5	kg.
Operating - Empty + Operating Liquid (No CA)	4712.3	kg.
Field Test - Empty Weight + Water (Full)	5792.1	kg.

Nozzle Calculation Summary:

Description	MAWP bars	Ext	MAPNC bars	UG-45	[tr] mm.	Weld Path	Areas or Stresses
N08 (1in)	10	OK	...	OK	9.20	OK	Passed
N08 (1in)	10	OK	...	OK	9.20	OK	Passed
N01 (1in)	15	OK	...	OK	9.24	OK	Passed
N05A (1.5in)	15	OK	...	OK	9.26	OK	Passed
N06 (1in)	15	OK	...	OK	9.24	OK	Passed
N07 (1in)	15	OK	...	OK	9.24	OK	Passed
N09 (1in)	15	OK	...	OK	9.24	OK	Passed
M1 (20in)	15	OK	...	...		OK	Passed
K06 (2in)	15	OK	...	OK	9.25	OK	Passed
K06 (2in)	15	OK	...	OK	9.25	OK	Passed
N02 (1in)	15	OK	...	OK	9.26	OK	Passed
N03 (1in)	15	OK	...	OK	9.24	OK	Passed
N04 (1in)	15	OK	...	OK	9.26	OK	Passed
N05B (1.5in)	15	OK	...	OK	9.26	OK	Passed
K3A (3in)	9	OK	...	OK	9.24	OK	Passed
K3A (3in)	9	OK	...	OK	9.24	OK	Passed
K3B (3in)	9	OK	...	OK	9.25	OK	Passed
K3B (3in)	9	OK	...	OK	9.25	OK	Passed
K05 (2in)	15	OK	...	OK	9.24	OK	Passed
K4B (2in)	15	OK	...	OK	9.25	OK	Passed
K4B (2in)	15	OK	...	OK	9.25	OK	Passed
K4A (2in)	15	OK	...	OK	9.24	OK	Passed
K4A (2in)	15	OK	...	OK	9.24	OK	Passed
K2B (2in)	15	OK	...	OK	9.24	OK	Passed
K2B (2in)	15	OK	...	OK	9.24	OK	Passed
K2A (2in)	15	OK	...	OK	9.24	OK	Passed
K2A (2in)	15	OK	...	OK	9.24	OK	Passed
K1B (3in)	9	OK	...	OK	9.25	OK	Passed
K1B (3in)	9	OK	...	OK	9.25	OK	Passed
K1A (3in)	9	OK	...	OK	9.24	OK	Passed
K1A (3in)	9	OK	...	OK	9.24	OK	Passed

Nozzle MAWP Summary:

```
Minimum MAWP Nozzles         :              9 Nozzle  : K1B (3in)
Minimum MAWP Shells/Flanges  :             10 Element :
Minimum MAPnc Shells/Flanges :             20 Element :
-----------------------------------------------------
Computed Vessel M.A.W.P.     :              9 bars
```

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.
10	N08 (1in)	0.000	270.000	74.800
20	N01 (1in)	200.000	90.000	74.800
20	N05A (1.5in)	1550.000	270.000	100.200
20	N06 (1in)	1350.000	90.000	74.800
20	N07 (1in)	1100.000	90.000	74.800
20	N09 (1in)	850.000	90.000	74.800
20	M1 (20in)	1150.000	0.000	992.000
20	K06 (2in)	250.000	-32.263	125.600
30	N02 (1in)	3250.000	270.000	74.800
30	N03 (1in)	3150.000	90.000	74.800
30	N04 (1in)	2126.000	270.000	74.800
30	N05B (1.5in)	3050.000	270.000	100.200
30	K3A (3in)	2126.000	6.334	162.862
30	K3B (3in)	2126.000	-45.377	162.862
30	K05 (2in)	1850.000	90.000	125.600
30	K4B (2in)	2400.000	-45.377	125.600
30	K4A (2in)	2400.000	-14.846	125.600
30	K2B (2in)	2650.000	-15.480	125.600
30	K2A (2in)	2650.000	10.872	125.600
30	K1B (3in)	3150.000	-45.377	162.862
30	K1A (3in)	3150.000	15.480	162.862

The nozzle spacing is computed by the following:
= Sqrt($ll^2 + lc^2$) where
ll - Arc length along the inside vessel surface in the long. direction.
lc - Arc length along the inside vessel surface in the circ. direction

If any interferences/violations are found, they will be noted below.
No interference violations have been detected !

Bill of Materials:

QTY	DESCRIPTION	MATERIAL
2	ELLIPTICAL HEAD: 2.0 X 1, 12.0mm. THK X 1100.0mm. ID X 50.0mm.	SA-516 70
1	CYLINDER: 12.0mm. THK X 1100.0mm. ID X 1600.0mm.	SA-516 70
1	CYLINDER: 12.0mm. THK X 1100.0mm. ID X 1700.0mm.	SA-516 70
2	INSULATION: 325mm X 50mm THK	
2	SADDLE: 150mm X 120 DEG	SA-516 70
1	INSULATION: 1600mm X 50mm THK	
1	INSULATION: 1700mm X 50mm THK	
1	BAR RING STIFFENER: 1124mm ID X 1300mm OD X 12mm	SA-516 70
1	CLASS 150 GR 1.1, 20.0" BLIND FLANGE(S)	SA-516 70
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
N08 (1in)	1.000 in	Actual	LW	2.000	12.700	...	...	172.4	150
N01 (1in)	1.000 in	Actual	LW	2.000	12.700	...	...	362.0	150
N06 (1in)	1.000 in	Actual	LW	2.000	12.700	...	...	162.5	150
N07 (1in)	1.000 in	Actual	LW	2.000	12.700	...	...	162.5	150
N09 (1in)	1.000 in	Actual	LW	2.000	12.700	...	...	162.5	150
N02 (1in)	1.000 in	Actual	LW	2.000	12.700	...	...	162.5	150
N03 (1in)	1.000 in	Actual	LW	2.000	12.700	...	...	162.5	150
N04 (1in)	1.000 in	Actual	LW	2.000	12.700	...	...	162.5	150
N05A (1.5in)	1.500 in	Actual	LW	2.638	14.450	...	...	163.0	150
N05B (1.5in)	1.500 in	Actual	LW	2.638	14.450	...	...	163.0	150
K06 (2in)	2.000 in	Actual	LW	3.320	16.764	...	...	194.6	300
K05 (2in)	2.000 in	Actual	LW	3.320	16.764	...	...	163.6	300
K4B (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	317.4	300
K4A (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	175.6	300
K2B (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	176.2	300
K2A (2in)	2.000 in	Actual	LW	3.307	16.600	...	...	172.2	300
K3A (3in)	3.000 in	160	WN	3.500	11.125	...	...	168.9	300
K3B (3in)	3.000 in	160	WN	3.500	11.125	...	...	320.7	300
K1B (3in)	3.000 in	160	WN	3.500	11.125	...	...	320.7	300
K1A (3in)	3.000 in	160	WN	3.500	11.125	...	...	227.1	300
M1 (20in)	20.000 in	Actual	WN	20.000	12.000	750.00	12.00	224.1	150

General Notes for the above table:

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

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

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

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

Description	Material	Shl Grve Weld	Noz Shl/Pad Weld	Pad OD Weld	Pad Grve Weld	Inside Weld
N08 (1in)	SA-105	10.000	8.000	...	...	...
N01 (1in)	SA-105	12.000	8.000	...	...	...
N06 (1in)	SA-105	12.000	8.000	...	...	...
N07 (1in)	SA-105	12.000	8.000	...	...	...
N09 (1in)	SA-105	12.000	8.000	...	...	...
N02 (1in)	SA-105	12.000	8.000	...	...	...
N03 (1in)	SA-105	12.000	8.000	...	...	...
N04 (1in)	SA-105	12.000	8.000	...	...	...
N05A (1.5in	SA-105	12.000	8.000	...	...	...
N05B (1.5in	SA-105	12.000	8.000	...	...	...
K06 (2in)	SA-105	12.000	10.000	...	...	...
K05 (2in)	SA-105	12.000	8.000	...	...	...
K4B (2in)	SA-105	12.000	8.000	...	...	...
K4A (2in)	SA-105	12.000	8.000	...	...	...
K2B (2in)	SA-105	12.000	8.000	...	...	...
K2A (2in)	SA-105	12.000	8.000	...	...	...
K3A (3in)	SA-106 B	12.000	6.000	...	...	...
K3B (3in)	SA-106 B	12.000	6.000	...	...	...
K1B (3in)	SA-106 B	12.000	6.000	...	...	...
K1A (3in)	SA-106 B	12.000	6.000	...	...	...
M1 (20in)	SA-516 70	12.000	8.000	10.000	12.000	...

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

Nozzle Miscellaneous Data:

Description	Elev/Distance From Datum mm.	Layout Angle deg	Proj Outside mm.	Proj Inside mm.	Installed in Component
N08 (1in)	...	270.0	150.00	0.00	Node: 10
N01 (1in)	200.000	90.0	150.00	200.00	Node: 20
N06 (1in)	1350.000	90.0	150.00	0.00	Node: 20
N07 (1in)	1100.000	90.0	150.00	0.00	Node: 20
N09 (1in)	850.000	90.0	150.00	0.00	Node: 20
N02 (1in)	3250.000	270.0	150.00	0.00	Node: 30
N03 (1in)	3150.000	90.0	150.00	0.00	Node: 30
N04 (1in)	2126.000	270.0	150.00	0.00	Node: 30
N05A (1.5in)	1550.000	270.0	150.00	0.00	Node: 20
N05B (1.5in)	3050.000	270.0	150.00	0.00	Node: 30
K06 (2in)	250.000	-32.3	150.00	0.00	Node: 20
K05 (2in)	1850.000	90.0	150.00	0.00	Node: 30
K4B (2in)	2400.000	-45.4	250.00	0.00	Node: 30
K4A (2in)	2400.000	-14.8	150.00	0.00	Node: 30
K2B (2in)	2650.000	-15.5	150.00	0.00	Node: 30
K2A (2in)	2650.000	10.9	150.00	0.00	Node: 30
K3A (3in)	2126.000	6.3	150.00	0.00	Node: 30
K3B (3in)	2126.000	-45.4	250.00	0.00	Node: 30
K1B (3in)	3150.000	-45.4	250.00	0.00	Node: 30
K1A (3in)	3150.000	15.5	200.00	0.00	Node: 30
M1 (20in)	1150.000	0.0	150.00	0.00	Node: 20

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
	[10]	B	-29	-37	-29	0.858	10.000	1.00	Yes
	[7]	B	-23	-47	-29	0.582	12.000	1.00	Yes
	[8]	B	-23	-47	-29	0.582	12.000	1.00	Yes
	[8]	B	-23	-47	-29	0.582	12.000	1.00	Yes
	[10]	B	-29	-37	-29	0.858	10.000	1.00	Yes
	[7]	B	-23	-47	-29	0.582	12.000	1.00	Yes
N08 (1in)	[1]	A	-8	-29	-29	0.722	10.000	1.00	Yes
Nozzle Flg	[5]	A	-18	-48					
N01 (1in)	[1]	A	-3	-30	-29	0.539	12.000	1.00	Yes
Nozzle Flg	[5]	A	-29	-48					
N05A (1.5in)	[1]	A	-3	-30	-29	0.543	12.000	1.00	Yes
Nozzle Flg	[5]	A	-29	-48					
N06 (1in)	[1]	A	-3	-30	-29	0.539	12.000	1.00	Yes
Nozzle Flg	[5]	A	-29	-48					
N07 (1in)	[1]	A	-3	-30	-29	0.539	12.000	1.00	Yes
Nozzle Flg	[5]	A	-29	-48					
N09 (1in)	[1]	A	-3	-30	-29	0.539	12.000	1.00	Yes
Nozzle Flg	[5]	A	-29	-48					
M1 (20in)	[1]	B	-23	-48	-29	0.539	12.000	1.00	Yes
Nozzle Flg	[5]	A	-29	-48					
K06 (2in)	[1]	A	-3	-30	-29	0.541	12.000	1.00	Yes
Nozzle Flg	[5]	A	-29	-104					
N02 (1in)	[1]	A	-3	-30	-29	0.543	12.000	1.00	Yes
Nozzle Flg	[5]	A	-18	-48					
N03 (1in)	[1]	A	-3	-30	-29	0.539	12.000	1.00	Yes
Nozzle Flg	[5]	A	-18	-48					
N04 (1in)	[1]	A	-3	-30	-29	0.543	12.000	1.00	Yes
Nozzle Flg	[5]	A	-18	-48					
N05B (1.5in)	[1]	A	-3	-30	-29	0.543	12.000	1.00	Yes
Nozzle Flg	[5]	A	-18	-48					
K3A (3in)	[1]	B	-8	-104	-29	0.074	9.735	1.00	Yes
Nozzle Flg	[5]	A	-18	-104					
K3B (3in)	[1]	B	-8	-104	-29	0.075	9.735	1.00	Yes
Nozzle Flg	[5]	A	-18	-104					
K05 (2in)	[1]	A	-3	-30	-29	0.539	12.000	1.00	Yes
Nozzle Flg	[5]	A	-18	-104					
K4B (2in)	[1]	A	-3	-30	-29	0.542	12.000	1.00	Yes
Nozzle Flg	[5]	A	-18	-104					
K4A (2in)	[1]	A	-3	-30	-29	0.540	12.000	1.00	Yes
Nozzle Flg	[5]	A	-18	-104					
K2B (2in)	[1]	A	-3	-30	-29	0.540	12.000	1.00	Yes
Nozzle Flg	[5]	A	-18	-104					
K2A (2in)	[1]	A	-3	-30	-29	0.539	12.000	1.00	Yes
Nozzle Flg	[5]	A	-18	-104					
K1B (3in)	[1]	B	-8	-104	-29	0.075	9.735	1.00	Yes
Nozzle Flg	[5]	A	-18	-104					
K1A (3in)	[1]	B	-8	-104	-29	0.074	9.735	1.00	Yes
Nozzle Flg	[5]	A	-18	-104					

Warmest MDMT: -3 -29

Required Minimum Design Metal Temperature 5.0 °C
Warmest Computed Minimum Design Metal Temperature -29.0 °C

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
================================================================================
```

There were no geometry errors or warnings.

PV Elite Vessel Analysis Program: Input Data

Design Internal Pressure (for Hydrotest)	8	bars
Design Internal Temperature	120.0	°C
Type of Hydrotest	UG-99(b) Note [36]	
Hydrotest Position	Horizontal	
Projection of Nozzle from Vessel Top	0	mm.
Projection of Nozzle from Vessel Bottom	0	mm.
Minimum Design Metal Temperature	5.0	°C
Type of Construction	Welded	
Special Service	Lethal	
Degree of Radiography	RT-1	
Use Higher Longitudinal Stresses (Flag)	Y	
Select t for Internal Pressure (Flag)	N	
Select t for External Pressure (Flag)	N	
Select t for Axial Stress (Flag)	N	
Select Location for Stiff. Rings (Flag)	N	
Consider Vortex Shedding	Y	
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
Distance "FROM" to "TO"                          50    mm.
Inside Diameter                                1100    mm.
Element Thickness                                10    mm.
Internal Corrosion Allowance                      6    mm.
```

Nominal Thickness	12	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	8	bars
Design Temperature Internal Pressure	120	°C
Design External Pressure	1.034	bars
Design Temperature External Pressure	100	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	
Allowable Stress, Ambient	137.9	N./mm²
Allowable Stress, Operating	137.9	N./mm²
Allowable Stress, Hydrotest	235.81	N./mm²
Material Density	7750.4	kg/m³
P Number Thickness	31.75	mm.
Yield Stress, Operating	235.98	N./mm²
UCS-66 Chart Curve Designation	B	
External Pressure Chart Name	CS-2	
UNS Number	K02700	
Product Form	Plate	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Elliptical Head Factor	2.0	
Weld is pre-Heated	No	
Element From Node	10	
Detail Type	Liquid	
Detail ID	Liquid: 10	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	550	mm.
Liquid Density	1019.5	kg/m³
Element From Node	10	
Detail Type	Insulation	
Detail ID	Ins: 20	
Dist. from "FROM" Node / Offset dist	-275	mm.
Height/Length of Insulation	325	mm.
Thickness of Insulation	50	mm.
Density	125	kg/m³
Element From Node	10	
Detail Type	Nozzle	
Detail ID	N08 (1in)	
Dist. from "FROM" Node / Offset dist	400	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.03182	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	

Element From Node	20	
Element To Node	30	

Element Type	Cylinder	
Description		
Distance "FROM" to "TO"	1600	mm.
Inside Diameter	1100	mm.
Element Thickness	12	mm.
Internal Corrosion Allowance	6	mm.
Nominal Thickness	0	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	8	bars
Design Temperature Internal Pressure	120	°C
Design External Pressure	1.034	bars
Design Temperature External Pressure	100	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Weld is pre-Heated	No	
Element From Node	20	
Detail Type	Saddle	
Detail ID	Lft Sdl	
Dist. from "FROM" Node / Offset dist	450	mm.
Width of Saddle	150	mm.
Height of Saddle at Bottom	1200	mm.
Saddle Contact Angle	120.0	
Height of Composite Ring Stiffener	0	mm.
Width of Wear Plate	200	mm.
Thickness of Wear Plate	12	mm.
Contact Angle, Wear Plate (degrees)	135.0	
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	20	
Detail Type	Liquid	
Detail ID	Liquid: 20	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	550	mm.
Liquid Density	1019.5	kg/m³
Element From Node	20	
Detail Type	Insulation	
Detail ID	Ins: 20	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	1600	mm.
Thickness of Insulation	50	mm.
Density	125	kg/m³
Element From Node	20	
Detail Type	Nozzle	
Detail ID	N01 (1in)	
Dist. from "FROM" Node / Offset dist	150	mm.

Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.05492	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	
Element From Node	20	
Detail Type	Nozzle	
Detail ID	N05A (1.5in)	
Dist. from "FROM" Node / Offset dist	1500	mm.
Nozzle Diameter	1.5	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.05009	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	
Element From Node	20	
Detail Type	Nozzle	
Detail ID	N06 (1in)	
Dist. from "FROM" Node / Offset dist	1300	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.03182	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	
Element From Node	20	
Detail Type	Nozzle	
Detail ID	N07 (1in)	
Dist. from "FROM" Node / Offset dist	1050	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.03182	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	
Element From Node	20	
Detail Type	Nozzle	
Detail ID	N09 (1in)	
Dist. from "FROM" Node / Offset dist	800	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	150	

Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.03182	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	
Element From Node	20	
Detail Type	Nozzle	
Detail ID	M1 (20in)	
Dist. from "FROM" Node / Offset dist	1100	mm.
Nozzle Diameter	20	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	0.0	
Blind Flange (Y/N)	Y	
Weight of Nozzle (Used if > 0)	2.6042	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-516 70	
Element From Node	20	
Detail Type	Nozzle	
Detail ID	K06 (2in)	
Dist. from "FROM" Node / Offset dist	200	mm.
Nozzle Diameter	2	in.
Nozzle Schedule	None	
Nozzle Class	300	
Layout Angle	-32.2631	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.08508	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	

Element From Node	30	
Element To Node	40	
Element Type	Cylinder	
Description		
Distance "FROM" to "TO"	1700	mm.
Inside Diameter	1100	mm.
Element Thickness	12	mm.
Internal Corrosion Allowance	6	mm.
Nominal Thickness	0	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	8	bars
Design Temperature Internal Pressure	120	°C
Design External Pressure	1.034	bars
Design Temperature External Pressure	100	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Weld is pre-Heated	No	
Element From Node	30	

Detail Type	Saddle	
Detail ID	New Sdl	
Dist. from "FROM" Node / Offset dist	1200	mm.
Width of Saddle	150	mm.
Height of Saddle at Bottom	1200	mm.
Saddle Contact Angle	120.0	
Height of Composite Ring Stiffener	0	mm.
Width of Wear Plate	200	mm.
Thickness of Wear Plate	12	mm.
Contact Angle, Wear Plate (degrees)	135.0	
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	30	
Detail Type	Liquid	
Detail ID	Liquid: 30	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	550	mm.
Liquid Density	1019.5	kg/m^3

Element From Node	30	
Detail Type	Insulation	
Detail ID	Ins: 20	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	1700	mm.
Thickness of Insulation	50	mm.
Density	125	kg/m^3

Element From Node	30	
Detail Type	Ring	
Detail ID	Ring R1 Fr30	
Dist. from "FROM" Node / Offset dist	50	mm.
Inside Diameter of Ring	1124	mm.
Thickness of Ring	12	mm.
Outside Diameter of Ring	1300	mm.
Material Name	SA-516 70	
Height of Section Ring	0	mm.
Using Custom Stiffener Section	No	

Element From Node	30	
Detail Type	Nozzle	
Detail ID	N02 (1in)	
Dist. from "FROM" Node / Offset dist	1600	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.03182	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	

Element From Node	30	
Detail Type	Nozzle	
Detail ID	N03 (1in)	
Dist. from "FROM" Node / Offset dist	1500	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.03182	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	

Element From Node	30	
Detail Type	Nozzle	
Detail ID	N04 (1in)	
Dist. from "FROM" Node / Offset dist	476	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.03182	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	

Element From Node	30	
Detail Type	Nozzle	
Detail ID	N05B (1.5in)	
Dist. from "FROM" Node / Offset dist	1400	mm.
Nozzle Diameter	1.5	in.
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.05009	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	

Element From Node	30	
Detail Type	Nozzle	
Detail ID	K3A (3in)	
Dist. from "FROM" Node / Offset dist	476	mm.
Nozzle Diameter	3	in.
Nozzle Schedule	160	
Nozzle Class	300	
Layout Angle	6.3337798	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.1105	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	

Element From Node	30
Detail Type	Nozzle

Detail ID	K3B (3in)	
Dist. from "FROM" Node / Offset dist	476	mm.
Nozzle Diameter	3	in.
Nozzle Schedule	160	
Nozzle Class	300	
Layout Angle	-45.376999	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.1282	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	
Element From Node	30	
Detail Type	Nozzle	
Detail ID	K05 (2in)	
Dist. from "FROM" Node / Offset dist	200	mm.
Nozzle Diameter	2	in.
Nozzle Schedule	None	
Nozzle Class	300	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.08508	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	
Element From Node	30	
Detail Type	Nozzle	
Detail ID	K4B (2in)	
Dist. from "FROM" Node / Offset dist	750	mm.
Nozzle Diameter	2	in.
Nozzle Schedule	None	
Nozzle Class	300	
Layout Angle	-45.376999	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.1113	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	
Element From Node	30	
Detail Type	Nozzle	
Detail ID	K4A (2in)	
Dist. from "FROM" Node / Offset dist	750	mm.
Nozzle Diameter	2	in.
Nozzle Schedule	None	
Nozzle Class	300	
Layout Angle	-14.8464	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.08459	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	
Element From Node	30	
Detail Type	Nozzle	
Detail ID	K2B (2in)	
Dist. from "FROM" Node / Offset dist	1000	mm.
Nozzle Diameter	2	in.

Nozzle Schedule	None	
Nozzle Class	300	
Layout Angle	-15.4801	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.08459	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	
Element From Node	30	
Detail Type	Nozzle	
Detail ID	K2A (2in)	
Dist. from "FROM" Node / Offset dist	1000	mm.
Nozzle Diameter	2	in.
Nozzle Schedule	None	
Nozzle Class	300	
Layout Angle	10.8718	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.08459	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	
Element From Node	30	
Detail Type	Nozzle	
Detail ID	K1B (3in)	
Dist. from "FROM" Node / Offset dist	1500	mm.
Nozzle Diameter	3	in.
Nozzle Schedule	160	
Nozzle Class	300	
Layout Angle	-45.376999	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.1282	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	
Element From Node	30	
Detail Type	Nozzle	
Detail ID	K1A (3in)	
Dist. from "FROM" Node / Offset dist	1500	mm.
Nozzle Diameter	3	in.
Nozzle Schedule	160	
Nozzle Class	300	
Layout Angle	15.4801	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.1193	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	
Element From Node	30	
Detail Type	Weight	
Detail ID	VORTEX BREAKER	
Dist. from "FROM" Node / Offset dist	1600	mm.
Miscellaneous Weight	0.4903	kN
Offset from Element Centerline	550	mm.
Element From Node	30	

Detail Type	Weight	
Detail ID	DEMISTER PAD	
Dist. from "FROM" Node / Offset dist	1500	mm.
Miscellaneous Weight	0.4903	kN
Offset from Element Centerline	550	mm.
Element From Node	30	
Detail Type	Weight	
Detail ID	BUCKET	
Dist. from "FROM" Node / Offset dist	450	mm.
Miscellaneous Weight	1.9612	kN
Offset from Element Centerline	0	mm.
Element From Node	30	
Detail Type	Weight	
Detail ID	WEIR	
Dist. from "FROM" Node / Offset dist	700	mm.
Miscellaneous Weight	0.4903	kN
Offset from Element Centerline	0	mm.

Element From Node	40	
Element To Node	50	
Element Type	Elliptical	
Description		
Distance "FROM" to "TO"	50	mm.
Inside Diameter	1100	mm.
Element Thickness	10	mm.
Internal Corrosion Allowance	6	mm.
Nominal Thickness	12	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	8	bars
Design Temperature Internal Pressure	120	°C
Design External Pressure	1.034	bars
Design Temperature External Pressure	100	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Elliptical Head Factor	2.0	
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	550	mm.
Liquid Density	1019.5	kg/m³
Element From Node	40	
Detail Type	Insulation	
Detail ID	Ins: 20	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	325	mm.

Thickness of Insulation	50	mm.
Density	125	kg/m³

XY Coordinate Calculations:

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
10	20	50	...	50	...
20	30	1650	...	1600	...
30	40	3350	...	1700	...
40	50	3400	...	50	...

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
10	20	8.0556	12	6	1100	137.9
20	30	8.0556	...	6	1100	137.9
30	40	8.0556	...	6	1100	137.9
40	50	8.0556	12	6	1100	137.9

Element Required Thickness and MAWP :

From	To	Design Pressure bars	M.A.W.P. Corroded bars	M.A.P. New & Cold bars	Minimum Thickness mm.	Required Thickness mm.
10	20	8	9.99983	25.0258	10	9.20401
20	30	8	14.7291	29.6968	12	9.25955
30	40	8	14.7291	29.6968	12	9.25955
40	50	8	9.99983	25.0258	10	9.20401
Minimum			10	20		

Note : The M.A.P.(NC) is Governed by a Flange !

MAWP: 9 bars, limited by: Nozzle Reinforcement.

Elements Suitable for Design Internal Pressure.

Internal Pressure Calculation Results:

ASME Code, Section VIII Division 1, 2019

Elliptical Head From 10 To 20 SA-516 70 , UCS-66 Crv. B at 120 °C

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
= (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
= (8.056*1112.0*0.986)/(2*137.9*1.0-0.2*8.056)
= 3.2040 + 6.0000 = 9.2040 mm.
```

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

Less Operating Hydrostatic Head Pressure of 0.056 bars

```
= (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
= (2*137.9*1.0*4.0)/(0.986*1112.0+0.2*4.0)
= 10 - 0.1 = 10  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
= (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
= (2*137.9*1.0*10.0)/(1.0*1100.0+0.2*10.0)
= 25 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(Kcor*D+0.2*t))/(2*E*t)
= (8.056*(0.986*1112.0+0.2*4.0))/(2*1.0*4.0)
= 110.474 N./mm²

Straight Flange Required Thickness:
= (P*R)/(S*E-0.6*P) + c per UG-27 (c)(1)
= (8.056*556.0)/(137.9*1.0-0.6*8.056)+6.0
= 9.260 mm.

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.056 bars
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (137.9 * 1.0 * 6.0)/(556.0 + 0.6 * 6.0)
= 15 - 0.1 = 15 bars

Factor K, corroded condition [Kcor]:
= (2 + (Inside Diameter/(2 * Inside Head Depth))²)/6
= (2 + (1112.0/(2 * 281.0))²)/6
= 0.985841

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 4.663 %

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 10.0, tr = 3.432, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.858, Temp. Reduction = 8 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-37 °C

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 12.0, tr = 3.493, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.582, Temp. Reduction = 24 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-23 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-47 °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-516 70 , UCS-66 Crv. B at 120 °C
Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
= (8.056*556.0)/(137.9*1.0-0.6*8.056)
= 3.2596 + 6.0000 = 9.2596 mm.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.056 bars
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (137.9*1.0*6.0)/(556.0+0.6*6.0)
= 15 - 0.1 = 15 bars

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (137.9*1.0*12.0)/(550.0+0.6*12.0)
= 30 bars

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(R+0.6*t))/(E*t)
= (8.056*(556.0+0.6*6.0))/(1.0*6.0)
= 75.136 N./mm²

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.079 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 12.0, tr = 3.493, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.582, Temp. Reduction = 24 °C

Min Metal Temp. w/o impact per UCS-66, Curve B	-23 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-47 °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 30 To 40 SA-516 70 , UCS-66 Crv. B at 120 °C
Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
= (8.056*556.0)/(137.9*1.0-0.6*8.056)
= 3.2596 + 6.0000 = 9.2596 mm.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.056 bars
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (137.9*1.0*6.0)/(556.0+0.6*6.0)
= 15 - 0.1 = 15 bars

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (137.9*1.0*12.0)/(550.0+0.6*12.0)
= 30 bars

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(R+0.6*t))/(E*t)
= (8.056*(556.0+0.6*6.0))/(1.0*6.0)
= 75.136 N./mm²

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.079 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 12.0, tr = 3.493, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.582, Temp. Reduction = 24 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -23 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -47 °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 40 To 50 SA-516 70 , UCS-66 Crv. B at 120 °C
Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
= (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
= (8.056*1112.0*0.986)/(2*137.9*1.0-0.2*8.056)
= 3.2040 + 6.0000 = 9.2040 mm.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.056 bars
= (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
= (2*137.9*1.0*4.0)/(0.986*1112.0+0.2*4.0)
= 10 - 0.1 = 10 bars

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
= (2*137.9*1.0*10.0)/(1.0*1100.0+0.2*10.0)
= 25 bars

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(Kcor*D+0.2*t))/(2*E*t)
= (8.056*(0.986*1112.0+0.2*4.0))/(2*1.0*4.0)
= 110.474 N./mm²

Straight Flange Required Thickness:
= (P*R)/(S*E-0.6*P) + c per UG-27 (c)(1)
= (8.056*556.0)/(137.9*1.0-0.6*8.056)+6.0
= 9.260 mm.

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.056 bars
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (137.9 * 1.0 * 6.0)/(556.0 + 0.6 * 6.0)
= 15 - 0.1 = 15 bars

Factor K, corroded condition [Kcor]:
= (2 + (Inside Diameter/(2 * Inside Head Depth))²)/6
= (2 + (1112.0/(2 * 281.0))²)/6

= 0.985841

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 4.663 %

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 10.0, tr = 3.432, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.858, Temp. Reduction = 8 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -29 °C
Min Metal Temp. at Required thickness (UCS 66.1)        -37 °C
```

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 12.0, tr = 3.493, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.582, Temp. Reduction = 24 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -23 °C
Min Metal Temp. at Required thickness (UCS 66.1)        -47 °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:

```
Pressure per UG99b      = 1.30 * M.A.W.P. * Sa/S        11.146  bars
Pressure per UG99b[36] = 1.30 * Design Pres * Sa/S       10.400  bars
Pressure per UG99c      = 1.30 * M.A.P. - Head(Hyd)     25.480  bars
Pressure per UG100      = 1.10 * M.A.W.P. * Sa/S         9.431  bars
Pressure per PED        = max(1.43*DP, 1.25*DP*ratio)   11.440  bars
Pressure per App 27-4   = M.A.W.P.                        8.574  bars
```

UG-99(b) Note 36, Test Pressure Calculation:

```
= Test Factor * Design Pressure * Stress Ratio
= 1.3 * 8.0 * 1.0
= 10.400 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
10	20	144.1	235.8	0.611	10.51
20	30	98.0	235.8	0.416	10.51
30	40	98.0	235.8	0.416	10.51
40	50	144.1	235.8	0.611	10.51

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

Description	Pad/Nozzle	Ambient	Operating	Ratio
N08 (1in)	Nozzle	137.90	137.90	1.000
N01 (1in)	Nozzle	137.90	137.90	1.000
N05A (1.5in)	Nozzle	137.90	137.90	1.000
N06 (1in)	Nozzle	137.90	137.90	1.000
N07 (1in)	Nozzle	137.90	137.90	1.000
N09 (1in)	Nozzle	137.90	137.90	1.000
M1 (20in)	Nozzle	137.90	137.90	1.000
M1 (20in)	Pad	137.90	137.90	1.000
K06 (2in)	Nozzle	137.90	137.90	1.000
N02 (1in)	Nozzle	137.90	137.90	1.000
N03 (1in)	Nozzle	137.90	137.90	1.000
N04 (1in)	Nozzle	137.90	137.90	1.000
N05B (1.5in)	Nozzle	137.90	137.90	1.000
K3A (3in)	Nozzle	117.90	117.90	1.000
K3B (3in)	Nozzle	117.90	117.90	1.000
K05 (2in)	Nozzle	137.90	137.90	1.000
K4B (2in)	Nozzle	137.90	137.90	1.000
K4A (2in)	Nozzle	137.90	137.90	1.000
K2B (2in)	Nozzle	137.90	137.90	1.000
K2A (2in)	Nozzle	137.90	137.90	1.000
K1B (3in)	Nozzle	117.90	117.90	1.000
K1A (3in)	Nozzle	117.90	117.90	1.000
Minimum				1.000

Stress ratios for Stiffening Ring Materials (N./mm²):

Description	Ambient	Operating	Ratio
Ring R1 Fr30	137.90	137.90	1.000
Minimum			1.000

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

Description	Ambient	Operating	Ratio
	137.90	137.90	1.000
	137.90	137.90	1.000
	137.90	137.90	1.000
	137.90	137.90	1.000
Minimum			1.000

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

Description	Ambient	Operating	Ratio
N08 (1in)	3.56	223.40	0.016
N01 (1in)	3.56	223.40	0.016
N05A (1.5in)	3.75	223.40	0.017
N06 (1in)	3.56	223.40	0.016
N07 (1in)	3.56	223.40	0.016
N09 (1in)	3.56	223.40	0.016
M1 (20in)	44.07	235.81	0.187
K06 (2in)	3.70	223.40	0.017
N02 (1in)	3.56	223.40	0.016
N03 (1in)	3.56	223.40	0.016
N04 (1in)	3.56	223.40	0.016
N05B (1.5in)	3.75	223.40	0.017
K3A (3in)	12.09	217.19	0.056
K3B (3in)	12.09	217.19	0.056
K05 (2in)	3.70	223.40	0.017
K4B (2in)	3.74	223.40	0.017
K4A (2in)	3.74	223.40	0.017
K2B (2in)	3.74	223.40	0.017
K2A (2in)	3.74	223.40	0.017
K1B (3in)	12.09	217.19	0.056
K1A (3in)	12.09	217.19	0.056

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	1120	4	0.00049603	49.592
20	30	1791.67	1124	6	0.00032246	32.2385
30	Ring	1791.67	1124	6	0.00032246	32.2385
Ring	40	1791.67	1124	6	0.00032246	32.2385
40	50	No Calc	1120	4	0.00049603	49.592

External Pressure Calculations:

From	To	External Actual T. mm.	External Required T. mm.	External Design Pressure bars	External M.A.W.P. bars
10	20	10	8.89963	1.034	1.96782
20	30	12	10.3799	1.034	2.29442
30	Ring	12	10.3799	1.034	2.29442
Ring	40	12	10.3799	1.034	2.29442
40	50	10	8.89963	1.034	1.96782
Minimum					2

External Pressure Calculations:

From	To	Actual Length Bet. Stiffeners mm.	Allowable Length Bet. Stiffeners mm.	Ring Inertia Required cm**4	Ring Inertia Available cm**4
10	20	No Calc	No Calc	No Calc	No Calc
20	30	1791.67	3830.13	No Calc	No Calc
30	Ring	1791.67	3830.13	No Calc	No Calc
Ring	40	1791.67	3830.13	18.0627	147.429
40	50	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

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
4.000	1120.00	280.00	0.0004960	49.59

MAEP = B/(K0*Do/t) = 49.592/(0.9 *280.0) = 1.9678 bars

Results for Required Thickness				Tca
Tca	Outer Dia	Do/t	Factor A	Factor B
2.900	1120.00	386.26	0.0003596	35.95

MAEP = B/(K0*Do/t) = 35.9496/(0.9 *386.2563) = 1.0341 bars

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

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
= (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
= (1.727*1112.0*0.986)/(2*137.9*1.0-0.2*1.727)
= 0.6865 + 6.0000 = 6.6865 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*137.9*1.0*4.0)/(0.986*1112.0+0.2*4.0))/1.67
= 6 bars

Maximum Allowable External Pressure [MAEP]:
= min(MAEP, MAWP)
= min(1.97, 6.0212)
= 1.968 bars

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

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

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
6.000	1124.00	1791.67	187.33	1.5940	0.0003225	32.24

MAEP = (4*B)/(3*(Do/t)) = (4*32.2385)/(3*187.3333) = 2.2944 bars

Results for Required Thickness						Tca
Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
4.380	1124.00	1791.67	256.63	1.5940	0.0001991	19.90

MAEP = (4*B)/(3*(Do/t)) = (4*19.9035)/(3*256.625) = 1.0341 bars

Results for Maximum Stiffened Length						Slen
Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
6.000	1124.00	3830.13	187.33	3.4076	0.0001454	14.54

MAEP = (4*B)/(3*(Do/t)) = (4*14.5355)/(3*187.3333) = 1.0345 bars

---

Cylindrical Shell From 30 to Ring R1 Fr30 Ext. Chart: CS-2 at 100 °C

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
6.000	1124.00	1791.67	187.33	1.5940	0.0003225	32.24

MAEP = (4*B)/(3*(Do/t)) = (4*32.2385)/(3*187.3333) = 2.2944 bars

Results for Required Thickness						Tca
Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
4.380	1124.00	1791.67	256.63	1.5940	0.0001991	19.90

MAEP = (4*B)/(3*(Do/t)) = (4*19.9035)/(3*256.625) = 1.0341 bars

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

```
  6.000 |    1124.00 |     3830.13 |    187.33 |    3.4076 |  0.0001454 |    14.54 |
-------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*14.5355)/(3*187.3333) = 1.0345 bars
```

Cylindrical Shell From Ring R1 Fr30 to 40 Ext. Chart: CS-2 at 100 °C

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 |
  6.000 |    1124.00 |     1791.67 |    187.33 |    1.5940 |  0.0003225 |    32.24 |
-------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*32.2385)/(3*187.3333) = 2.2944 bars

                                          |                                |
Results for Required Thickness                 |                            Tca  |
-------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |       L/D |   Factor A | Factor B |
  4.380 |    1124.00 |     1791.67 |    256.63 |    1.5940 |  0.0001991 |    19.90 |
-------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*19.9035)/(3*256.625) = 1.0341 bars

                                          |                                |
Results for Maximum Stiffened Length           |                           Slen  |
-------------------------------------------------------------------------------
    Tca |  Outer Dia |        Slen |      Do/t |       L/D |   Factor A | Factor B |
  6.000 |    1124.00 |     3830.13 |    187.33 |    3.4076 |  0.0001454 |    14.54 |
-------------------------------------------------------------------------------
MAEP = (4*B)/(3*(Do/t)) = (4*14.5355)/(3*187.3333) = 1.0345 bars
```

Elliptical Head From 40 to 50 Ext. Chart: CS-2 at 100 °C

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 |
  4.000 |    1120.00 |      280.00 | 0.0004960 |                           49.59 |
-------------------------------------------------------------------------------
MAEP = B/(K0*Do/t) = 49.592/( 0.9 *280.0 ) = 1.9678 bars

                                          |                                |
Results for Required Thickness                 |                            Tca  |
-------------------------------------------------------------------------------
    Tca |  Outer Dia |        Do/t |  Factor A |                        Factor B |
  2.900 |    1120.00 |      386.26 | 0.0003596 |                           35.95 |
-------------------------------------------------------------------------------
```

```
MAEP = B/(K0*Do/t) = 35.9496/( 0.9 *386.2563 ) = 1.0341 bars
```

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

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
= (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
= (1.727*1112.0*0.986)/(2*137.9*1.0-0.2*1.727)
= 0.6865 + 6.0000 = 6.6865 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*137.9*1.0*4.0)/(0.986*1112.0+0.2*4.0))/1.67
= 6 bars
```

Maximum Allowable External Pressure [MAEP]:

```
= min( MAEP, MAWP )
= min( 1.97, 6.0212 )
= 1.968 bars
```

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

Stiffening Ring Calcs for : Ring R1 Fr30 , SA-516 70 , Bar Ring: 88 x 12 mm.

Effective Length of Shell: 90 mm.

	Area (cm²)	Distance (mm.)	Area*Dist
Shell:	5.420	3.0000	16.260
Ring :	10.560	50.0000	528.000
Total:	15.980		544.260

Centroid of Ring plus Shell: 34 mm.

	Inertia	Distance	A*Dist²
Shell:	0.163	31.0587	5228.421
Ring :	68.147	-15.9413	2683.547
Total:	68.310		7911.968

Available Moment of Inertia, Ring plus Shell: 147 cm**4

Required Stress in Ring plus Shell	Breq	13.23	N./mm²
Required Strain in Ring plus Shell	Areq	0.0001320	

Required Moment of Inertia, Ring plus Shell:

```
= ( OD² * Slen(Tca + Aring/Slen)Areq )/10.9
= (1124.0²*1791.6666(6.0+10.56/1791.6666)0.000132)/10.9
= 18 cm**4
```

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	153.891	221784	76.9454	228592	15.3891
20	30	519.861	1520803	261.331	1554165	51.9861
30	40	552.351	1615853	277.664	1651301	55.2351
40	50	153.891	221784	76.9454	228592	15.3891
Total		1379	3580224.25	692	3662650.25	137

Weight of Details:

From	Type	Weight of Detail kg.	X Offset, Dtl. Cent. mm.	Y Offset, Dtl. Cent. mm.	Description
10	Liqd	113.04	-91.6667	275	Liquid: 10
10	Insl	13.0809	-112.5	...	Ins: 20
10	Nozl	3.56901	-188.746	...	N08 (1in)
20	Sadl	216.957	450	863	Lft Sdl
20	Liqd	775.134	800	275	Liquid: 20
20	Insl	36.8833	800	...	Ins: 20
20	Nozl	6.16098	150	562.7	N01 (1in)
20	Nozl	5.61931	1500	569.05	N05A (1.5in)
20	Nozl	3.56901	1300	562.7	N06 (1in)
20	Nozl	3.56901	1050	562.7	N07 (1in)
20	Nozl	3.56901	800	562.7	N09 (1in)
20	Nozl	292.135	1100	804	M1 (20in)
20	Nozl	9.54402	200	575.4	K06 (2in)
30	Sadl	216.957	1200	863	New Sdl
30	Liqd	823.58	850	275	Liquid: 30
30	Insl	39.1885	850	...	Ins: 20
30	Ring	34.2799	50	...	Ring R1 Fr30
30	Nozl	3.56901	1600	562.7	N02 (1in)
30	Nozl	3.56901	1500	562.7	N03 (1in)
30	Nozl	3.56901	476	562.7	N04 (1in)
30	Nozl	5.61931	1400	569.05	N05B (1.5in)
30	Nozl	12.391	476	584.715	K3A (3in)
30	Nozl	14.3825	476	584.715	K3B (3in)
30	Nozl	9.54402	200	575.4	K05 (2in)
30	Nozl	12.4852	750	575.4	K4B (2in)
30	Nozl	9.48856	750	575.4	K4A (2in)
30	Nozl	9.48856	1000	575.4	K2B (2in)
30	Nozl	9.48856	1000	575.4	K2A (2in)
30	Nozl	14.3825	1500	584.715	K1B (3in)
30	Nozl	13.3868	1500	584.715	K1A (3in)
30	Wght	50	1600	550	VORTEX BREAKER
30	Wght	50	1500	550	DEMISTER PAD
30	Wght	200	450	...	BUCKET
30	Wght	50	700	...	WEIR
40	Liqd	113.04	141.667	275	Liquid: 40

```
   40|Insl|    13.0809 |      162.5 |       ... |   Ins: 20
-------------------------------------------------
```

Total Weight of Each Detail Type:

```
Saddles                                433.9
Liquid                                1824.8
Insulation                             102.2
Stiffeners                              34.3
Nozzles                                449.1
Weights                                350.0
-----------------------------------------
Sum of the Detail Weights             3194.3 kg.
```

Weight Summation Results: (kg.)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	1518.0	1518.0	1518.0	1518.0	1518.0	1518.0
Saddles	433.9	433.9	433.9	433.9	433.9	433.9
Stif. Rings	34.3	34.3	34.3	34.3	34.3	34.3
Nozzles	449.1	449.1	449.1	449.1	449.1	449.1
Wld Weights	350.0	350.0	350.0	350.0	350.0	350.0
Insulation	...	...	102.2	102.2	102.2	102.2
Ope. Liquid	...	...	...	...	...	1824.8
Test Liquid	...	3578.0	...	...	...	...
Totals	2785.3	6363.3	2887.5	2887.5	2887.5	4712.3

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              2785.3 kg.
Shop Test Wt.    - Fabricated Weight + Water ( Full )                   6363.3 kg.
Shipping Wt.     - Fab. Weight + removable Intls.+ Shipping App.        2887.5 kg.
Erected  Wt.     - Fab. Wt + or - loose items (trays,platforms etc.)    2887.5 kg.
Ope. Wt. no Liq - Fab. Weight + Internals. + Details + Weights         2887.5 kg.
Operating Wt.    - Empty Weight + Operating Liq. Uncorroded             4712.3 kg.
Oper. Wt. + CA   - Corr Wt. + Operating Liquid                         3956.5 kg.
Field Test Wt.   - Empty Weight + Water (Full)                         5792.1 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	15460.4
20	30	56498.4
30	40	60029.6
40	50	15460.4
Total		147448.734 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
N08 (1in)	16.94	19.60	120	150	GR 1.1	...	...	...	...
N01 (1in)	16.94	19.60	120	150	GR 1.1	...	...	...	...
N05A (1.5in)	16.94	19.60	120	150	GR 1.1	...	...	...	...
N06 (1in)	16.94	19.60	120	150	GR 1.1	...	...	...	...
N07 (1in)	16.94	19.60	120	150	GR 1.1	...	...	...	...
N09 (1in)	16.94	19.60	120	150	GR 1.1	...	...	...	...
M1 (20in)	16.94	19.60	120	150	GR 1.1	...	...	...	...
K06 (2in)	46.00	51.10	120	300	GR 1.1	...	...	...	...
N02 (1in)	16.94	19.60	120	150	GR 1.1	...	...	...	...
N03 (1in)	16.94	19.60	120	150	GR 1.1	...	...	...	...
N04 (1in)	16.94	19.60	120	150	GR 1.1	...	...	...	...
N05B (1.5in)	16.94	19.60	120	150	GR 1.1	...	...	...	...
K3A (3in)	46.00	51.10	120	300	GR 1.1	...	...	...	...
K3B (3in)	46.00	51.10	120	300	GR 1.1	...	...	...	...
K05 (2in)	46.00	51.10	120	300	GR 1.1	...	...	...	...
K4B (2in)	46.00	51.10	120	300	GR 1.1	...	...	...	...
K4A (2in)	46.00	51.10	120	300	GR 1.1	...	...	...	...
K2B (2in)	46.00	51.10	120	300	GR 1.1	...	...	...	...
K2A (2in)	46.00	51.10	120	300	GR 1.1	...	...	...	...
K1B (3in)	46.00	51.10	120	300	GR 1.1	...	...	...	...
K1A (3in)	46.00	51.10	120	300	GR 1.1	...	...	...	...
Min Rating	16.940	19.600 bars [for Core Elements]					0.000	0.000	0.000

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

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

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*0.228*0.983)/(1+1.7*3.4*0.228)))
  = min(0.85, 0.916 )
  = 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] 0.535
Structure Height to Diameter ratio                    3.112
```

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
  = 1200.0 + 100.0 = 1300.0 mm.
  = 4.265 ft. Imperial Units
```

Velocity Pressure coefficient evaluated at height z [Kz]:

```
  Because z (4.265 ft.) < 15 ft.
  = 2.01 * ( 15 / Zg ) 2 / Alpha
```

$= 2.01 * (15/900.0)^{2/9.5}$
$= 0.849$

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]:
$= (1 + K1 * K2 * K3)^2$
$= (1 + 0.0* 0.0* 0.0)^2$
$= 1.0$

Velocity Pressure evaluated at height z, Imperial Units [qz]:
$= \max(16, 0.00256 * Kz * Kzt * Kd * V(mph)^2)$
$= \max(16, 0.00256 * 0.849 * 1.0 * 0.95 * 74.567^2)$
$= 16.0$ psf [78.12] Kgs/m²

Force on the first element [F]:
$= qz * G * Cf * WindArea$
$= 16.0 * 0.85 * 0.535 * 4.243$
$= 30.9$ lbs. [0.1] kN

Element	Hgt (z) mm.	K1	K2	K3	Kz	Kzt	qz Kgs/m²
Node 10 to 20	1300.0	0.000	0.000	0.000	0.849	1.000	78.120
Node 20 to 30	1300.0	0.000	0.000	0.000	0.849	1.000	78.120
Node 30 to 40	1300.0	0.000	0.000	0.000	0.849	1.000	78.120
Node 40 to 50	1300.0	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
VORTEX BREAKE	0.00	100.00	78.12	0.00
DEMISTER PAD	0.00	1850.00	78.12	0.00
BUCKET	0.00	1300.00	78.12	0.00
WEIR	0.00	1300.00	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	1300	1464	3941.92	78.12	0.082424
20	30	1300	1468.8	23500.8	78.12	0.49139
30	40	1300	1468.8	24969.6	78.12	0.5221
40	50	1300	1464	3941.92	78.12	0.082424

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 = 1.111 * 1.377 = 1.53
Sm1 = Fv * S1 = 1.575 * 0.367 = 0.578
Sds = 2/3 * Sms = 2/3 * 1.53 = 1.02

Sds = Max( 0.8*Sds, SdsUser )
    = Max( 0.816, 1.02 )
    = 1.020

Sd1 = 2/3 * Sm1 = 2/3 * 0.578 = 0.385

Sd1 = Max( 0.8*Sd1, Sd1User )
    = Max( 0.308, 0.385 )
    = 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.)

$= 0.020 * (5.7415^{0.75})$

$= 0.074$ seconds

The Coefficient Cu from Table 12.8-1 is : 1.400

Fundamental Period (1/Frequency) [T]:

= (1/Natural Frequency) = (1/33.0)

= 0.030

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

= Minimum Value of (1.4 * 0.074, 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 * 39 * 1.25
  = 14.840 kN

 Final Base Shear,      V = 10.39 kN
```

Earthquake Load Calculation:

From	To	Earthquake Height mm.	Earthquake Weight kN	Element Ope Load kN
10	20	550	6.46623	1.73133
20	30	550	6.46623	1.73133
20	30	550	6.46623	1.73133
30	0	550	6.46623	1.73133
30	40	550	6.46623	1.73133
40	50	550	6.46623	1.73133

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                          1675.000 mm.
Center of Gravity of the Liquid                           1700.000 mm.
Center of Gravity of the Insulation                       1700.000 mm.
Center of Gravity of the Stiffening Rings                 1700.000 mm.
Center of Gravity of the Nozzles                          1496.400 mm.
Center of Gravity of the Added Weights (Operating)        2450.000 mm.
Center of Gravity of the Added Weights (Empty)            2450.000 mm.

Center of Gravity of Bare Shell New and Cold              1694.424 mm.
Center of Gravity of Bare Shell Corroded                  1694.448 mm.

Vessel CG in the Operating Condition                      1739.425 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition        1752.554 mm.
Vessel CG in the Test Condition                           1721.757 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 : 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( 150.0 + 1.56*sqrt( 559.0 * 6.0 ), 2 * 300.0 )
= 240.3454 mm.
```

Input and Calculated Values:

Vessel Mean Radius	Rm	559.00	mm.
Stiffened Vessel Length per 4.15.6	L	3400.00	mm.
Distance from Saddle to Vessel tangent	a	300.00	mm.
Saddle Width	b	150.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Inside Depth of Head	h2	281.00	mm.
Shell Allowable Stress used in Calculation		137.90	N./mm²
Head Allowable Stress used in Calculation		137.90	N./mm²
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Distance from Saddle Base to Centerline	B	1200.00	mm.
Coefficient of Friction	mu	0.30	
Saddle Force Q, Operating Case		35.00	kN

Horizontal Vessel Analysis Results:	Actual N./mm²	Allowable N./mm²
Long. Stress at Top of Midspan	34.32	137.90
Long. Stress at Bottom of Midspan	40.22	137.90
Long. Stress at Top of Saddles	38.53	137.90
Long. Stress at Bottom of Saddles	36.57	137.90
Tangential Shear in Shell	9.06	110.32
Circ. Stress at Horn of Saddle	36.99	172.38
Circ. Compressive Stress in Shell	1.85	137.90

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

Saddle Reaction Force due to Wind Ft [Fwt]:
```
= Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
= 3.0( 1.2/2 + 0 ) * 1200.0/994.1971
= 2.1 kN
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
= max( Fl, Friction Load, Sum of X Forces) * B / Ls
= max( 0.65, 5.5, 0 ) * 1200.0/2350.0002
= 2.8 kN
```

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:
```
= max( Fl, Friction Force, Sum of X Forces ) * B / Ls
= max( 10.39, 5.5, 0 ) * 1200.0/2350.0002
= 5.3 kN
```

Saddle Reaction Force due to Earthquake Ft [Fst]:
```
= Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
= 3.0( 10/2 + 0 ) * 1200.0/994.1971
= 18.8 kN
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
= Saddle Load + max( Fwl, Fwt, Fsl, Fst )
= 16 + max( 3, 2, 5, 19 )
= 35.0 kN
```

Longitudinal Wind Force [Fl]:
```
= WindScalar * WindPress( Platform Area + ( End Area * WindDiaMult ) )
= 0.6 * 766.08( 0.0 + ( 1.177 * 1.2 ))
= 649.027 N
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		37.12	kN
Transverse Shear Load Saddle	Ft	5.19	kN
Longitudinal Shear Load Saddle		10.39	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( 1100.0/2 + 12.0 + 12.0 )sin( 60.0/2 ), 2*559.0 )
= 994.197 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	= 0.0161	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)]
  = -35*300.0[1-(1-300.0/3400.0+(559.0²-281.0²)/
    (2*300.0*3400.0))/(1+(4*281.0)/(3*3400.0))]
  = -794.3 N-m
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 35*3400/4(1+2(559²-281²)/(3400²))/(1+(4*281)/
    (3*3400))-4*300/3400
  = 17385.5 N-m
```

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

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 8.0 * 559.0/(2*6.0) - 17385.5/(pi*559.0²*6.0)
  = 34.32 N./mm²
```

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

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 8.0 * 559.0/(2 * 6.0) + 17385.5/(pi * 559.0² * 6.0 )
  = 40.22 N./mm²
```

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

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 8.0*559.0/(2*6.0)--794.3/(0.1066*pi*559.0²*6.0)
  = 38.53 N./mm²
```

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

```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 8.0*559.0/(2*6.0)+-794.3/(0.1923*pi*559.0²*6.0)
  = 36.57 N./mm²
```

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

```
  = Q(L-2a)/(L+(4*h2/3))
  = 35( 3400.0 - 2 * 300.0)/(3400.0 + ( 4 * 281.0/3))
  = 26.0 kN
```

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

```
  = K2 * T / ( Rm * t )
  = 1.1707 * 25.96/( 559.0 * 6.0 )
  = 9.06 N./mm²
```

Decay Length (4.15.22) [x1,x2]:

```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 559.0 * 6.0 )
  = 45.173 mm.
```

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

```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 35 * 0.1/( 6.0 * ( 150.0 + 45.17 + 45.17 ) )
  = -1.85 N./mm²
```

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.25) [sigma7*]:

```
  = -Q/(4*t*(b+X1+X2)) - 12*K7*Q*Rm/(L*t²)
  = -35/(4*6.0*(150.0+45.173+45.173)) -
     12 * 0.016 * 35 * 559.0/(3400.0 * 6.0²)
```

= -36.99 N./mm²

Effective reinforcing plate width (4.15.1) [B1]:
= min(b + 1.56 * sqrt(Rm * t), 2a)
= min(150.0 + 1.56 * sqrt(559.0 * 6.0), 2 * 300.0)
= 240.35 mm.

Distance between Saddle Supports [Ls]:
= 2350.0 mm.

Free Un-Restrained Thermal Expansion between the Saddles [Exp]:
= Alpha * Ls(Design Temperature - Ambient Temperature)
= 0.000012 * 2350.0(120.0 - 21.1)
= 2.842 mm.

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1100.0000	mm.
Baseplate Thickness	Bpthk	15.0000	mm.
Baseplate Width	Bpwid	170.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	15.0000	mm.
Web Thickness	Webtk	15.0000	mm.
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	239.9	N./
Height of Web at Center	Hw,c	635.0	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	290.1	6.0	3.0	17.4	5221.8	0.145E+05
Wearplate	200.0	12.0	12.0	24.0	28800.0	0.188E+05
Web	15.0	611.0	323.5	91.6	2964876.5	0.295E+05
BasePlate	170.0	15.0	636.5	25.5	1623074.8	0.304E+05
Totals	...	...	...	158.6	4621973.5	0.930E+05

Distance to Centroid [C1]:
= AY / A
= 1819.675/158.556
= 291.504 mm.

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

Saddle Splitting Coefficient [K1]:
= (1 + cos(beta) - 0.5*sin(beta)²)/(pi - beta + sin(beta)cos(beta))
= (1 + cos(120.0) - 0.5*sin(120.0)²)/(pi - 2.094 + sin(120.0)cos(120.0))
= 0.2035

Saddle Splitting Force [Fh]:
```
= K1 * Q
= 0.204 * 34.997
= 7.1227 kN
```

```
Tension Stress, St = ( Fh/As )       =          0.5047  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)
= 1200.0 - 556.0 * sin(120.0/2)/1.0472
= 740.192 mm.
```

```
Bending Moment, M  = Fh * d          =       5274.3340  N-m

Bending Stress, Sb = ( M * C1 / I  ) =          1.6519  N./mm²
Allowed Stress, Sa = 2/3 * Yield Str =        159.9640  N./mm²
```

Minimum Thickness of Baseplate per Moss:
```
= ( 3( Q + Saddle_Wt )BasePlateWidth / ( 4 * BasePlateLength * AllStress ))½
= ( 3(35 + 2)170.0/( 4 * 1100.0 * 159.964 ))½
= 5.187 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 - 120.0/2 )( 550.0 + 12.0 + 12.0 )
= 994.197 mm.
```

Distance between Ribs [e]:
```
= Web Length / ( Nribs - 1 )
= 994.1971/( 4 - 1 )
= 331.399 mm.
```

Baseplate Pressure Area [Ap]:
```
= e * Bpwid / 2
= 331.399 * 170.0/2
= 281.689 cm²
```

Bearing Pressure [Bp]:
```
= Q / ( BasePlateLength * BasePlateWidth )
= 34.997/( 1100.0 * 170.0 )
= 0.019 kN/cm²
```

Axial Load [P]:
```
= Ap * Bp
= 281.7 * 0.02
= 5.272 kN
```

Area of the Rib and Web [Ar]:
```
= Rib Area + Web Area
= 20.25 + 24.855
= 45.105 cm²
```

Compressive Stress [Sc]:
= P/Ar
= 5.3/45.1049
= 1.169 N./mm²

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	15.0	150.0	...	22.5	...	422.

Rib dimension [D]:
= Saddle Width - Web Thickness
= 150.0 - 15.0
= 135.000 mm.

Distance to Centroid from Datum [ytot]:
= AY / A
= 0.0/45.105
= 0.000 mm.

Distance to Centroid [C1]:
= Saddle Width / 2
= 150.0/2
= 75.000 mm.

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(421.9/45.105)
= 30.583 mm.

Length of Outer Rib [L]:
= Saddle Height - cos(theta/2)(radius + shlthk + wpdthk) - bpthk
= 1200.0 - cos(120.0/2)(550.0 + 12.0 + 12.0) - 15.0
= 898.000 mm.

Intermediate Term [Cc]:
= sqrt(2 * pi² * Elastic Modulus / Yield Stress)
= sqrt(2 * pi² * 0.19994E+09/239.9)
= 128.255

Slenderness ratio [KL/r]:
= KL/r
= 1 * 898.0/30.583
= 29.363

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * L / 2
= 10.4/(2 * 1100.0) * 331.399 * 898.0/2
= 702.883 N-m

Compressive Allowable, KL/r < Cc (29.3627 < 128.2549) per AISC E2-1 [Sca]:

= (1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= (1-(29.36)²/(2 * 128.25²))240/
(5/3+3*(29.36)/(8* 128.25)-(29.36³)/(8*128.25³)
= 133.4 N./mm²

AISC Unity Check of Outside Ribs (must be <= 1)
= Sc/Sca + (Rm * C1 / I)/Sba
= 1.17/133.44 + (702.88 * 75.0/4218750)/159.96
= 0.087

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	15.0	135.0	0.0	20.2	0.0	421.
Web	331.4	15.0	0.0	49.7	0.0	9.32
Totals	...	...	...	70.0	...	431.

Distance to Centroid from Datum [ytot]:
= AY / A
= 0.0/69.96
= 0.000 mm.

Distance to Centroid [C1]:
= Saddle Width / 2
= 150.0/2
= 75.000 mm.

Length of Inner Rib [L]:
= Saddle Height - sqrt((Ro + Wpdthk)^2 - (Pitch/2)^2) - Bpthk
= 1200.0 - sqrt((574.0 + 12.0)^2 - (331.399/2)^2) - 15.0
= 635.437 mm.

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(430.8/69.96)
= 24.814 mm.

Slenderness ratio [KL/r]:
= KL/r
= 1 * 635.437/24.814
= 25.608

Unit Force [Force,u]:
= Fl / (2 * Baseplate Length)
= 10.388/(2 * 1100.0)
= 0.005 kN/mm.

Moment at base of inner Rib [Mbase,c]:
= Unit Force * e * L
= 0.005 * 331.399 * 635.437
= 994.739 N-m

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
= Bending Moment / Section Modulus
= 994.739/57436.492
= 17.313 N./mm²

Compressive Allowable, KL/r < Cc (25.6078 < 128.2549) per AISC E2-1 [Sca]:
= (1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= (1-(25.61)²/(2 * 128.25²))240/
(5/3+3*(25.61)/(8* 128.25)-(25.61³)/(8*128.25³)
= 135.1 N./mm²

AISC Unity Check of Inside Ribs (must be <= 1)
= Sc/Sca + (Mbase,c * C1/I)/Sba
= 1.52/135.11 + (994.74 * 75.0/430.773)/159.96
= 0.120

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	135.00	N./mm²
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	30.5	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	18.3	kN
Saddle Load QL (Wind/Seismic contribution)	QL	5.3	kN
Maximum Transverse Force	Ft	5.2	kN
Maximum Longitudinal Force	Fl	10.4	kN
Saddle Bolted to Steel Foundation		No	

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)
= 10.39/(135.0 * 4.0)
= 0.1924 cm²

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
= B * Ft + Sum of X Moments
= 1200.0 * 5.19 + 0.0
= 6235.33 N-m

Eccentricity (e):
= Rmom / QO
= 6235.33/18.32

```
  = 340.27 mm. > Bplen/6 --> Uplift in Transverse direction

 f = Bplen / 2 - Edgedis
   = 1100.0/2 - 30.51
   = 519.49 mm.
```

Modular Ratio Of Steel/Concrete (n1):

```
  = ES / EC
  = 203402.5/21526.32
  = 9.45

 K1 = 3 (e - 0.5 * Bplen)
    = 3 (340.27 - 0.5*1100.0)
    = -629.20 mm.

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 9.45 * 4.34/170.0 * (519.49 + 340.27)
    = 124468.18 mm.²

 K3 = -K2 * (0.5 * Bplen + f)
    = -124468.18 * (0.5 * 1100.0 + 519.49)
    = -133118038.92 mm.³
```

Iteratively Solving for the Effective Bearing Length:

```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + -629.2 * Y² + 124468.18 * Y + -0.1E+09 = 0
 Y  = 715.34 mm.

 Num = (Bplen / 2 - Y / 3 - e)
     = (1100.0/2 - 715.34/3 - 340.27)
     = -28.71

 Denom = (Bplen / 2 - Y / 3 + f)
       = (1100.0/2 - 715.34/3 + 519.49)
       = 831.05
```

Total Bolt Tension Force [Tforce]:

```
  = - QO * Num / Denom
  = - 18.32 * -28.71/831.05
  = 0.63 kN
```

Bolt Area Required due to Transverse Load [Bltareart]:

```
  = Tforce / (Stba * Nbt)
  = 0.63/( 135.0 * 2.0 )
  = 0.0234 cm²
```

Required Area of a Single Bolt [Bltarear]:

```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0.0, 0.1924, 0.0234]
  = 0.1924 cm²
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)
```
= 2(QO + Tforce) / (Y * Bpwid)
= 2(18.32 + 0.63)/(715.34 * 170.0)
= 3.12 bars
```

Distance from Baseplate Edge to the Web [ADIST]:
```
= (Bplen - Weblngth) / 2
= (1100.0 - 1049.2)/2
= 25.4000 mm.
```

Overturning Moment due To Bolt Tension [Mt]:
```
= Tforce * Adist
= 0.63 * 25.4
= 16.08 N-m
```

Equivalent Bearing Pressure (f1):
```
= fc * (Y - Adist) / Y
= 3.12 * (715.34 - 25.4)/715.34
= 3.01 bars
```

Overturning Moment due to Bearing Pressure [Mc]:
```
= (Adist² * Bpwid / 6) * (f1 + 2 * fc)
= (25.4² * 170.0/6) * (3.01 + 2 * 3.12)
= 16.90 N-m
```

Baseplate Required Thickness [Treq]:
```
= (6 * max(Mt,Mc) / (Bpwid * Sba))½
= (6 *max(16.08,16.9/(170.0 * 142.73))½
= 2.0437 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( 150.0 + 1.56*sqrt( 559.0 * 6.0 ), 2 * 500.0 )
= 240.3454 mm.
```

Input and Calculated Values:

Vessel Mean Radius	Rm	559.00	mm.
Stiffened Vessel Length per 4.15.6	L	3400.00	mm.
Distance from Saddle to Vessel tangent	a	500.00	mm.
Saddle Width	b	150.00	mm.
Saddle Bearing Angle	theta	120.00	degrees

```
Inside Depth of Head                              h2      281.00  mm.

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

Distance from Saddle Base to Centerline            B     1200.00  mm.
Coefficient of Friction                           mu        0.00

Saddle Force Q, Operating Case                              37.16  kN

Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                         N./mm² |       N./mm² |
-------------------------------------------------------------------
Long. Stress at Top    of Midspan         35.40 |       137.90 |
Long. Stress at Bottom of Midspan         39.14 |       137.90 |
Long. Stress at Top    of Saddles         42.29 |       137.90 |
Long. Stress at Bottom of Saddles         34.48 |       137.90 |
-------------------------------------------------------------------
Tangential Shear in Shell                  8.25 |       110.32 |
Circ. Stress at Horn of Saddle            97.04 |       172.38 |
Circ. Compressive Stress in Shell          1.96 |       137.90 |
-------------------------------------------------------------------
```

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

Saddle Reaction Force due to Wind Ft [Fwt]:

```
= Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
= 3.0( 1.2/2 + 0 ) * 1200.0/994.1971
= 2.1 kN
```

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

```
= max( Fl, Friction Load, Sum of X Forces) * B / Ls
= max( 0.65, 0.0, 0 ) * 1200.0/2350.0002
= 0.3 kN
```

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

```
= max( Fl, Friction Force, Sum of X Forces ) * B / Ls
= max( 10.39, 0.0, 0 ) * 1200.0/2350.0002
= 5.3 kN
```

Saddle Reaction Force due to Earthquake Ft [Fst]:

```
= Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
= 3.0( 10/2 + 0 ) * 1200.0/994.1971
= 18.8 kN
```

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

```
= Saddle Load + max( Fwl, Fwt, Fsl, Fst )
= 18 + max( 0.3, 2, 5, 19 )
= 37.2 kN
```

Longitudinal Wind Force [Fl]:

```
= WindScalar * WindPress( Platform Area + ( End Area * WindDiaMult ) )
= 0.6 * 766.08( 0.0 + ( 1.177 * 1.2 ))
```

= 649.027 N

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		39.29	kN
Transverse Shear Load Saddle	Ft	5.19	kN
Longitudinal Shear Load Saddle		10.39	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(1100.0/2 + 12.0 + 12.0)sin(60.0/2), 2*559.0)
= 994.197 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 = 0.0445	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)]
= -37*500.0[1-(1-500.0/3400.0+(559.0²-281.0²)/
(2*500.0*3400.0))/(1+(4*281.0)/(3*3400.0))]
= -3157.2 N-m

Moment per Equation 4.15.4 [M2]:

= Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/(3L))-4a/L
= 37*3400/4(1+2(559²-281²)/(3400²))/(1+(4*281)/
(3*3400))-4*500/3400
= 11024.8 N-m

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

= P * Rm/(2t) - M2/(pi*Rm²t)
= 8.0 * 559.0/(2*6.0) - 11024.8/(pi*559.0²*6.0)
= 35.40 N./mm²

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

= P * Rm/(2t) + M2/(pi * Rm² * t)
= 8.0 * 559.0/(2 * 6.0) + 11024.8/(pi * 559.0² * 6.0)
= 39.14 N./mm²

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

= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 8.0*559.0/(2*6.0)--3157.2/(0.1066*pi*559.0²*6.0)
= 42.29 N./mm²

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

= P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
= 8.0*559.0/(2*6.0)+-3157.2/(0.1923*pi*559.0²*6.0)
= 34.48 N./mm²

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

```
= Q(L-2a)/(L+(4*h2/3))
= 37( 3400.0 - 2 * 500.0)/(3400.0 + ( 4 * 281.0/3))
= 23.6 kN
```

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

```
= K2 * T / ( Rm * t )
= 1.1707 * 23.63/( 559.0 * 6.0 )
= 8.25 N./mm²
```

Decay Length (4.15.22) [x1,x2]:

```
= 0.78 * sqrt( Rm * t )
= 0.78 * sqrt( 559.0 * 6.0 )
= 45.173 mm.
```

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

```
= -K5 * Q * k / ( t * ( b + X1 + X2 ) )
= - 0.7603 * 37 * 0.1/( 6.0 * ( 150.0 + 45.17 + 45.17 ) )
= -1.96 N./mm²
```

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.25) [sigma7*]:

```
= -Q/(4*t*(b+X1+X2)) - 12*K7*Q*Rm/(L*t²)
= -37/(4*6.0*(150.0+45.173+45.173)) -
    12 * 0.044 * 37 * 559.0/(3400.0 * 6.0²)
= -97.04 N./mm²
```

Effective reinforcing plate width (4.15.1) [B1]:

```
= min( b + 1.56 * sqrt( Rm * t ), 2a  )
= min( 150.0 + 1.56 * sqrt( 559.0 * 6.0 ), 2 * 500.0 )
= 240.35 mm.
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1100.0000	mm.
Baseplate Thickness	Bpthk	15.0000	mm.
Baseplate Width	Bpwid	170.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	15.0000	mm.
Web Thickness	Webtk	15.0000	mm.
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	239.9	N./
Height of Web at Center	Hw,c	635.0	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	290.1	6.0	3.0	17.4	5221.8	0.145E+05
Wearplate	200.0	12.0	12.0	24.0	28800.0	0.188E+05
Web	15.0	611.0	323.5	91.6	2964876.5	0.295E+05

```
BasePlate        170.0 |        15.0 |        636.5 |        25.5 |    1623074.8 |    0.304E+05 |
Totals             ... |         ... |          ... |       158.6 |    4621973.5 |    0.930E+05 |
```

Distance to Centroid [C1]:

```
= AY / A
= 1819.675/158.556
= 291.504 mm.
```

Angle [beta]:

```
= 180 - Saddle Angle/2
= 180 - 120.0/2
= 120.0
```

Saddle Splitting Coefficient [K1]:

```
= ( 1 + cos(beta) - 0.5*sin(beta)² )/(pi - beta + sin(beta)cos(beta) )
= ( 1 + cos(120.0) - 0.5*sin(120.0)² )/(pi - 2.094 + sin(120.0)cos(120.0) )
= 0.2035
```

Saddle Splitting Force [Fh]:

```
= K1 * Q
= 0.204 * 37.16
= 7.5629 kN
```

```
Tension Stress, St = ( Fh/As )       =          0.5358  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)
= 1200.0 - 556.0 * sin(120.0/2)/1.0472
= 740.192 mm.
```

```
Bending Moment, M  = Fh * d          =       5600.2456  N-m

Bending Stress, Sb = ( M * C1 / I  ) =          1.7539  N./mm²
Allowed Stress, Sa = 2/3 * Yield Str =        159.9640  N./mm²
```

Minimum Thickness of Baseplate per Moss:

```
= ( 3( Q + Saddle_Wt )BasePlateWidth / ( 4 * BasePlateLength * AllStress ))½
= ( 3(37 + 2)170.0/( 4 * 1100.0 * 159.964 ))½
= 5.336 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 - 120.0/2 )( 550.0 + 12.0 + 12.0 )
= 994.197 mm.
```

Distance between Ribs [e]:

```
= Web Length / ( Nribs - 1 )
= 994.1971/( 4 - 1 )
= 331.399 mm.
```

Baseplate Pressure Area [Ap]:

```
= e * Bpwid / 2
```

```
  = 331.399 * 170.0/2
  = 281.689 cm²
```

Bearing Pressure [Bp]:
```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 37.16/( 1100.0 * 170.0 )
  = 0.020 kN/cm²
```

Axial Load [P]:
```
  = Ap * Bp
  = 281.7 * 0.02
  = 5.598 kN
```

Area of the Rib and Web [Ar]:
```
  = Rib Area + Web Area
  = 20.25 + 24.855
  = 45.105 cm²
```

Compressive Stress [Sc]:
```
  = P/Ar
  = 5.6/45.1049
  = 1.241 N./mm²
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	15.0	150.0	...	22.5	...	422.

Rib dimension [D]:
```
  = Saddle Width - Web Thickness
  = 150.0 - 15.0
  = 135.000 mm.
```

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 0.0/45.105
  = 0.000 mm.
```

Distance to Centroid [C1]:
```
  = Saddle Width / 2
  = 150.0/2
  = 75.000 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 421.9/45.105 )
  = 30.583 mm.
```

Length of Outer Rib [L]:
```
  = Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
  = 1200.0 - cos( 120.0/2 )( 550.0 + 12.0 + 12.0 ) - 15.0
```

= 898.000 mm.

Intermediate Term [Cc]:
= sqrt(2 * pi² * Elastic Modulus / Yield Stress)
= sqrt(2 * pi² * 0.19994E+09/239.9)
= 128.255

Slenderness ratio [KL/r]:
= KL/r
= 1 * 898.0/30.583
= 29.363

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * L / 2
= 10.4/(2 * 1100.0) * 331.399 * 898.0/2
= 702.883 N-m

Compressive Allowable, KL/r < Cc (29.3627 < 128.2549) per AISC E2-1 [Sca]:
= (1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= (1-(29.36)²/(2 * 128.25²))240/
(5/3+3*(29.36)/(8* 128.25)-(29.36³)/(8*128.25³)
= 133.4 N./mm²

AISC Unity Check of Outside Ribs (must be <= 1)
= Sc/Sca + (Rm * C1 / I)/Sba
= 1.24/133.44 + (702.88 * 75.0/4218750)/159.96
= 0.087

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	15.0	135.0	0.0	20.2	0.0	421.
Web	331.4	15.0	0.0	49.7	0.0	9.32
Totals	...	...	...	70.0	...	431.

Distance to Centroid from Datum [ytot]:
= AY / A
= 0.0/69.96
= 0.000 mm.

Distance to Centroid [C1]:
= Saddle Width / 2
= 150.0/2
= 75.000 mm.

Length of Inner Rib [L]:
= Saddle Height - sqrt((Ro + Wpdthk)^2 - (Pitch/2)^2) - Bpthk
= 1200.0 - sqrt((574.0 + 12.0)^2 - (331.399/2)^2) - 15.0
= 635.437 mm.

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)

```
  = sqrt( 430.8/69.96 )
  = 24.814 mm.
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 635.437/24.814
  = 25.608
```

Unit Force [Force,u]:

```
  = Fl / ( 2 * Baseplate Length )
  = 10.388/( 2 * 1100.0 )
  = 0.005 kN/mm.
```

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

```
  = Unit Force * e * L
  = 0.005 * 331.399 * 635.437
  = 994.739 N-m
```

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

```
  = Bending Moment / Section Modulus
  = 994.739/57436.492
  = 17.313 N./mm²
```

Compressive Allowable, KL/r < Cc (25.6078 < 128.2549) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 25.61 )²/(2 * 128.25² ))240/
    ( 5/3+3*(25.61)/(8* 128.25)-( 25.61³)/(8*128.25³)
  = 135.1 N./mm²
```

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

```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 1.62/135.11 + ( 994.74 * 75.0/430.773 )/159.96
  = 0.120
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	135.00	N./mm²
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	30.5	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	20.5	kN
Saddle Load QL (Wind/Seismic contribution)	QL	5.3	kN
Maximum Transverse Force	Ft	5.2	kN
Maximum Longitudinal Force	Fl	10.4	kN
Saddle Bolted to Steel Foundation		No	

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 )
  = 10.39/(135.0 * 4.0)
  = 0.1924 cm²
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 1200.0 * 5.19 + 0.0
  = 6235.33 N-m
```

Eccentricity (e):
```
  = Rmom / QO
  = 6235.33/20.48
  = 304.34 mm. > Bplen/6 --> Uplift in Transverse direction

f = Bplen / 2 - Edgedis
  = 1100.0/2 - 30.51
  = 519.49 mm.
```

Modular Ratio Of Steel/Concrete (n1):
```
  = ES / EC
  = 203402.5/21526.32
  = 9.45

K1 = 3 (e - 0.5 * Bplen)
   = 3 (304.34 - 0.5*1100.0)
   = -736.99 mm.

K2 = 6 * n1 * At / Bpwid * (f + e)
   = 6 * 9.45 * 4.34/170.0 * (519.49 + 304.34)
   = 119266.56 mm.²

K3 = -K2 * (0.5 * Bplen + f)
   = -119266.55 * (0.5 * 1100.0 + 519.49)
   = -127554932.57 mm.³
```

Iteratively Solving for the Effective Bearing Length:
```
Y³ + K1 * Y² + K2 * Y + K3 = 0
Y³ + -736.99 * Y² + 119266.55 * Y + -0.1E+09 = 0
Y  = 790.30 mm.

Num = (Bplen / 2 - Y / 3 - e)
    = (1100.0/2 - 790.3/3 - 304.34)
    = -17.77

Denom = (Bplen / 2 - Y / 3 + f)
      = (1100.0/2 - 790.3/3 + 519.49)
```

= 806.06

Total Bolt Tension Force [Tforce]:
= - QO * Num / Denom
= - 20.48 * -17.77/806.06
= 0.45 kN

Bolt Area Required due to Transverse Load [Bltareart]:
= Tforce / (Stba * Nbt)
= 0.45/(135.0 * 2.0)
= 0.0167 cm²

Required Area of a Single Bolt [Bltarear]:
= max[Bltarearl, Bltarears, Bltareart]
= max[0.0, 0.1924, 0.0167]
= 0.1924 cm²

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)
= 2(QO + Tforce) / (Y * Bpwid)
= 2(20.48 + 0.45)/(790.3 * 170.0)
= 3.12 bars

Distance from Baseplate Edge to the Web [ADIST]:
= (Bplen - Weblngth) / 2
= (1100.0 - 1049.2)/2
= 25.4000 mm.

Overturning Moment due To Bolt Tension [Mt]:
= Tforce * Adist
= 0.45 * 25.4
= 11.47 N-m

Equivalent Bearing Pressure (f1):
= fc * (Y - Adist) / Y
= 3.12 * (790.3 - 25.4)/790.3
= 3.02 bars

Overturning Moment due to Bearing Pressure [Mc]:
= (Adist² * Bpwid / 6) * (f1 + 2 * fc)
= (25.4² * 170.0/6) * (3.02 + 2 * 3.12)
= 16.91 N-m

Baseplate Required Thickness [Treq]:
= (6 * max(Mt,Mc) / (Bpwid * Sba))½
= (6 *max(11.47,16.91/(170.0 * 142.73))½
= 2.0446 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( 150.0 + 1.56*sqrt( 559.0 * 6.0 ), 2 * 300.0 )
= 240.3454 mm.
```

Input and Calculated Values:

Vessel Mean Radius	Rm	559.00	mm.
Stiffened Vessel Length per 4.15.6	L	3400.00	mm.
Distance from Saddle to Vessel tangent	a	300.00	mm.
Saddle Width	b	150.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Inside Depth of Head	h2	281.00	mm.
Shell Allowable Stress used in Calculation		212.38	N./mm²
Head Allowable Stress used in Calculation		212.38	N./mm²
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Distance from Saddle Base to Centerline	B	1200.00	mm.
Coefficient of Friction	mu	0.30	
Saddle Force Q, Test Case, no Ext. Forces		28.93	kN

Horizontal Vessel Analysis Results:	Actual N./mm²	Allowable N./mm²
Long. Stress at Top of Midspan	46.27	212.38
Long. Stress at Bottom of Midspan	51.14	212.38
Long. Stress at Top of Saddles	49.75	212.38
Long. Stress at Bottom of Saddles	48.13	212.38
Tangential Shear in Shell	7.49	139.65
Circ. Stress at Horn of Saddle	30.58	318.57
Circ. Compressive Stress in Shell	1.53	212.38

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( 0.4/2 + 0 ) * 1200.0/994.1971
```

= 0.7 kN

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
= max(Fl, Friction Load, Sum of X Forces) * B / Ls
= max(0.21, 0.0, 0) * 1200.0/2350.0002
= 0.1 kN

Load Combination Results for Q + Wind or Seismic [Q]:
= Saddle Load + max(Fwl, Fwt, Fsl, Fst)
= 28 + max(0.1, 0.7, 0, 0)
= 28.9 kN

Longitudinal Wind Force [Fl]:
= WindScalar * WindPress(Platform Area + (End Area * WindDiaMult))
= 0.6 * 766.08(0.0 + (1.177 * 1.2))
= 649.027 N

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		31.06	kN
Transverse Shear Load Saddle	Ft	0.19	kN
Longitudinal Shear Load Saddle		0.21	kN

Hydrostatic Test Pressure at center of Vessel 10.455 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(1100.0/2 + 12.0 + 12.0)sin(60.0/2), 2*559.0)
= 994.197 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 = 0.0161	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)]
= -29*300.0[1-(1-300.0/3400.0+(559.0²-281.0²)/
(2*300.0*3400.0))/(1+(4*281.0)/(3*3400.0))]
= -656.7 N-m

Moment per Equation 4.15.4 [M2]:
= Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/(3L))-4a/L
= 29*3400/4(1+2(559²-281²)/(3400²))/(1+(4*281)/
(3*3400))-4*300/3400
= 14373.5 N-m

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
= P * Rm/(2t) - M2/(pi*Rm²t)

```
  = 10.455 * 559.0/(2*6.0) - 14373.5/(pi*559.0²*6.0)
  = 46.27 N./mm²
```

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

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 10.455 * 559.0/(2 * 6.0) + 14373.5/(pi * 559.0² * 6.0 )
  = 51.14 N./mm²
```

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

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 10.455*559.0/(2*6.0)--656.7/(0.1066*pi*559.0²*6.0)
  = 49.75 N./mm²
```

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

```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 10.455*559.0/(2*6.0)+-656.7/(0.1923*pi*559.0²*6.0)
  = 48.13 N./mm²
```

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

```
  = Q(L-2a)/(L+(4*h2/3))
  = 29( 3400.0 - 2 * 300.0)/(3400.0 + ( 4 * 281.0/3))
  = 21.5 kN
```

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

```
  = K2 * T / ( Rm * t )
  = 1.1707 * 21.46/( 559.0 * 6.0 )
  = 7.49 N./mm²
```

Decay Length (4.15.22) [x1,x2]:

```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 559.0 * 6.0 )
  = 45.173 mm.
```

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

```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 29 * 0.1/( 6.0 * ( 150.0 + 45.17 + 45.17 ) )
  = -1.53 N./mm²
```

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.25) [sigma7*]:

```
  = -Q/(4*t*(b+X1+X2)) - 12*K7*Q*Rm/(L*t²)
  = -29/(4*6.0*(150.0+45.173+45.173)) -
     12 * 0.016 * 29 * 559.0/(3400.0 * 6.0²)
  = -30.58 N./mm²
```

Effective reinforcing plate width (4.15.1) [B1]:

```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 150.0 + 1.56 * sqrt( 559.0 * 6.0 ), 2 * 300.0 )
  = 240.35 mm.
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1100.0000	mm.
Baseplate Thickness	Bpthk	15.0000	mm.
Baseplate Width	Bpwid	170.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	15.0000	mm.

Web Thickness	Webtk	15.0000	mm.
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	239.9	N./
Height of Web at Center	Hw,c	635.0	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	290.1	6.0	3.0	17.4	5221.8	0.145E+05
Wearplate	200.0	12.0	12.0	24.0	28800.0	0.188E+05
Web	15.0	611.0	323.5	91.6	2964876.5	0.295E+05
BasePlate	170.0	15.0	636.5	25.5	1623074.8	0.304E+05
Totals	...	...	...	158.6	4621973.5	0.930E+05

Distance to Centroid [C1]:
= AY / A
= 1819.675/158.556
= 291.504 mm.

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

Saddle Splitting Coefficient [K1]:
= (1 + cos(beta) - 0.5*sin(beta)²)/(pi - beta + sin(beta)cos(beta))
= (1 + cos(120.0) - 0.5*sin(120.0)²)/(pi - 2.094 + sin(120.0)cos(120.0))
= 0.2035

Saddle Splitting Force [Fh]:
= K1 * Q
= 0.204 * 28.934
= 5.8887 kN

Tension Stress, St = (Fh/As)	=	0.4172 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)
= 1200.0 - 556.0 * sin(120.0/2)/1.0472
= 740.192 mm.

Bending Moment, M = Fh * d	=	4360.5527 N-m
Bending Stress, Sb = (M * C1 / I)	=	1.3657 N./mm²
Allowed Stress, Sa = 2/3 * Yield Str	=	159.9640 N./mm²

Minimum Thickness of Baseplate per Moss:
= (3(Q + Saddle_Wt)BasePlateWidth / (4 * BasePlateLength * AllStress))½
= (3(29 + 2)170.0/(4 * 1100.0 * 159.964))½
= 4.744 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 - 120.0/2 )( 550.0 + 12.0 + 12.0 )
= 994.197 mm.
```

Distance between Ribs [e]:
```
= Web Length / ( Nribs - 1 )
= 994.1971/( 4 - 1 )
= 331.399 mm.
```

Baseplate Pressure Area [Ap]:
```
= e * Bpwid / 2
= 331.399 * 170.0/2
= 281.689 cm²
```

Bearing Pressure [Bp]:
```
= Q / ( BasePlateLength * BasePlateWidth )
= 28.934/( 1100.0 * 170.0 )
= 0.015 kN/cm²
```

Axial Load [P]:
```
= Ap * Bp
= 281.7 * 0.02
= 4.359 kN
```

Area of the Rib and Web [Ar]:
```
= Rib Area + Web Area
= 20.25 + 24.855
= 45.105 cm²
```

Compressive Stress [Sc]:
```
= P/Ar
= 4.4/45.1049
= 0.966 N./mm²
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	15.0	150.0	...	22.5	...	422.

Rib dimension [D]:
```
= Saddle Width - Web Thickness
= 150.0 - 15.0
= 135.000 mm.
```

Distance to Centroid from Datum [ytot]:
```
= AY / A
= 0.0/45.105
```

= 0.000 mm.

Distance to Centroid [C1]:
= Saddle Width / 2
= 150.0/2
= 75.000 mm.

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(421.9/45.105)
= 30.583 mm.

Length of Outer Rib [L]:
= Saddle Height - cos(theta/2)(radius + shlthk + wpdthk) - bpthk
= 1200.0 - cos(120.0/2)(550.0 + 12.0 + 12.0) - 15.0
= 898.000 mm.

Intermediate Term [Cc]:
= sqrt(2 * pi² * Elastic Modulus / Yield Stress)
= sqrt(2 * pi² * 0.19994E+09/239.9)
= 128.255

Slenderness ratio [KL/r]:
= KL/r
= 1 * 898.0/30.583
= 29.363

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * L / 2
= 0.2/(2 * 1100.0) * 331.399 * 898.0/2
= 14.491 N-m

Compressive Allowable, KL/r < Cc (29.3627 < 128.2549) per AISC E2-1 [Sca]:
= (1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= (1-(29.36)²/(2 * 128.25²))240/
(5/3+3*(29.36)/(8* 128.25)-(29.36³)/(8*128.25³)
= 133.4 N./mm²

AISC Unity Check of Outside Ribs (must be <= 1)
= Sc/Sca + (Rm * C1 / I)/Sba
= 0.97/133.44 + (14.49 * 75.0/4218750)/159.96
= 0.009

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	15.0	135.0	0.0	20.2	0.0	421.
Web	331.4	15.0	0.0	49.7	0.0	9.32
Totals	...	...	...	70.0	...	431.

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

```
  = 0.0/69.96
  = 0.000 mm.
```

Distance to Centroid [C1]:
```
  = Saddle Width / 2
  = 150.0/2
  = 75.000 mm.
```

Length of Inner Rib [L]:
```
  = Saddle Height - sqrt( (Ro + Wpdthk)^2 - (Pitch/2)^2 ) - Bpthk
  = 1200.0 - sqrt( (574.0 + 12.0)^2 - (331.399/2)^2 ) - 15.0
  = 635.437 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 430.8/69.96 )
  = 24.814 mm.
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 635.437/24.814
  = 25.608
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 0.214/( 2 * 1100.0 )
  = 0.000 kN/mm.
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 0. * 331.399 * 635.437
  = 20.508 N-m
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 20.508/57436.492
  = 0.357 N./mm²
```

Compressive Allowable, KL/r < Cc (25.6078 < 128.2549) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 25.61 )²/(2 * 128.25² ))240/
    ( 5/3+3*(25.61)/(8* 128.25)-( 25.61³)/(8*128.25³)
  = 135.1 N./mm²
```

AISC Unity Check of Inside Ribs (must be <= 1)
```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 1.26/135.11 + ( 20.51 * 75.0/430.773 )/159.96
  = 0.012
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	135.00	N./mm²

Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	30.5	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	30.4	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.1	kN
Maximum Transverse Force	Ft	0.2	kN
Maximum Longitudinal Force	Fl	0.2	kN
Saddle Bolted to Steel Foundation		No	

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)
= 0.21/(135.0 * 4.0)
= 0.0040 cm²

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
= B * Ft + Sum of X Moments
= 1200.0 * 0.19 + 0.0
= 233.41 N-m

Eccentricity (e):
= Rmom / QO
= 233.41/30.36
= 7.69 mm. < Bplen/6 --> No Uplift in Transverse direction

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

Required Area of a Single Bolt [Bltarear]:
= max[Bltarearl, Bltarears, Bltareart]
= max[0.0, 0.004, 0.0]
= 0.0040 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(150.0 + 1.56*sqrt(559.0 * 6.0), 2 * 500.0)
= 240.3454 mm.

Input and Calculated Values:

Vessel Mean Radius	Rm	559.00	mm.
Stiffened Vessel Length per 4.15.6	L	3400.00	mm.
Distance from Saddle to Vessel tangent	a	500.00	mm.
Saddle Width	b	150.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Inside Depth of Head	h2	281.00	mm.
Shell Allowable Stress used in Calculation		212.38	N./mm²
Head Allowable Stress used in Calculation		212.38	N./mm²
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Distance from Saddle Base to Centerline	B	1200.00	mm.
Coefficient of Friction	mu	0.00	
Saddle Force Q, Test Case, no Ext. Forces		31.62	kN

Horizontal Vessel Analysis Results:	Actual N./mm²	Allowable N./mm²
Long. Stress at Top of Midspan	47.11	212.38
Long. Stress at Bottom of Midspan	50.30	212.38
Long. Stress at Top of Saddles	52.98	212.38
Long. Stress at Bottom of Saddles	46.33	212.38
Tangential Shear in Shell	7.02	139.65
Circ. Stress at Horn of Saddle	82.58	318.57
Circ. Compressive Stress in Shell	1.67	212.38

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( 0.4/2 + 0 ) * 1200.0/994.1971
= 0.7 kN
```

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

```
= max( Fl, Friction Load, Sum of X Forces) * B / Ls
= max( 0.21, 0.0, 0 ) * 1200.0/2350.0002
= 0.1 kN
```

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

```
= Saddle Load + max( Fwl, Fwt, Fsl, Fst )
= 31 + max( 0.1, 0.7, 0, 0 )
= 31.6 kN
```

Longitudinal Wind Force [Fl]:

```
= WindScalar * WindPress( Platform Area + ( End Area * WindDiaMult ) )
= 0.6 * 766.08( 0.0 + ( 1.177 * 1.2 ))
```

= 649.027 N

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		33.75	kN
Transverse Shear Load Saddle	Ft	0.19	kN
Longitudinal Shear Load Saddle		0.21	kN

Hydrostatic Test Pressure at center of Vessel 10.455 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(1100.0/2 + 12.0 + 12.0)sin(60.0/2), 2*559.0)
= 994.197 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 = 0.0445	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)]
= -32*500.0[1-(1-500.0/3400.0+(559.0²-281.0²)/
(2*500.0*3400.0))/(1+(4*281.0)/(3*3400.0))]
= -2686.5 N-m

Moment per Equation 4.15.4 [M2]:

= Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/(3L))-4a/L
= 32*3400/4(1+2(559²-281²)/(3400²))/(1+(4*281)/
(3*3400))-4*500/3400
= 9381.2 N-m

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

= P * Rm/(2t) - M2/(pi*Rm²t)
= 10.455 * 559.0/(2*6.0) - 9381.2/(pi*559.0²*6.0)
= 47.11 N./mm²

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

= P * Rm/(2t) + M2/(pi * Rm² * t)
= 10.455 * 559.0/(2 * 6.0) + 9381.2/(pi * 559.0² * 6.0)
= 50.30 N./mm²

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

= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 10.455*559.0/(2*6.0)--2686.5/(0.1066*pi*559.0²*6.0)
= 52.98 N./mm²

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

= P * Rm/(2t) + M1/(K1* * pi * Rm² * t)

```
  = 10.455*559.0/(2*6.0)+-2686.5/(0.1923*pi*559.0²*6.0)
  = 46.33 N./mm²
```

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

```
  = Q(L-2a)/(L+(4*h2/3))
  = 32( 3400.0 - 2 * 500.0)/(3400.0 + ( 4 * 281.0/3))
  = 20.1 kN
```

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

```
  = K2 * T / ( Rm * t )
  = 1.1707 * 20.1/( 559.0 * 6.0 )
  = 7.02 N./mm²
```

Decay Length (4.15.22) [x1,x2]:

```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 559.0 * 6.0 )
  = 45.173 mm.
```

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

```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 32 * 0.1/( 6.0 * ( 150.0 + 45.17 + 45.17 ) )
  = -1.67 N./mm²
```

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.25) [sigma7*]:

```
  = -Q/(4*t*(b+X1+X2)) - 12*K7*Q*Rm/(L*t²)
  = -32/(4*6.0*(150.0+45.173+45.173)) -
     12 * 0.044 * 32 * 559.0/(3400.0 * 6.0²)
  = -82.58 N./mm²
```

Effective reinforcing plate width (4.15.1) [B1]:

```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 150.0 + 1.56 * sqrt( 559.0 * 6.0 ), 2 * 500.0 )
  = 240.35 mm.
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1100.0000	mm.
Baseplate Thickness	Bpthk	15.0000	mm.
Baseplate Width	Bpwid	170.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	15.0000	mm.
Web Thickness	Webtk	15.0000	mm.
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	239.9	N./
Height of Web at Center	Hw,c	635.0	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	290.1	6.0	3.0	17.4	5221.8	0.145E+05

```
Wearplate        200.0 |        12.0 |        12.0 |        24.0 |     28800.0 |   0.188E+05 |
Web               15.0 |       611.0 |       323.5 |        91.6 |   2964876.5 |   0.295E+05 |
BasePlate        170.0 |        15.0 |       636.5 |        25.5 |   1623074.8 |   0.304E+05 |
Totals             ... |         ... |         ... |       158.6 |   4621973.5 |   0.930E+05 |
```

Distance to Centroid [C1]:

```
= AY / A
= 1819.675/158.556
= 291.504 mm.
```

Angle [beta]:

```
= 180 - Saddle Angle/2
= 180 - 120.0/2
= 120.0
```

Saddle Splitting Coefficient [K1]:

```
= ( 1 + cos(beta) - 0.5*sin(beta)² )/(pi - beta + sin(beta)cos(beta) )
= ( 1 + cos(120.0) - 0.5*sin(120.0)² )/(pi - 2.094 + sin(120.0)cos(120.0) )
= 0.2035
```

Saddle Splitting Force [Fh]:

```
= K1 * Q
= 0.204 * 31.62
= 6.4354 kN

Tension Stress, St = ( Fh/As )       =          0.4560  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)
= 1200.0 - 556.0 * sin(120.0/2)/1.0472
= 740.192 mm.

Bending Moment, M  = Fh * d          =       4765.3545  N-m

Bending Stress, Sb = ( M * C1 / I  ) =          1.4924  N./mm²
Allowed Stress, Sa = 2/3 * Yield Str =        159.9640  N./mm²
```

Minimum Thickness of Baseplate per Moss:

```
= ( 3( Q + Saddle_Wt )BasePlateWidth / ( 4 * BasePlateLength * AllStress ))½
= ( 3(32 + 2)170.0/( 4 * 1100.0 * 159.964 ))½
= 4.945 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 - 120.0/2 )( 550.0 + 12.0 + 12.0 )
= 994.197 mm.
```

Distance between Ribs [e]:

```
= Web Length / ( Nribs - 1 )
= 994.1971/( 4 - 1 )
= 331.399 mm.
```

Baseplate Pressure Area [Ap]:
```
= e * Bpwid / 2
= 331.399 * 170.0/2
= 281.689 cm²
```

Bearing Pressure [Bp]:
```
= Q / ( BasePlateLength * BasePlateWidth )
= 31.62/( 1100.0 * 170.0 )
= 0.017 kN/cm²
```

Axial Load [P]:
```
= Ap * Bp
= 281.7 * 0.02
= 4.763 kN
```

Area of the Rib and Web [Ar]:
```
= Rib Area + Web Area
= 20.25 + 24.855
= 45.105 cm²
```

Compressive Stress [Sc]:
```
= P/Ar
= 4.8/45.1049
= 1.056 N./mm²
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	15.0	150.0	...	22.5	...	422.

Rib dimension [D]:
```
= Saddle Width - Web Thickness
= 150.0 - 15.0
= 135.000 mm.
```

Distance to Centroid from Datum [ytot]:
```
= AY / A
= 0.0/45.105
= 0.000 mm.
```

Distance to Centroid [C1]:
```
= Saddle Width / 2
= 150.0/2
= 75.000 mm.
```

Radius of Gyration [r]:
```
= sqrt( Total Inertia / Total Area )
= sqrt( 421.9/45.105 )
= 30.583 mm.
```

Length of Outer Rib [L]:

```
  = Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
  = 1200.0 - cos( 120.0/2 )( 550.0 + 12.0 + 12.0 ) - 15.0
  = 898.000 mm.
```

Intermediate Term [Cc]:

```
  = sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
  = sqrt( 2 * pi² * 0.19994E+09/239.9 )
  = 128.255
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 898.0/30.583
  = 29.363
```

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 0.2/( 2 * 1100.0 ) * 331.399 * 898.0/2
  = 14.491 N-m
```

Compressive Allowable, KL/r < Cc (29.3627 < 128.2549) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 29.36 )²/(2 * 128.25² ))240/
    ( 5/3+3*(29.36)/(8* 128.25)-( 29.36³)/(8*128.25³)
  = 133.4 N./mm²
```

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

```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 1.06/133.44 + ( 14.49 * 75.0/4218750 )/159.96
  = 0.010
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	15.0	135.0	0.0	20.2	0.0	421.
Web	331.4	15.0	0.0	49.7	0.0	9.32
Totals	...	...	...	70.0	...	431.

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 0.0/69.96
  = 0.000 mm.
```

Distance to Centroid [C1]:

```
  = Saddle Width / 2
  = 150.0/2
  = 75.000 mm.
```

Length of Inner Rib [L]:

```
  = Saddle Height - sqrt( (Ro + Wpdthk)^2 - (Pitch/2)^2 ) - Bpthk
  = 1200.0 - sqrt( (574.0 + 12.0)^2 - (331.399/2)^2 ) - 15.0
  = 635.437 mm.
```

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(430.8/69.96)
= 24.814 mm.

Slenderness ratio [KL/r]:
= KL/r
= 1 * 635.437/24.814
= 25.608

Unit Force [Force,u]:
= Fl / (2 * Baseplate Length)
= 0.214/(2 * 1100.0)
= 0.000 kN/mm.

Moment at base of inner Rib [Mbase,c]:
= Unit Force * e * L
= 0. * 331.399 * 635.437
= 20.508 N-m

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
= Bending Moment / Section Modulus
= 20.508/57436.492
= 0.357 N./mm²

Compressive Allowable, KL/r < Cc (25.6078 < 128.2549) per AISC E2-1 [Sca]:
= (1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= (1-(25.61)²/(2 * 128.25²))240/
(5/3+3*(25.61)/(8* 128.25)-(25.61³)/(8*128.25³)
= 135.1 N./mm²

AISC Unity Check of Inside Ribs (must be <= 1)
= Sc/Sca + (Mbase,c * C1/I)/Sba
= 1.38/135.11 + (20.51 * 75.0/430.773)/159.96
= 0.012

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	135.00	N./mm²
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	30.5	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	33.0	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.1	kN
Maximum Transverse Force	Ft	0.2	kN
Maximum Longitudinal Force	Fl	0.2	kN
Saddle Bolted to Steel Foundation		No	

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 )
= 0.21/(135.0 * 4.0)
= 0.0040 cm²
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
= B * Ft + Sum of X Moments
= 1200.0 * 0.19 + 0.0
= 233.41 N-m
```

Eccentricity (e):
```
= Rmom / QO
= 233.41/33.04
= 7.06 mm. < Bplen/6 --> No Uplift in Transverse direction
```

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

Required Area of a Single Bolt [Bltarear]:
```
= max[Bltarearl, Bltarears, Bltareart]
= max[0.0, 0.004, 0.0]
= 0.0040 cm²
```

Input, Nozzle Desc: N08 (1in) **From: 10**

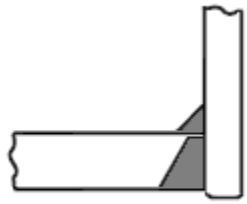
Pressure for Reinforcement Calculations	P	8.040	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Elliptical Head	D	1100.00	mm.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	10.0000	mm.
Head Internal Corrosion Allowance	c	6.0000	mm.
Head External Corrosion Allowance	co	0.0000	mm.
Distance from Head Centerline	L1	400.0000	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		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.7000	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	6.0000	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	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 1.1	
Flange Series	Series	ù	

The Pressure Design option was Design Pressure + static head.

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



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

Note : Checking Nozzle in the Meridional direction.

Reinforcement CALCULATION, Description: N08 (1in)

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

```
Actual Inside Diameter Used in Calculation          1.000  in.
Actual Thickness Used in Calculation                0.500  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 Elliptical Head, Tr [Int. Press]

```
= (P*K1*D))/(2*Sv*E-0.2*P) per UG-37(a)(3)
= (8.04*0.891*1112.0)/(2 *137.9*1.0-0.2*8.04)
= 2.8896 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)
= (8.04*18.7)/(138*1.0-0.6*8.04)
= 0.1094 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2564 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)          Dl     84.3035  mm.
Parallel to Vessel Wall, opening length            d     42.1518  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp    10.0000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
= min( 1, Sn/Sv )
= min( 1, 137.9/137.9 )
= 1.000
```

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 137.9/137.9)
= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(1.0, 1.0)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.218	0.611	NA
Area in Shell	A1	0.468	0.464	NA
Area in Nozzle Wall	A2	1.454	1.421	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	2.562	2.525	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 62.53 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (42.1518*2.8896*1.0+2*6.7*2.8896*1.0*(1-1.0))
= 1.218 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)
= 42.152(1.0 * 4.0 - 1.0 * 2.89) - 2 * 6.7
(1.0 * 4.0 - 1.0 * 2.8896) * (1 - 1.0)
= 0.468 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2/sin(alpha3)
= (2 * 10.0)(6.7 - 0.11)1.0/sin(65.1)
= 1.454 cm²

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

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 8.0² * 1.0 + (0.0)² * 1.0
= 0.640 cm²

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 = 10.0, tr = 2.89, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.722, Temp. Reduction = 15 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -23 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :   -29 °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)       -48 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
`Design Pressure/Ambient Rating = 8.04/19.60 = 0.410`

Weld Size Calculations, Description: N08 (1in)

`Intermediate Calc. for nozzle/shell Welds   Tmin      6.0000  mm.`

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.2000 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.

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

Weld Load [W]:

```
= max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max( 0, (1.218 - 0.468 + 2 * 6.7 * 1.0 *
  (1.0 * 4.0 - 2.8896 ) )138)
= 12.39 kN
```

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

Weld Load [W1]:

```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 1.4536 + 0.0 + 0.64 - 0.0 * 1.0 ) * 138
= 28.87 kN
```

Weld Load [W2]:

```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 1.4536 + 0.0 + 0.64 + ( 0.536 ) ) * 138
= 36.26 kN
```

Weld Load [W3]:

```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 1.4536 + 0.0 + 0.64 + 0.0 + ( 0.536 ) ) * 138
= 36.26 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 57.2543 * 8.0 * 0.49 * 138
= 49. kN
```

Shear, Nozzle Wall [Snw]:
```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 24.8515) * ( 12.7 - 6.0 ) * 0.7 * 138
= 50. kN
```

Tension, Shell Groove Weld [Tngw]:
```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 57.2543 * ( 10.0 - 6.0 ) * 0.74 * 138
= 37. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 49 + 50 ) = 99 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 49 + 0 + 37 + 0 ) = 85 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 49 + 37 + 0 ) = 85 kN
```

Summary of Failure Path Calculations:
```
Path 1-1 = 99 kN , must exceed W = 12 kN  or W1 = 28 kN
Path 2-2 = 85 kN , must exceed W = 12 kN  or W2 = 36 kN
Path 3-3 = 85 kN , must exceed W = 12 kN  or W3 = 36 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
Converged Max. Allow. Pressure in Operating case   10  bars
```

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

```
Nozzle is O.K. for the External Pressure          1  bars
```

Note : Checking Nozzle in the Latitudinal direction.

Reinforcement CALCULATION, Description: N08 (1in)

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

```
Actual Inside Diameter Used in Calculation            1.000  in.
Actual Thickness Used in Calculation                  0.500  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Elliptical Head, Tr [Int. Press]
```
= (P*K1*D))/(2*Sv*E-0.2*P) per UG-37(a)(3)
= (8.04*0.891*1112.0)/(2 *137.9*1.0-0.2*8.04)
= 2.8896 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)
= (8.04*18.7)/(138*1.0-0.6*8.04)
= 0.1094 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2564 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl    74.8000  mm.
Parallel to Vessel Wall, opening length              d    37.4000  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    10.0000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.081	0.542	NA
Area in Shell	A1	0.415	0.412	NA
Area in Nozzle Wall	A2	1.318	1.289	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	2.373	2.340	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)
= (37.4*2.8896*1.0+2*6.7*2.8896*1.0*(1-1.0))
= 1.081 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 )
= 37.4( 1.0 * 4.0 - 1.0 * 2.89 ) - 2 * 6.7
  ( 1.0 * 4.0 - 1.0 * 2.8896 ) * ( 1 - 1.0 )
= 0.415 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
= ( 2 * tlnp )( tn - trn )fr2
= ( 2 * 10.0 )( 6.7 - 0.11 )1.0
= 1.318 cm²
```

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

```
= Wo² * fr2 + ( Wi-can/0.707 )² * fr2
= 8.0² * 1.0 + ( 0.0 )² * 1.0
= 0.640 cm²
```

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

```
 Wall Thickness for Internal/External pressures      ta = 6.2564 mm.
 Wall Thickness per UG16(b),                      tr16b = 7.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 9.1978 mm.
 Wall Thickness                 tb1 = max(trb1, tr16b) = 9.1978 mm.
 Wall Thickness, shell/head, external pressure     trb2 = 6.4111 mm.
 Wall Thickness                 tb2 = max(trb2, tr16b) = 7.5000 mm.
 Wall Thickness per table UG-45                    tb3 = 9.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 9.42, max( 9.1978, 7.5 ) ]
  = 9.1978 mm.
```

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

```
  = max( ta, tb )
  = max( 6.2564, 9.1978 )
  = 9.1978 mm.
```

Available Nozzle Neck Thickness = 12.7000 mm. --> OK

Weld Size Calculations, Description: N08 (1in)

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      6.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
 Nozzle Weld          4.2000 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
```

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (1.0807 - 0.4153 + 2 * 6.7 * 1.0 *
    (1.0 * 4.0 - 2.8896 ) )138)
  = 11.23 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.3181 + 0.0 + 0.64 - 0.0 * 1.0 ) * 138
  = 27.00 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.3181 + 0.0 + 0.64 + ( 0.536 ) ) * 138
  = 34.39 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.3181 + 0.0 + 0.64 + 0.0 + ( 0.536 ) ) * 138
  = 34.39 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 50.8 * 8.0 * 0.49 * 138
= 43. kN
```

Shear, Nozzle Wall [Snw]:

```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 22.05) * ( 12.7 - 6.0 ) * 0.7 * 138
= 45. kN
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 50.8 * ( 10.0 - 6.0 ) * 0.74 * 138
= 33. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 43 + 45 ) = 88 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 43 + 0 + 33 + 0 ) = 76 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 43 + 33 + 0 ) = 76 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 87 kN , must exceed W = 11 kN  or W1 = 27 kN
Path 2-2 = 75 kN , must exceed W = 11 kN  or W2 = 34 kN
Path 3-3 = 75 kN , must exceed W = 11 kN  or W3 = 34 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   10  bars
```

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

```
Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 11.5375 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 172.4421 mm.

Input, Nozzle Desc: N01 (1in) **From: 20**

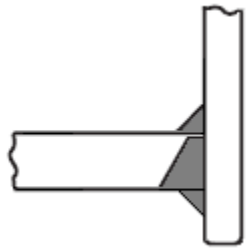
Pressure for Reinforcement Calculations	P	8.000	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1100.00	mm.
Design Length of Section	L	1791.6666	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	6.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		200.00	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		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.7000	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	6.0000	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	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	200.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 1.1	
Flange Series	Series	z	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: N01 (1in)

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

```
Actual Inside Diameter Used in Calculation          1.000  in.
Actual Thickness Used in Calculation                0.500  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)
= (8.0*556.0)/(138*1.0-0.6*8.0)
= 3.2370 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)
= (8.0*18.7)/(138*1.0-0.6*8.0)
= 0.1089 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2564 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)          Dl    74.8000  mm.
Parallel to Vessel Wall, opening length            d    37.4000  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp   15.0000  mm.
Normal to Vessel Wall, Inward                           1.7500  mm.
```

Weld Strength Reduction Factor [fr1]:

```
= min( 1, Sn/Sv )
= min( 1, 137.9/137.9 )
= 1.000
```

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 137.9/137.9)
= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(1.0, 1.0)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.211	0.819	NA
Area in Shell	A1	1.033	0.606	NA
Area in Nozzle Wall	A2	1.977	1.933	NA
Area in Inward Nozzle	A3	0.024	0.024	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	3.675	3.203	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(37.4*4.3799*1+2*6.7*4.3799*1(1-1.0))
= 0.819 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)
= 37.4(1.0 * 6.0 - 1.0 * 4.38) - 2 * 6.7
(1.0 * 6.0 - 1.0 * 4.3799) * (1 - 1.0)
= 0.606 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 15.0)(6.7 - 0.26)1.0
= 1.933 cm²

Area Available in Inward Nozzle [A3]:
= 2 * ti * min(h, Tl, 2.5 * ti) * fr2
= 2 * 0.7 * (1.75) * 1.0
= 0.024 cm²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 8.0² * 1.0 + (0.0)² * 1.0

= 0.640 cm²

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

```
Wall Thickness for Internal/External pressures      ta = 6.2564 mm.
Wall Thickness per UG16(b),                      tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 9.2370 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 9.2370 mm.
Wall Thickness, shell/head, external pressure     trb2 = 6.4171 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 7.5000 mm.
Wall Thickness per table UG-45                    tb3 = 9.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
= min[ tb3, max( tb1,tb2) ]
= min[ 9.42, max( 9.237, 7.5 ) ]
= 9.2370 mm.
```

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

```
= max( ta, tb )
= max( 6.2564, 9.237 )
= 9.2370 mm.
```

Available Nozzle Neck Thickness = 12.7000 mm. --> OK

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 = 12.0, tr = 3.237, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.539, Temp. Reduction = 28 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A          -3 °C
Min Metal Temp. at Required thickness (UCS 66.1)       -30 °C
Min Metal Temp. w/o impact per UG-20(f)                -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :   -30 °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 = 8.00/19.60 = 0.408
```

Weld Size Calculations, Description: N01 (1in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.0000  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.2000 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.

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

Weld Load [W]:

```
= max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max( 0, ( 0.819 - 0.6059 + 2 * 6.7 * 1.0 *
  (1.0 * 6.0 - 4.3799 ) )138)
= 5.93 kN
```

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

Weld Load [W1]:

```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 1.9331 + 0.0 + 0.64 - 0.0 * 1.0 ) * 138
= 35.48 kN
```

Weld Load [W2]:

```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 1.9331 + 0.0245 + 0.64 + ( 0.804 ) ) * 138
= 46.90 kN
```

Weld Load [W3]:

```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 1.9331 + 0.0245 + 0.64 + 0.0 + ( 0.804 ) ) * 138
= 46.90 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 50.8 * 8.0 * 0.49 * 138
= 43. kN
```

Shear, Nozzle Wall [Snw]:

```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 22.05) * ( 12.7 - 6.0 ) * 0.7 * 138
= 45. kN
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 50.8 * ( 12.0 - 6.0 ) * 0.74 * 138
= 49. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 43 + 45 ) = 88 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 43 + 0 + 49 + 0 ) = 92 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 43 + 49 + 0 ) = 92 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 87 kN , must exceed W = 5 kN  or W1 = 35 kN
Path 2-2 = 91 kN , must exceed W = 5 kN  or W2 = 46 kN
Path 3-3 = 91 kN , must exceed W = 5 kN  or W3 = 46 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   15  bars
```

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

```
Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 0.5868 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 362.0000 mm.

Input, Nozzle Desc: N05A (1.5in) From: 20

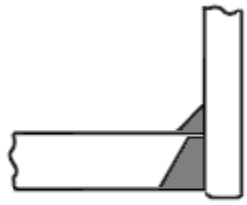
Pressure for Reinforcement Calculations	P	8.055	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1100.00	mm.
Design Length of Section	L	1791.6666	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	6.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1550.00	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		1.5000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	14.4500	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	6.0000	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	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: N05A (1.5in)

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

```
Actual Inside Diameter Used in Calculation          1.500  in.
Actual Thickness Used in Calculation                0.569  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)
  = (8.05*556.0)/(138*1.0-0.6*8.05)
  = 3.2593 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)
  = (8.05*25.05)/(138*1.0-0.6*8.05)
  = 0.1468 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3000 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)          Dl   100.2000  mm.
Parallel to Vessel Wall, opening length            d    50.1000  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp   15.0000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 137.9/137.9 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 137.9/137.9 )
```

= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(1.0, 1.0)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.633	1.097	NA
Area in Shell	A1	1.373	0.812	NA
Area in Nozzle Wall	A2	2.491	2.445	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	4.504	3.897	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(50.1*4.3799*1+2*8.45*4.3799*1(1-1.0))
= 1.097 cm²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 50.1(1.0 * 6.0 - 1.0 * 4.38) - 2 * 8.45
(1.0 * 6.0 - 1.0 * 4.3799) * (1 - 1.0)
= 0.812 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 15.0)(8.45 - 0.3)1.0
= 2.445 cm²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 8.0² * 1.0 + (0.0)² * 1.0
= 0.640 cm²

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

Wall Thickness for Internal/External pressures ta = 6.3000 mm.
Wall Thickness per UG16(b), tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 9.2593 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 9.2593 mm.
Wall Thickness, shell/head, external pressure trb2 = 6.4171 mm.

```
Wall Thickness                  tb2 = max(trb2, tr16b) = 7.5000 mm.
Wall Thickness per table UG-45                  tb3 = 10.5200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 10.52, max( 9.2593, 7.5 ) ]
  = 9.2593 mm.
```

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

```
  = max( ta, tb )
  = max( 6.3, 9.2593 )
  = 9.2593 mm.
```

Available Nozzle Neck Thickness = 14.4500 mm. --> OK

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 = 12.0, tr = 3.259, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.543, Temp. Reduction = 27 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A          -3 °C
Min Metal Temp. at Required thickness (UCS 66.1)       -30 °C
Min Metal Temp. w/o impact per UG-20(f)                -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :   -30 °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 = 8.05/19.60 = 0.411
```

Weld Size Calculations, Description: N05A (1.5in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          4.2000 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
```

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (1.0972 - 0.8117 + 2 * 8.45 * 1.0 *
    (1.0 * 6.0 - 4.3799 ) )138)
  = 7.71 kN
```

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

Weld Load [W1]:

```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 2.445 + 0.0 + 0.64 - 0.0 * 1.0 ) * 138
= 42.54 kN
```

Weld Load [W2]:

```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 2.445 + 0.0 + 0.64 + ( 1.014 ) ) * 138
= 56.52 kN
```

Weld Load [W3]:

```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 2.445 + 0.0 + 0.64 + 0.0 + ( 1.014 ) ) * 138
= 56.52 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 67.0 * 8.0 * 0.49 * 138
= 57. kN
```

Shear, Nozzle Wall [Snw]:

```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 29.275) * ( 14.45 - 6.0 ) * 0.7 * 138
= 75. kN
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 67.0 * ( 12.0 - 6.0 ) * 0.74 * 138
= 64. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 57 + 75 ) = 132 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 57 + 0 + 64 + 0 ) = 121 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 57 + 64 + 0 ) = 121 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 131 kN , must exceed W = 7 kN  or W1 = 42 kN
Path 2-2 = 121 kN , must exceed W = 7 kN  or W2 = 56 kN
Path 3-3 = 121 kN , must exceed W = 7 kN  or W3 = 56 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   15  bars
```

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

```
Nozzle is O.K. for the External Pressure          1  bars
```

The Drop for this Nozzle is : 1.0212 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 163.0211 mm.

Input, Nozzle Desc: N06 (1in) **From: 20**

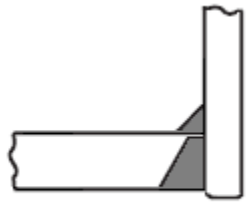
Pressure for Reinforcement Calculations	P	8.000	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1100.00	mm.
Design Length of Section	L	1791.6666	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	6.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1350.00	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		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.7000	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	6.0000	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	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: N06 (1in)

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

```
Actual Inside Diameter Used in Calculation          1.000  in.
Actual Thickness Used in Calculation                0.500  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)
  = (8.0*556.0)/(138*1.0-0.6*8.0)
  = 3.2370 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)
  = (8.0*18.7)/(138*1.0-0.6*8.0)
  = 0.1089 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2564 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)          Dl     74.8000  mm.
Parallel to Vessel Wall, opening length            d     37.4000  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp    15.0000  mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 137.9/137.9 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 137.9/137.9 )
```

= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(1.0, 1.0)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.211	0.819	NA
Area in Shell	A1	1.033	0.606	NA
Area in Nozzle Wall	A2	1.977	1.933	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	3.651	3.179	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(37.4*4.3799*1+2*6.7*4.3799*1(1-1.0))
= 0.819 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)
= 37.4(1.0 * 6.0 - 1.0 * 4.38) - 2 * 6.7
(1.0 * 6.0 - 1.0 * 4.3799) * (1 - 1.0)
= 0.606 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 15.0)(6.7 - 0.26)1.0
= 1.933 cm²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 8.0² * 1.0 + (0.0)² * 1.0
= 0.640 cm²

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

Wall Thickness for Internal/External pressures ta = 6.2564 mm.
Wall Thickness per UG16(b), tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 9.2370 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 9.2370 mm.
Wall Thickness, shell/head, external pressure trb2 = 6.4171 mm.

```
Wall Thickness                  tb2 = max(trb2, tr16b) = 7.5000 mm.
Wall Thickness per table UG-45                  tb3 = 9.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 9.42, max( 9.237, 7.5 ) ]
  = 9.2370 mm.
```

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

```
  = max( ta, tb )
  = max( 6.2564, 9.237 )
  = 9.2370 mm.
```

Available Nozzle Neck Thickness = 12.7000 mm. --> OK

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 = 12.0, tr = 3.237, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.539, Temp. Reduction = 28 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A          -3 °C
Min Metal Temp. at Required thickness (UCS 66.1)       -30 °C
Min Metal Temp. w/o impact per UG-20(f)                -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :   -30 °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 = 8.00/19.60 = 0.408
```

Weld Size Calculations, Description: N06 (1in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.0000  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.2000 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, ( 0.819 - 0.6059 + 2 * 6.7 * 1.0 *
    (1.0 * 6.0 - 4.3799 ) )138)
  = 5.93 kN
```

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

Weld Load [W1]:

```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 1.9331 + 0.0 + 0.64 - 0.0 * 1.0 ) * 138
= 35.48 kN
```

Weld Load [W2]:

```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 1.9331 + 0.0 + 0.64 + ( 0.804 ) ) * 138
= 46.57 kN
```

Weld Load [W3]:

```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 1.9331 + 0.0 + 0.64 + 0.0 + ( 0.804 ) ) * 138
= 46.57 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 50.8 * 8.0 * 0.49 * 138
= 43. kN
```

Shear, Nozzle Wall [Snw]:

```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 22.05) * ( 12.7 - 6.0 ) * 0.7 * 138
= 45. kN
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 50.8 * ( 12.0 - 6.0 ) * 0.74 * 138
= 49. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 43 + 45 ) = 88 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 43 + 0 + 49 + 0 ) = 92 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 43 + 49 + 0 ) = 92 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 87 kN , must exceed W = 5 kN  or W1 = 35 kN
Path 2-2 = 91 kN , must exceed W = 5 kN  or W2 = 46 kN
Path 3-3 = 91 kN , must exceed W = 5 kN  or W3 = 46 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   15  bars
```

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

```
 Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 0.5868 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 162.5868 mm.

Input, Nozzle Desc: N07 (1in) **From: 20**

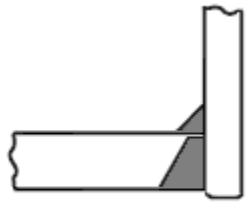
Pressure for Reinforcement Calculations	P	8.000	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1100.00	mm.
Design Length of Section	L	1791.6666	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	6.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1100.00	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		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.7000	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	6.0000	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	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: N07 (1in)

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

```
Actual Inside Diameter Used in Calculation          1.000  in.
Actual Thickness Used in Calculation                0.500  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)
= (8.0*556.0)/(138*1.0-0.6*8.0)
= 3.2370 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)
= (8.0*18.7)/(138*1.0-0.6*8.0)
= 0.1089 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2564 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)          Dl    74.8000  mm.
Parallel to Vessel Wall, opening length            d    37.4000  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp   15.0000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
= min( 1, Sn/Sv )
= min( 1, 137.9/137.9 )
= 1.000
```

Weld Strength Reduction Factor [fr2]:

```
= min( 1, Sn/Sv )
= min( 1, 137.9/137.9 )
```

= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(1.0, 1.0)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.211	0.819	NA
Area in Shell	A1	1.033	0.606	NA
Area in Nozzle Wall	A2	1.977	1.933	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	3.651	3.179	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(37.4*4.3799*1+2*6.7*4.3799*1(1-1.0))
= 0.819 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)
= 37.4(1.0 * 6.0 - 1.0 * 4.38) - 2 * 6.7
(1.0 * 6.0 - 1.0 * 4.3799) * (1 - 1.0)
= 0.606 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 15.0)(6.7 - 0.26)1.0
= 1.933 cm²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 8.0² * 1.0 + (0.0)² * 1.0
= 0.640 cm²

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

Wall Thickness for Internal/External pressures ta = 6.2564 mm.
Wall Thickness per UG16(b), tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 9.2370 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 9.2370 mm.
Wall Thickness, shell/head, external pressure trb2 = 6.4171 mm.

```
Wall Thickness                  tb2 = max(trb2, tr16b) = 7.5000 mm.
Wall Thickness per table UG-45                  tb3 = 9.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 9.42, max( 9.237, 7.5 ) ]
  = 9.2370 mm.
```

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

```
  = max( ta, tb )
  = max( 6.2564, 9.237 )
  = 9.2370 mm.
```

Available Nozzle Neck Thickness = 12.7000 mm. --> OK

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 = 12.0, tr = 3.237, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.539, Temp. Reduction = 28 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A          -3 °C
Min Metal Temp. at Required thickness (UCS 66.1)       -30 °C
Min Metal Temp. w/o impact per UG-20(f)                -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :   -30 °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 = 8.00/19.60 = 0.408
```

Weld Size Calculations, Description: N07 (1in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          4.2000 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
```

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, ( 0.819 - 0.6059 + 2 * 6.7 * 1.0 *
    (1.0 * 6.0 - 4.3799 ) )138)
  = 5.93 kN
```

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

Weld Load [W1]:

```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 1.9331 + 0.0 + 0.64 - 0.0 * 1.0 ) * 138
= 35.48 kN
```

Weld Load [W2]:

```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 1.9331 + 0.0 + 0.64 + ( 0.804 ) ) * 138
= 46.57 kN
```

Weld Load [W3]:

```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 1.9331 + 0.0 + 0.64 + 0.0 + ( 0.804 ) ) * 138
= 46.57 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 50.8 * 8.0 * 0.49 * 138
= 43. kN
```

Shear, Nozzle Wall [Snw]:

```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 22.05) * ( 12.7 - 6.0 ) * 0.7 * 138
= 45. kN
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 50.8 * ( 12.0 - 6.0 ) * 0.74 * 138
= 49. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 43 + 45 ) = 88 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 43 + 0 + 49 + 0 ) = 92 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 43 + 49 + 0 ) = 92 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 87 kN , must exceed W = 5 kN  or W1 = 35 kN
Path 2-2 = 91 kN , must exceed W = 5 kN  or W2 = 46 kN
Path 3-3 = 91 kN , must exceed W = 5 kN  or W3 = 46 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   15  bars
```

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

```
Nozzle is O.K. for the External Pressure          1  bars
```

The Drop for this Nozzle is : 0.5868 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 162.5868 mm.

Input, Nozzle Desc: N09 (1in) **From: 20**

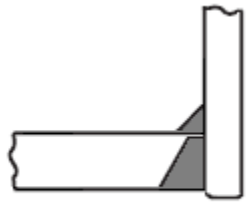
Pressure for Reinforcement Calculations	P	8.000	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1100.00	mm.
Design Length of Section	L	1791.6666	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	6.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		850.00	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		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.7000	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	6.0000	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	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: N09 (1in)

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

```
Actual Inside Diameter Used in Calculation          1.000  in.
Actual Thickness Used in Calculation                0.500  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)
  = (8.0*556.0)/(138*1.0-0.6*8.0)
  = 3.2370 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)
  = (8.0*18.7)/(138*1.0-0.6*8.0)
  = 0.1089 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2564 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)          Dl    74.8000  mm.
Parallel to Vessel Wall, opening length            d    37.4000  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp   15.0000  mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 137.9/137.9 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 137.9/137.9 )
```

= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(1.0, 1.0)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.211	0.819	NA
Area in Shell	A1	1.033	0.606	NA
Area in Nozzle Wall	A2	1.977	1.933	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	3.651	3.179	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(37.4*4.3799*1+2*6.7*4.3799*1(1-1.0))
= 0.819 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)
= 37.4(1.0 * 6.0 - 1.0 * 4.38) - 2 * 6.7
(1.0 * 6.0 - 1.0 * 4.3799) * (1 - 1.0)
= 0.606 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 15.0)(6.7 - 0.26)1.0
= 1.933 cm²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 8.0² * 1.0 + (0.0)² * 1.0
= 0.640 cm²

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

Wall Thickness for Internal/External pressures ta = 6.2564 mm.
Wall Thickness per UG16(b), tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 9.2370 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 9.2370 mm.
Wall Thickness, shell/head, external pressure trb2 = 6.4171 mm.

```
Wall Thickness                  tb2 = max(trb2, tr16b) = 7.5000 mm.
Wall Thickness per table UG-45                  tb3 = 9.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 9.42, max( 9.237, 7.5 ) ]
  = 9.2370 mm.
```

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

```
  = max( ta, tb )
  = max( 6.2564, 9.237 )
  = 9.2370 mm.
```

Available Nozzle Neck Thickness = 12.7000 mm. --> OK

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 = 12.0, tr = 3.237, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.539, Temp. Reduction = 28 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A          -3 °C
Min Metal Temp. at Required thickness (UCS 66.1)       -30 °C
Min Metal Temp. w/o impact per UG-20(f)                -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :   -30 °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 = 8.00/19.60 = 0.408
```

Weld Size Calculations, Description: N09 (1in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          4.2000 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
```

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, ( 0.819 - 0.6059 + 2 * 6.7 * 1.0 *
    (1.0 * 6.0 - 4.3799 ) )138)
  = 5.93 kN
```

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

Weld Load [W1]:

```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 1.9331 + 0.0 + 0.64 - 0.0 * 1.0 ) * 138
= 35.48 kN
```

Weld Load [W2]:

```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 1.9331 + 0.0 + 0.64 + ( 0.804 ) ) * 138
= 46.57 kN
```

Weld Load [W3]:

```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 1.9331 + 0.0 + 0.64 + 0.0 + ( 0.804 ) ) * 138
= 46.57 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 50.8 * 8.0 * 0.49 * 138
= 43. kN
```

Shear, Nozzle Wall [Snw]:

```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 22.05) * ( 12.7 - 6.0 ) * 0.7 * 138
= 45. kN
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 50.8 * ( 12.0 - 6.0 ) * 0.74 * 138
= 49. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 43 + 45 ) = 88 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 43 + 0 + 49 + 0 ) = 92 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 43 + 49 + 0 ) = 92 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 87 kN , must exceed W = 5 kN  or W1 = 35 kN
Path 2-2 = 91 kN , must exceed W = 5 kN  or W2 = 46 kN
Path 3-3 = 91 kN , must exceed W = 5 kN  or W3 = 46 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   15  bars
```

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

```
 Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 0.5868 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 162.5868 mm.

Input, Nozzle Desc: M1 (20in) **From: 20**

Pressure for Reinforcement Calculations	P	8.000	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1100.00	mm.
Design Length of Section	L	1791.6666	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	6.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1150.00	mm.
User Entered Minimum Design Metal Temperature		5.00	°C

Type of Element Connected to the Shell : Nozzle

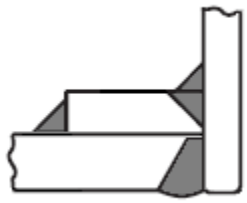
Material		SA-516 70	
Material UNS Number		K02700	
Material Specification/Type		Plate	
Allowable Stress at Temperature	Sn	137.90	N./mm²
Allowable Stress At Ambient	Sna	137.90	N./mm²
Diameter Basis (for tr calc only)		OD	
Layout Angle		0.00	deg
Diameter		20.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.0000	mm.
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	6.0000	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	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		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	750.0000	mm.
Thickness of Pad	te	12.0000	mm.

```
Weld leg size between Pad and Shell              Wp      10.0000  mm.
Groove weld depth between Pad and Nozzle         Wgpn    12.0000  mm.
Reinforcing Pad Width                                    121.0000  mm.
This is a Manway or Access Opening.

Flange Class                                             150
Flange Grade                                             GR 1.1
```

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: M1 (20in)

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

```
Actual Outside Diameter Used in Calculation          20.000  in.
Actual Thickness Used in Calculation                  0.472  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)
= (8.0*556.0)/(138*1.0-0.6*8.0)
= 3.2370 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]

```
= (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
= (8.0*254.0)/(138*1.0+0.4*8.0)
= 1.4702 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.9796 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)          Dl    992.0000  mm.
Parallel to Vessel Wall, opening length            d    496.0000  mm.
```

Normal to Vessel Wall (Thickness Limit), pad side Tlwp 15.0000 mm.

Weld Strength Reduction Factor [fr1]:
= min(1, Sn/Sv)
= min(1, 137.9/137.9)
= 1.000

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 137.9/137.9)
= 1.000

Weld Strength Reduction Factor [fr4]:
= min(1, Sp/Sv)
= min(1, 137.9/137.9)
= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(1.0, 1.0)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	16.055	10.862	NA
Area in Shell	A1	13.705	8.036	NA
Area in Nozzle Wall	A2	1.359	1.506	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.390	1.390	NA
Area in Element	A5	29.040	29.040	NA
TOTAL AREA AVAILABLE	Atot	45.494	39.972	NA

The External 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:	508.0000	12.0000	mm.
Based on given Pad Diameter:	750.0000	0.0000	mm.
Based on Shell or Nozzle Thickness:	508.0000	12.0000	mm.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(496.0*4.3799*1+2*6.0*4.3799*1(1-1.0))
= 10.862 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 )
  = 496.0( 1.0 * 6.0 - 1.0 * 4.38 ) - 2 * 6.0
    ( 1.0 * 6.0 - 1.0 * 4.3799 ) * ( 1 - 1.0 )
  = 8.036 cm²
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 15.0 ) * ( 6.0 - 0.98 ) * 1.0
  = 1.506 cm²
```

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

```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
  = ( 0.39 ) * 1.0 + (0.0 ) * 1.0 + 254.0² * 1.0
  = 1.390 cm²
```

Area Available in Element [A5]:

```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 750.0 - 508.0 ) * 12.0 * 1.0
  = 29.040 cm²
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 12.0, tr = 1.47, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.245, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve A              -3 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
 Min Metal Temp. w/o impact per UG-20(f)                    -29 °C
```

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

Govrn. thk, tg = 12.0, tr = 1.47, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.245, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B             -23 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
 Min Metal Temp. w/o impact per UG-20(f)                    -29 °C
```

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

Govrn. thk, tg = 12.0, tr = 1.47, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.245, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B             -23 °C
 Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
 Min Metal Temp. w/o impact per UG-20(f)                    -29 °C
```

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

Govrn. thk, tg = 12.0, tr = 3.237, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.539, Temp. Reduction = 28 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -23 °C
Min Metal Temp. at Required thickness (UCS 66.1)            -48 °C
Min Metal Temp. w/o impact per UG-20(f)                     -29 °C
```

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

Govrn. thk, tg = 12.0, tr = 3.237, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.539, Temp. Reduction = 28 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -23 °C
Min Metal Temp. at Required thickness (UCS 66.1)            -48 °C
Min Metal Temp. w/o impact per UG-20(f)                     -29 °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)      -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 = 8.00/19.60 = 0.408
```

Weld Size Calculations, Description: M1 (20in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.0000  mm.
Intermediate Calc. for pad/shell Welds      TminPad   6.0000  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.2000 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.
Pad Weld	3.0000 = 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, (10.8622 - 8.0355 + 2 * 6.0 * 1.0 *
    (1.0 * 6.0 - 4.3799 ) )138)
  = 41.66 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.5061 + 29.04 + 1.39 - 0.0 * 1.0 ) * 138
  = 440.36 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.5061 + 0.0 + 0.64 + ( 0.72 ) ) * 138
  = 39.52 kN
```

Weld Load [W3]:
```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 1.5061 + 0.0 + 1.39 + 29.04 + ( 0.72 ) ) * 138
= 450.29 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 508.0 * 8.0 * 0.49 * 138
= 431. kN
```

Shear, Pad Element Weld [Spew]:
```
= (pi/2) * DP * WP * 0.49 * SEW
= ( 3.1416/2.0 ) * 750.0 * 10.0 * 0.49 * 138
= 796. kN
```

Shear, Nozzle Wall [Snw]:
```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 251.0) * ( 12.0 - 6.0 ) * 0.7 * 138
= 457. kN
```

Tension, Pad Groove Weld [Tpgw]:
```
= ( pi/2) * Dlo * Wgpn * 0.74 * Seg
=  (3.1416/2 ) * 508.0 * 12.0 * 0.74 * 138
= 977. kN
```

Tension, Shell Groove Weld [Tngw]:
```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 508.0 * ( 12.0 - 6.0 ) * 0.74 * 138
= 489. kN
```

Strength of Failure Paths:

```
PATH11 = ( SPEW + SNW ) = ( 796 + 457 ) = 1253 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 431 + 977 + 489 + 0 ) = 1897 kN
PATH33 = ( Spew + Tngw + Sinw )
       = ( 796 + 489 + 0 ) = 1285 kN
```

Summary of Failure Path Calculations:
```
Path 1-1 = 1252 kN , must exceed W = 41 kN  or W1 = 440 kN
Path 2-2 = 1896 kN , must exceed W = 41 kN  or W2 = 39 kN
Path 3-3 = 1284 kN , must exceed W = 41 kN  or W3 = 450 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   15  bars
```

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

```
 Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 62.1639 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 224.1639 mm.

Percent Elongation Calculations:

```
 % Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro))  2.419 %
```

Input, Nozzle Desc: K06 (2in) **From: 20**

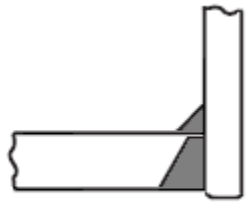
Pressure for Reinforcement Calculations	P	8.029	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1100.00	mm.
Design Length of Section	L	1791.6666	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	6.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Cylinder/Cone Centerline	L1	300.0000	mm.
Distance from Bottom/Left Tangent		250.00	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		-32.26	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.7640	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	6.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: K06 (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                0.660  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)
= (8.03*556.0)/(138*1.0-0.6*8.03)
= 3.2489 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)
= (8.03*31.4)/(138*1.0-0.6*8.03)
= 0.1835 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3439 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)          Dl   149.1862  mm.
Parallel to Vessel Wall, opening length            d    74.5931  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp   15.0000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.212	1.634	NA
Area in Shell	A1	3.264	1.208	NA
Area in Nozzle Wall	A2	3.663	3.608	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	7.927	5.816	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 57.34 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(74.5931*4.3799*1+2*10.764*4.3799*1(1-1.0))
= 1.634 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)
= 74.593(1.0 * 6.0 - 1.0 * 4.38) - 2 * 10.764
(1.0 * 6.0 - 1.0 * 4.3799) * (1 - 1.0)
= 1.208 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2/sin(alpha3)
= (2 * 15.0)(10.76 - 0.34)1.0/sin(60.0)
= 3.608 cm²

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

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 10.0² * 1.0 + (0.0)² * 1.0
= 1.000 cm²

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 = 12.0, tr = 3.249, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.541, Temp. Reduction = 28 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -3 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -30 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :   -30 °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)      -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
`Design Pressure/Ambient Rating = 8.03/51.10 = 0.157`

Weld Size Calculations, Description: K06 (2in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.0000  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.2000 = 0.7 * tmin.	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, (1.6336 - 1.2085 + 2 * 10.764 * 1.0 *
  (1.0 * 6.0 - 4.3799 ) )138)
= 10.67 kN
```

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

Weld Load [W1]:

```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 3.6079 + 0.0 + 1. - 0.0 * 1.0 ) * 138
= 63.54 kN
```

Weld Load [W2]:

```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 3.6079 + 0.0 + 1. + ( 1.2917 ) ) * 138
= 81.35 kN
```

Weld Load [W3]:

```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 3.6079 + 0.0 + 1. + 0.0 + ( 1.2917 ) ) * 138
= 81.35 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 100.1638 * 10.0 * 0.49 * 138
= 106. kN
```

Shear, Nozzle Wall [Snw]:
```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 43.6892) * ( 16.764 - 6.0 ) * 0.7 * 138
= 143. kN
```

Tension, Shell Groove Weld [Tngw]:
```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 100.1638 * ( 12.0 - 6.0 ) * 0.74 * 138
= 96. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 106 + 143 ) = 249 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 106 + 0 + 96 + 0 ) = 203 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 106 + 96 + 0 ) = 203 kN
```

Summary of Failure Path Calculations:
```
Path 1-1 = 248 kN , must exceed W = 10 kN  or W1 = 63 kN
Path 2-2 = 202 kN , must exceed W = 10 kN  or W2 = 81 kN
Path 3-3 = 202 kN , must exceed W = 10 kN  or W3 = 81 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
Converged Max. Allow. Pressure in Operating case   15  bars
```

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

```
Nozzle is O.K. for the External Pressure           1  bars
```

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

Reinforcement CALCULATION, Description: K06 (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                  0.660  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (8.03*556.0)/(138*1.0-0.6*8.03)
= 3.2489 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)
= (8.03*31.4)/(138*1.0-0.6*8.03)
= 0.1835 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3439 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl   125.6000  mm.
Parallel to Vessel Wall, opening length              d    62.8000  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    15.0000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	2.040	1.375	NA
Area in Shell	A1	1.728	1.017	NA
Area in Nozzle Wall	A2	3.174	3.126	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	5.902	5.143	NA

The External Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:

```
= 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
= 0.5(62.8*4.3799*1+2*10.764*4.3799*1(1-1.0))
= 1.375 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 )
= 62.8( 1.0 * 6.0 - 1.0 * 4.38 ) - 2 * 10.764
  ( 1.0 * 6.0 - 1.0 * 4.3799 ) * ( 1 - 1.0 )
= 1.017 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
= ( 2 * tlnp )( tn - trn )fr2
= ( 2 * 15.0 )( 10.76 - 0.34 )1.0
= 3.126 cm²
```

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

```
= Wo² * fr2 + ( Wi-can/0.707 )² * fr2
= 10.0² * 1.0 + ( 0.0 )² * 1.0
= 1.000 cm²
```

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

```
Wall Thickness for Internal/External pressures      ta = 6.3439 mm.
```

```
Wall Thickness per UG16(b),                      tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 9.2489 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 9.2489 mm.
Wall Thickness, shell/head, external pressure     trb2 = 6.4171 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 7.5000 mm.
Wall Thickness per table UG-45                    tb3 = 10.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 10.8, max( 9.2489, 7.5 ) ]
  = 9.2489 mm.
```

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

```
  = max( ta, tb )
  = max( 6.3439, 9.2489 )
  = 9.2489 mm.
```

Available Nozzle Neck Thickness = 16.7640 mm. --> OK

Weld Size Calculations, Description: K06 (2in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.0000  mm.
```

Results Per UW-16.1:

```
                        Required Thickness    Actual Thickness
Nozzle Weld           4.2000 = 0.7 * tmin.  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, (1.3753 - 1.0174 + 2 * 10.764 * 1.0 *
    (1.0 * 6.0 - 4.3799 ) )138)
  = 9.74 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.126 + 0.0 + 1. - 0.0 * 1.0 ) * 138
  = 56.89 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.126 + 0.0 + 1. + ( 1.2917 ) ) * 138
  = 74.70 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.126 + 0.0 + 1. + 0.0 + ( 1.2917 ) ) * 138
  = 74.70 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 84.328 * 10.0 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 36.782) * ( 16.764 - 6.0 ) * 0.7 * 138
  = 120. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 84.328 * ( 12.0 - 6.0 ) * 0.74 * 138
  = 81. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89 + 120 ) = 210 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89 + 0 + 81 + 0 ) = 171 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89 + 81 + 0 ) = 171 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 209 kN , must exceed W = 9 kN  or W1 = 56 kN
 Path 2-2 = 170 kN , must exceed W = 9 kN  or W2 = 74 kN
 Path 3-3 = 170 kN , must exceed W = 9 kN  or W3 = 74 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case   15  bars
```

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

```
 Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 30.3686 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 194.6218 mm.

Input, Nozzle Desc: N02 (1in) **From: 30**

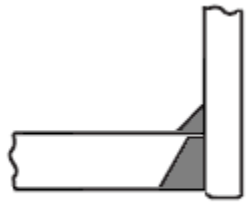
Pressure for Reinforcement Calculations	P	8.055	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1100.00	mm.
Design Length of Section	L	1791.6666	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	6.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3250.00	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		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.7000	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	6.0000	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	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: N02 (1in)

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

```
Actual Inside Diameter Used in Calculation          1.000  in.
Actual Thickness Used in Calculation                0.500  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)
  = (8.05*556.0)/(138*1.0-0.6*8.05)
  = 3.2593 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)
  = (8.05*18.7)/(138*1.0-0.6*8.05)
  = 0.1096 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2564 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)          Dl     74.8000  mm.
Parallel to Vessel Wall, opening length            d     37.4000  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp    15.0000  mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 137.9/137.9 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 137.9/137.9 )
```

= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(1.0, 1.0)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.219	0.819	NA
Area in Shell	A1	1.025	0.606	NA
Area in Nozzle Wall	A2	1.977	1.933	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	3.642	3.179	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(37.4*4.3799*1+2*6.7*4.3799*1(1-1.0))
= 0.819 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)
= 37.4(1.0 * 6.0 - 1.0 * 4.38) - 2 * 6.7
(1.0 * 6.0 - 1.0 * 4.3799) * (1 - 1.0)
= 0.606 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 15.0)(6.7 - 0.26)1.0
= 1.933 cm²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 8.0² * 1.0 + (0.0)² * 1.0
= 0.640 cm²

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

Wall Thickness for Internal/External pressures ta = 6.2564 mm.
Wall Thickness per UG16(b), tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 9.2593 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 9.2593 mm.
Wall Thickness, shell/head, external pressure trb2 = 6.4171 mm.

```
Wall Thickness                  tb2 = max(trb2, tr16b) = 7.5000 mm.
Wall Thickness per table UG-45                  tb3 = 9.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 9.42, max( 9.2593, 7.5 ) ]
  = 9.2593 mm.
```

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

```
  = max( ta, tb )
  = max( 6.2564, 9.2593 )
  = 9.2593 mm.
```

Available Nozzle Neck Thickness = 12.7000 mm. --> OK

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 = 12.0, tr = 3.259, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.543, Temp. Reduction = 27 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A          -3 °C
Min Metal Temp. at Required thickness (UCS 66.1)       -30 °C
Min Metal Temp. w/o impact per UG-20(f)                -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :   -30 °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)       -48 °C
```

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

```
Design Pressure/Ambient Rating = 8.05/19.60 = 0.411
```

Weld Size Calculations, Description: N02 (1in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          4.2000 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
```

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, ( 0.819 - 0.6059 + 2 * 6.7 * 1.0 *
    (1.0 * 6.0 - 4.3799 ) )138)
  = 5.93 kN
```

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

Weld Load [W1]:

```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 1.9331 + 0.0 + 0.64 - 0.0 * 1.0 ) * 138
= 35.48 kN
```

Weld Load [W2]:

```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 1.9331 + 0.0 + 0.64 + ( 0.804 ) ) * 138
= 46.57 kN
```

Weld Load [W3]:

```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 1.9331 + 0.0 + 0.64 + 0.0 + ( 0.804 ) ) * 138
= 46.57 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 50.8 * 8.0 * 0.49 * 138
= 43. kN
```

Shear, Nozzle Wall [Snw]:

```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 22.05) * ( 12.7 - 6.0 ) * 0.7 * 138
= 45. kN
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 50.8 * ( 12.0 - 6.0 ) * 0.74 * 138
= 49. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 43 + 45 ) = 88 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 43 + 0 + 49 + 0 ) = 92 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 43 + 49 + 0 ) = 92 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 87 kN , must exceed W = 5 kN  or W1 = 35 kN
Path 2-2 = 91 kN , must exceed W = 5 kN  or W2 = 46 kN
Path 3-3 = 91 kN , must exceed W = 5 kN  or W3 = 46 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   15  bars
```

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

```
 Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 0.5868 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 162.5868 mm.

Input, Nozzle Desc: N03 (1in) **From: 30**

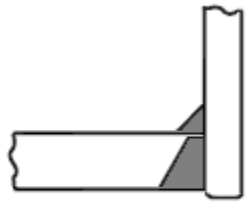
Pressure for Reinforcement Calculations	P	8.000	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1100.00	mm.
Design Length of Section	L	1791.6666	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	6.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3150.00	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		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.7000	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	6.0000	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	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: N03 (1in)

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

```
Actual Inside Diameter Used in Calculation          1.000  in.
Actual Thickness Used in Calculation                0.500  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)
  = (8.0*556.0)/(138*1.0-0.6*8.0)
  = 3.2370 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)
  = (8.0*18.7)/(138*1.0-0.6*8.0)
  = 0.1089 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2564 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)          Dl    74.8000  mm.
Parallel to Vessel Wall, opening length            d    37.4000  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp   15.0000  mm.
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 137.9/137.9 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 137.9/137.9 )
```

= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(1.0, 1.0)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.211	0.819	NA
Area in Shell	A1	1.033	0.606	NA
Area in Nozzle Wall	A2	1.977	1.933	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	3.651	3.179	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(37.4*4.3799*1+2*6.7*4.3799*1(1-1.0))
= 0.819 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)
= 37.4(1.0 * 6.0 - 1.0 * 4.38) - 2 * 6.7
(1.0 * 6.0 - 1.0 * 4.3799) * (1 - 1.0)
= 0.606 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 15.0)(6.7 - 0.26)1.0
= 1.933 cm²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 8.0² * 1.0 + (0.0)² * 1.0
= 0.640 cm²

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

Wall Thickness for Internal/External pressures ta = 6.2564 mm.
Wall Thickness per UG16(b), tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 9.2370 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 9.2370 mm.
Wall Thickness, shell/head, external pressure trb2 = 6.4171 mm.

```
Wall Thickness                  tb2 = max(trb2, tr16b) = 7.5000 mm.
Wall Thickness per table UG-45                  tb3 = 9.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 9.42, max( 9.237, 7.5 ) ]
  = 9.2370 mm.
```

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

```
  = max( ta, tb )
  = max( 6.2564, 9.237 )
  = 9.2370 mm.
```

Available Nozzle Neck Thickness = 12.7000 mm. --> OK

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 = 12.0, tr = 3.237, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.539, Temp. Reduction = 28 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A          -3 °C
Min Metal Temp. at Required thickness (UCS 66.1)       -30 °C
Min Metal Temp. w/o impact per UG-20(f)                -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :   -30 °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)       -48 °C
```

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

```
Design Pressure/Ambient Rating = 8.00/19.60 = 0.408
```

Weld Size Calculations, Description: N03 (1in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          4.2000 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
```

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, ( 0.819 - 0.6059 + 2 * 6.7 * 1.0 *
    (1.0 * 6.0 - 4.3799 ) )138)
  = 5.93 kN
```

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

Weld Load [W1]:

```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 1.9331 + 0.0 + 0.64 - 0.0 * 1.0 ) * 138
= 35.48 kN
```

Weld Load [W2]:

```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 1.9331 + 0.0 + 0.64 + ( 0.804 ) ) * 138
= 46.57 kN
```

Weld Load [W3]:

```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 1.9331 + 0.0 + 0.64 + 0.0 + ( 0.804 ) ) * 138
= 46.57 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 50.8 * 8.0 * 0.49 * 138
= 43. kN
```

Shear, Nozzle Wall [Snw]:

```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 22.05) * ( 12.7 - 6.0 ) * 0.7 * 138
= 45. kN
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 50.8 * ( 12.0 - 6.0 ) * 0.74 * 138
= 49. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 43 + 45 ) = 88 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 43 + 0 + 49 + 0 ) = 92 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 43 + 49 + 0 ) = 92 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 87 kN , must exceed W = 5 kN  or W1 = 35 kN
Path 2-2 = 91 kN , must exceed W = 5 kN  or W2 = 46 kN
Path 3-3 = 91 kN , must exceed W = 5 kN  or W3 = 46 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   15  bars
```

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

```
 Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 0.5868 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 162.5868 mm.

Input, Nozzle Desc: N04 (1in) **From: 30**

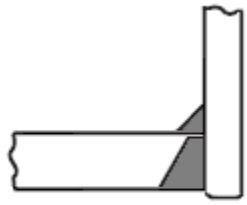
Pressure for Reinforcement Calculations	P	8.055	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1100.00	mm.
Design Length of Section	L	1791.6666	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	6.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		2126.00	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		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.7000	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	6.0000	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	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: N04 (1in)

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

```
Actual Inside Diameter Used in Calculation          1.000  in.
Actual Thickness Used in Calculation                0.500  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)
  = (8.05*556.0)/(138*1.0-0.6*8.05)
  = 3.2593 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)
  = (8.05*18.7)/(138*1.0-0.6*8.05)
  = 0.1096 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2564 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)          Dl    74.8000  mm.
Parallel to Vessel Wall, opening length            d    37.4000  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp   15.0000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 137.9/137.9 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 137.9/137.9 )
```

= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(1.0, 1.0)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.219	0.819	NA
Area in Shell	A1	1.025	0.606	NA
Area in Nozzle Wall	A2	1.977	1.933	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	3.642	3.179	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(37.4*4.3799*1+2*6.7*4.3799*1(1-1.0))
= 0.819 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)
= 37.4(1.0 * 6.0 - 1.0 * 4.38) - 2 * 6.7
(1.0 * 6.0 - 1.0 * 4.3799) * (1 - 1.0)
= 0.606 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 15.0)(6.7 - 0.26)1.0
= 1.933 cm²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 8.0² * 1.0 + (0.0)² * 1.0
= 0.640 cm²

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

Wall Thickness for Internal/External pressures ta = 6.2564 mm.
Wall Thickness per UG16(b), tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 9.2593 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 9.2593 mm.
Wall Thickness, shell/head, external pressure trb2 = 6.4171 mm.

```
Wall Thickness                  tb2 = max(trb2, tr16b) = 7.5000 mm.
Wall Thickness per table UG-45                  tb3 = 9.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 9.42, max( 9.2593, 7.5 ) ]
  = 9.2593 mm.
```

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

```
  = max( ta, tb )
  = max( 6.2564, 9.2593 )
  = 9.2593 mm.
```

Available Nozzle Neck Thickness = 12.7000 mm. --> OK

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 = 12.0, tr = 3.259, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.543, Temp. Reduction = 27 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A          -3 °C
Min Metal Temp. at Required thickness (UCS 66.1)       -30 °C
Min Metal Temp. w/o impact per UG-20(f)                -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :   -30 °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)       -48 °C
```

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

```
Design Pressure/Ambient Rating = 8.05/19.60 = 0.411
```

Weld Size Calculations, Description: N04 (1in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          4.2000 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
```

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, ( 0.819 - 0.6059 + 2 * 6.7 * 1.0 *
    (1.0 * 6.0 - 4.3799 ) )138)
  = 5.93 kN
```

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

Weld Load [W1]:

```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 1.9331 + 0.0 + 0.64 - 0.0 * 1.0 ) * 138
= 35.48 kN
```

Weld Load [W2]:

```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 1.9331 + 0.0 + 0.64 + ( 0.804 ) ) * 138
= 46.57 kN
```

Weld Load [W3]:

```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 1.9331 + 0.0 + 0.64 + 0.0 + ( 0.804 ) ) * 138
= 46.57 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 50.8 * 8.0 * 0.49 * 138
= 43. kN
```

Shear, Nozzle Wall [Snw]:

```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 22.05) * ( 12.7 - 6.0 ) * 0.7 * 138
= 45. kN
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 50.8 * ( 12.0 - 6.0 ) * 0.74 * 138
= 49. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 43 + 45 ) = 88 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 43 + 0 + 49 + 0 ) = 92 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 43 + 49 + 0 ) = 92 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 87 kN , must exceed W = 5 kN  or W1 = 35 kN
Path 2-2 = 91 kN , must exceed W = 5 kN  or W2 = 46 kN
Path 3-3 = 91 kN , must exceed W = 5 kN  or W3 = 46 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   15  bars
```

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

```
 Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 0.5868 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 162.5868 mm.

Input, Nozzle Desc: N05B (1.5in) From: 30

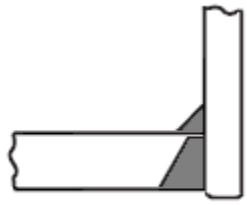
Pressure for Reinforcement Calculations	P	8.055	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1100.00	mm.
Design Length of Section	L	1791.6666	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	6.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3050.00	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		1.5000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	14.4500	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	6.0000	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	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: N05B (1.5in)

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

```
Actual Inside Diameter Used in Calculation          1.500  in.
Actual Thickness Used in Calculation                0.569  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)
  = (8.05*556.0)/(138*1.0-0.6*8.05)
  = 3.2593 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)
  = (8.05*25.05)/(138*1.0-0.6*8.05)
  = 0.1468 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3000 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)          Dl   100.2000  mm.
Parallel to Vessel Wall, opening length            d    50.1000  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp   15.0000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 137.9/137.9 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 137.9/137.9 )
```

= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(1.0, 1.0)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.633	1.097	NA
Area in Shell	A1	1.373	0.812	NA
Area in Nozzle Wall	A2	2.491	2.445	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	4.504	3.897	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(50.1*4.3799*1+2*8.45*4.3799*1(1-1.0))
= 1.097 cm²

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 50.1(1.0 * 6.0 - 1.0 * 4.38) - 2 * 8.45
(1.0 * 6.0 - 1.0 * 4.3799) * (1 - 1.0)
= 0.812 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 15.0)(8.45 - 0.3)1.0
= 2.445 cm²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 8.0² * 1.0 + (0.0)² * 1.0
= 0.640 cm²

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

Wall Thickness for Internal/External pressures ta = 6.3000 mm.
Wall Thickness per UG16(b), tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 9.2593 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 9.2593 mm.
Wall Thickness, shell/head, external pressure trb2 = 6.4171 mm.

```
Wall Thickness                  tb2 = max(trb2, tr16b) = 7.5000 mm.
Wall Thickness per table UG-45                  tb3 = 10.5200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 10.52, max( 9.2593, 7.5 ) ]
  = 9.2593 mm.
```

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

```
  = max( ta, tb )
  = max( 6.3, 9.2593 )
  = 9.2593 mm.
```

Available Nozzle Neck Thickness = 14.4500 mm. --> OK

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 = 12.0, tr = 3.259, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.543, Temp. Reduction = 27 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -3 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -30 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :   -30 °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)       -48 °C
```

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

```
Design Pressure/Ambient Rating = 8.05/19.60 = 0.411
```

Weld Size Calculations, Description: N05B (1.5in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          4.2000 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
```

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (1.0972 - 0.8117 + 2 * 8.45 * 1.0 *
    (1.0 * 6.0 - 4.3799 ) )138)
  = 7.71 kN
```

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

Weld Load [W1]:

```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 2.445 + 0.0 + 0.64 - 0.0 * 1.0 ) * 138
= 42.54 kN
```

Weld Load [W2]:

```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 2.445 + 0.0 + 0.64 + ( 1.014 ) ) * 138
= 56.52 kN
```

Weld Load [W3]:

```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 2.445 + 0.0 + 0.64 + 0.0 + ( 1.014 ) ) * 138
= 56.52 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 67.0 * 8.0 * 0.49 * 138
= 57. kN
```

Shear, Nozzle Wall [Snw]:

```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 29.275) * ( 14.45 - 6.0 ) * 0.7 * 138
= 75. kN
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 67.0 * ( 12.0 - 6.0 ) * 0.74 * 138
= 64. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 57 + 75 ) = 132 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 57 + 0 + 64 + 0 ) = 121 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 57 + 64 + 0 ) = 121 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 131 kN , must exceed W = 7 kN  or W1 = 42 kN
Path 2-2 = 121 kN , must exceed W = 7 kN  or W2 = 56 kN
Path 3-3 = 121 kN , must exceed W = 7 kN  or W3 = 56 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   15  bars
```

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

```
 Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 1.0212 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 163.0211 mm.

Input, Nozzle Desc: K3A (3in) **From: 30**

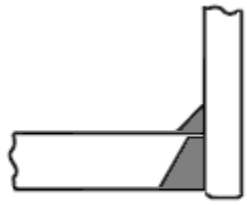
Pressure for Reinforcement Calculations	P	8.000	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1100.00	mm.
Design Length of Section	L	1791.6666	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	6.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Cylinder/Cone Centerline	L1	62.0000	mm.
Distance from Bottom/Left Tangent		2126.00	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		6.33	deg
Diameter		3.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	6.0000	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	6.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: K3A (3in)

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

```
Actual Inside Diameter Used in Calculation          2.734   in.
Actual Thickness Used in Calculation                0.383   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)
= (8.0*556.0)/(138*1.0-0.6*8.0)
= 3.2370 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)
= (8.0*40.72)/(118*1.0-0.6*8.0)
= 0.2774 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3552 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)          Dl    164.0289  mm.
Parallel to Vessel Wall, opening length            d     82.0144  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp     9.3364  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.345	1.820	NA
Area in Shell	A1	3.546	1.311	NA
Area in Nozzle Wall	A2	0.553	0.540	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.308	0.308	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	4.407	2.159	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 83.16 Degs.

The area available without a pad is Sufficient.

Area Required [A]:

= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(82.0144*4.3799*1+2*3.7345*4.3799*1(1-0.86))
= 1.820 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)
= 82.014(1.0 * 6.0 - 1.0 * 4.38) - 2 * 3.735
(1.0 * 6.0 - 1.0 * 4.3799) * (1 - 0.855)
= 1.311 cm²

Area Available in Nozzle Projecting Outward [A2]:

= (2 * tlnp)(tn - trn)fr2/sin(alpha3)
= (2 * 9.34)(3.73 - 0.36) 0.855/sin(86.6)
= 0.540 cm²

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

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

= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 6.0² * 0.855 + (0.0)² * 0.855
= 0.308 cm²

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 9.735, tr = 0.277, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.074, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C
```

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

Govrn. thk, tg = 9.735, tr = 0.277, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.074, Temp. Reduction = 78 °C

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

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

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)      -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
`Design Pressure/Ambient Rating = 8.00/51.10 = 0.157`

Weld Size Calculations, Description: K3A (3in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      3.7345  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	2.6142 = 0.7 * tmin.	4.2420 = 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, (1.8198 - 1.3111 + 2 * 3.7345 * 0.855 *
  (1.0 * 6.0 - 4.3799 ) )138)
= 8.44 kN
```

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

Weld Load [W1]:

```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 0.5405 + 0.0 + 0.3078 - 0.0 * 0.86 ) * 138
= 11.70 kN
```

Weld Load [W2]:

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

```
  = ( 0.5405 + 0.0 + 0.3078 + ( 0.3832 ) ) * 138
  = 16.98 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = (  0.5405 + 0.0 + 0.3078 + 0.0 + ( 0.3832 ) ) * 138
  = 16.98 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 89.5371 * 6.0 * 0.49 * 118
  = 49. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 42.8879) * ( 9.7345 - 6.0 ) * 0.7 * 118
  = 42. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 89.5371 * ( 12.0 - 6.0 ) * 0.74 * 138
  = 86. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 49 + 42 ) = 90 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 49 + 0 + 86 + 0 ) = 135 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 49 + 86 + 0 ) = 135 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 90 kN , must exceed W = 8 kN  or W1 = 11 kN
 Path 2-2 = 134 kN , must exceed W = 8 kN  or W2 = 16 kN
 Path 3-3 = 134 kN , must exceed W = 8 kN  or W3 = 16 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   9  bars
```

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

```
 Nozzle is O.K. for the External Pressure          1  bars
```

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

Reinforcement CALCULATION, Description: K3A (3in)

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

```
 Actual Inside Diameter Used in Calculation            2.734  in.
 Actual Thickness Used in Calculation                  0.383  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (8.0*556.0)/(138*1.0-0.6*8.0)
= 3.2370 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)
= (8.0*40.72)/(118*1.0-0.6*8.0)
= 0.2774 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3552 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	162.8618	mm.
Parallel to Vessel Wall, opening length	d	81.4309	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	9.3364	mm.

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	2.671	1.807	NA
Area in Shell	A1	2.220	1.302	NA
Area in Nozzle Wall	A2	0.552	0.540	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.308	0.308	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	3.080	2.149	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
```
= 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
= 0.5(81.4309*4.3799*1+2*3.7345*4.3799*1(1-0.86))
= 1.807 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 )
= 81.431( 1.0 * 6.0 - 1.0 * 4.38 ) - 2 * 3.735
  ( 1.0 * 6.0 - 1.0 * 4.3799 ) * ( 1 - 0.855 )
= 1.302 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
= ( 2 * tlnp )( tn - trn )fr2
= ( 2 * 9.34 )( 3.73 - 0.36 ) 0.855
= 0.540 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 6.0² * 0.855 + (0.0)² * 0.855
= 0.308 cm²

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

```
Wall Thickness for Internal/External pressures      ta = 6.3552 mm.
Wall Thickness per UG16(b),                      tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 9.2370 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 9.2370 mm.
Wall Thickness, shell/head, external pressure     trb2 = 6.4171 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 7.5000 mm.
Wall Thickness per table UG-45                     tb3 = 10.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[10.8, max(9.237, 7.5)]
= 9.2370 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(6.3552, 9.237)
= 9.2370 mm.

Available Nozzle Neck Thickness = 9.7345 mm. --> OK

Weld Size Calculations, Description: K3A (3in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      3.7345  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	2.6142 = 0.7 * tmin.	4.2420 = 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, (1.807 - 1.3017 + 2 * 3.7345 * 0.855 *
(1.0 * 6.0 - 4.3799))138)
= 8.39 kN

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

Weld Load [W1]:
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= (0.5395 + 0.0 + 0.3078 - 0.0 * 0.86) * 138
= 11.68 kN

Weld Load [W2]:
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= (0.5395 + 0.0 + 0.3078 + (0.3832)) * 138
= 16.97 kN

Weld Load [W3]:
```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= (  0.5395 + 0.0 + 0.3078 + 0.0 + ( 0.3832 ) ) * 138
= 16.97 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 88.9 * 6.0 * 0.49 * 118
= 48. kN
```

Shear, Nozzle Wall [Snw]:
```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 42.5827) * ( 9.7345 - 6.0 ) * 0.7 * 118
= 41. kN
```

Tension, Shell Groove Weld [Tngw]:
```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 88.9 * ( 12.0 - 6.0 ) * 0.74 * 138
= 85. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 48 + 41 ) = 90 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 48 + 0 + 85 + 0 ) = 134 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 48 + 85 + 0 ) = 134 kN
```

Summary of Failure Path Calculations:
```
Path 1-1 = 89 kN , must exceed W = 8 kN  or W1 = 11 kN
Path 2-2 = 133 kN , must exceed W = 8 kN  or W2 = 16 kN
Path 3-3 = 133 kN , must exceed W = 8 kN  or W3 = 16 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
Converged Max. Allow. Pressure in Operating case   9  bars

Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 6.8941 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 168.9694 mm.

Input, Nozzle Desc: K3B (3in) **From: 30**

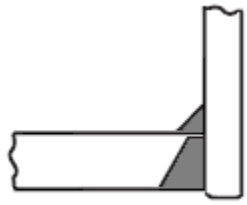
Pressure for Reinforcement Calculations	P	8.039	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1100.00	mm.
Design Length of Section	L	1791.6666	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	6.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Cylinder/Cone Centerline	L1	400.0000	mm.
Distance from Bottom/Left Tangent		2126.00	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		-45.38	deg
Diameter		3.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	6.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	250.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	6.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: K3B (3in)

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

```
Actual Inside Diameter Used in Calculation          2.734   in.
Actual Thickness Used in Calculation                0.383   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)
  = (8.04*556.0)/(138*1.0-0.6*8.04)
  = 3.2529 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)
  = (8.04*40.72)/(118*1.0-0.6*8.04)
  = 0.2788 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.4399 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)          Dl    235.3265  mm.
Parallel to Vessel Wall, opening length            d    117.6632  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp     9.3364  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

```
AREA AVAILABLE, A1 to A5     |    Design|  External|     Mapnc|
-------------------------------------------------------------
```

Area Required	Ar	1.931	2.601	NA
Area in Shell	A1	5.099	1.889	NA
Area in Nozzle Wall	A2	0.735	0.701	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.308	0.308	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	6.141	2.897	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 43.79 Degs.

The area available without a pad is Sufficient.

Area Required [A]:

$= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1))$ per UG-37(d)

$= 0.5(117.6632*4.3799*1+2*3.7345*4.3799*1(1-0.86))$

$= 2.601 \text{ cm}^2$

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

$= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)$

$= 117.663(1.0 * 6.0 - 1.0 * 4.38) - 2 * 3.735 (1.0 * 6.0 - 1.0 * 4.3799) * (1 - 0.855)$

$= 1.889 \text{ cm}^2$

Area Available in Nozzle Projecting Outward [A2]:

$= (2 * tlnp)(tn - trn)fr2/sin(alpha3)$

$= (2 * 9.34)(3.73 - 0.44) 0.855/sin(48.7)$

$= 0.701 \text{ cm}^2$

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

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

$= Wo^2 * fr2 + (Wi-can/0.707)^2 * fr2$

$= 6.0^2 * 0.855 + (0.0)^2 * 0.855$

$= 0.308 \text{ cm}^2$

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 9.735, tr = 0.279, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.075, Temp. Reduction = 78 °C

Min Metal Temp. w/o impact per UCS-66, Curve A	-8 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-104 °C
Min Metal Temp. w/o impact per UG-20(f)	-29 °C

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

Govrn. thk, tg = 9.735, tr = 0.279, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.075, Temp. Reduction = 78 °C

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

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

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)      -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
```
Design Pressure/Ambient Rating = 8.04/51.10 = 0.157
```

Weld Size Calculations, Description: K3B (3in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      3.7345  mm.
```

Results Per UW-16.1:

```
                        Required Thickness    Actual Thickness
Nozzle Weld          2.6142 = 0.7 * tmin.  4.2420 = 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, (2.6005 - 1.8887 + 2 * 3.7345 * 0.855 *
    (1.0 * 6.0 - 4.3799 ) )138)
  = 11.24 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.7007 + 0.0 + 0.3078 - 0.0 * 0.86 ) * 138
  = 13.91 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.7007 + 0.0 + 0.3078 + ( 0.3832 ) ) * 138
  = 19.19 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = (  0.7007 + 0.0 + 0.3078 + 0.0 + ( 0.3832 ) ) * 138
  = 19.19 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 128.4557 * 6.0 * 0.49 * 118
  = 70. kN
```

Shear, Nozzle Wall [Snw]:
```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 61.5297) * ( 9.7345 - 6.0 ) * 0.7 * 118
= 60. kN
```

Tension, Shell Groove Weld [Tngw]:
```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 128.4557 * ( 12.0 - 6.0 ) * 0.74 * 138
= 124. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 70 + 60 ) = 130 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 70 + 0 + 124 + 0 ) = 193 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 70 + 124 + 0 ) = 193 kN
```

Summary of Failure Path Calculations:
```
Path 1-1 = 129 kN , must exceed W = 11 kN  or W1 = 13 kN
Path 2-2 = 193 kN , must exceed W = 11 kN  or W2 = 19 kN
Path 3-3 = 193 kN , must exceed W = 11 kN  or W3 = 19 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
Converged Max. Allow. Pressure in Operating case   9  bars
```

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

```
Nozzle is O.K. for the External Pressure           1  bars
```

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

Reinforcement CALCULATION, Description: K3B (3in)

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

```
Actual Inside Diameter Used in Calculation            2.734  in.
Actual Thickness Used in Calculation                  0.383  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (8.04*556.0)/(138*1.0-0.6*8.04)
= 3.2529 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)
= (8.04*40.72)/(118*1.0-0.6*8.04)
= 0.2788 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.4399 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl    162.8618  mm.
Parallel to Vessel Wall, opening length              d     81.4309  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp      9.3364  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	2.684	1.807	NA
Area in Shell	A1	2.207	1.302	NA
Area in Nozzle Wall	A2	0.552	0.526	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.308	0.308	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	3.067	2.135	NA

The External Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:

```
= 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
= 0.5(81.4309*4.3799*1+2*3.7345*4.3799*1(1-0.86))
= 1.807 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 )
= 81.431( 1.0 * 6.0 - 1.0 * 4.38 ) - 2 * 3.735
  ( 1.0 * 6.0 - 1.0 * 4.3799 ) * ( 1 - 0.855 )
= 1.302 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
= ( 2 * tlnp )( tn - trn )fr2
= ( 2 * 9.34 )( 3.73 - 0.44 ) 0.855
= 0.526 cm²
```

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

```
= Wo² * fr2 + ( Wi-can/0.707 )² * fr2
= 6.0² * 0.855 + ( 0.0 )² * 0.855
= 0.308 cm²
```

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

```
Wall Thickness for Internal/External pressures      ta = 6.4399 mm.
Wall Thickness per UG16(b),                      tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 9.2529 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 9.2529 mm.
Wall Thickness, shell/head, external pressure     trb2 = 6.4171 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 7.5000 mm.
Wall Thickness per table UG-45                    tb3 = 10.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
= min[ tb3, max( tb1,tb2) ]
= min[ 10.8, max( 9.2529, 7.5 ) ]
= 9.2529 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
= max( ta, tb )
= max( 6.4399, 9.2529 )
= 9.2529 mm.
```

Available Nozzle Neck Thickness = 9.7345 mm. --> OK

Weld Size Calculations, Description: K3B (3in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      3.7345  mm.
```

Results Per UW-16.1:

```
                    Required Thickness    Actual Thickness
Nozzle Weld        2.6142 = 0.7 * tmin.  4.2420 = 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, (1.807 - 1.3017 + 2 * 3.7345 * 0.855 *
  (1.0 * 6.0 - 4.3799 ) )138)
= 8.39 kN
```

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

Weld Load [W1]:
```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 0.526 + 0.0 + 0.3078 - 0.0 * 0.86 ) * 138
= 11.50 kN
```

Weld Load [W2]:
```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 0.526 + 0.0 + 0.3078 + ( 0.3832 ) ) * 138
= 16.78 kN
```

Weld Load [W3]:
```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= (  0.526 + 0.0 + 0.3078 + 0.0 + ( 0.3832 ) ) * 138
= 16.78 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 88.9 * 6.0 * 0.49 * 118
= 48. kN
```

Shear, Nozzle Wall [Snw]:
```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
```

```
= (3.1416 * 42.5827) * ( 9.7345 - 6.0 ) * 0.7 * 118
= 41. kN
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 88.9 * ( 12.0 - 6.0 ) * 0.74 * 138
= 85. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 48 + 41 ) = 90 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 48 + 0 + 85 + 0 ) = 134 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 48 + 85 + 0 ) = 134 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 89 kN , must exceed W = 8 kN  or W1 = 11 kN
Path 2-2 = 133 kN , must exceed W = 8 kN  or W2 = 16 kN
Path 3-3 = 133 kN , must exceed W = 8 kN  or W3 = 16 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   9  bars

Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 53.5099 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 320.7890 mm.

Input, Nozzle Desc: K05 (2in) **From: 30**

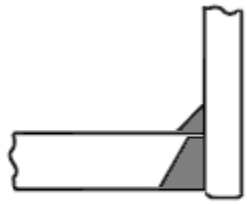
Pressure for Reinforcement Calculations	P	8.000	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1100.00	mm.
Design Length of Section	L	1791.6666	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	6.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1850.00	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	16.7640	mm.
Flange Material		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	6.0000	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	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		300	
Flange Grade		GR 1.1	
Flange Series	Series	@	

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: K05 (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                0.660  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)
  = (8.0*556.0)/(138*1.0-0.6*8.0)
  = 3.2370 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)
  = (8.0*31.4)/(138*1.0-0.6*8.0)
  = 0.1828 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3439 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)          Dl   125.6000  mm.
Parallel to Vessel Wall, opening length            d    62.8000  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp   15.0000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 137.9/137.9 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:

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

```
  = min( 1, 137.9/137.9 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 1.0, 1.0 )
  = 1.000
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	2.033	1.375	NA
Area in Shell	A1	1.735	1.017	NA
Area in Nozzle Wall	A2	3.174	3.126	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	5.550	4.783	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:

```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(62.8*4.3799*1+2*10.764*4.3799*1(1-1.0))
  = 1.375 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 )
  = 62.8( 1.0 * 6.0 - 1.0 * 4.38 ) - 2 * 10.764
    ( 1.0 * 6.0 - 1.0 * 4.3799 ) * ( 1 - 1.0 )
  = 1.017 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 15.0 )( 10.76 - 0.34 )1.0
  = 3.126 cm²
```

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

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 8.0² * 1.0 + ( 0.0 )² * 1.0
  = 0.640 cm²
```

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

```
Wall Thickness for Internal/External pressures      ta = 6.3439 mm.
Wall Thickness per UG16(b),                      tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 9.2370 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 9.2370 mm.
```

```
Wall Thickness, shell/head, external pressure     trb2 = 6.4171 mm.
Wall Thickness                  tb2 = max(trb2, tr16b) = 7.5000 mm.
Wall Thickness per table UG-45                    tb3 = 10.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 10.8, max( 9.237, 7.5 ) ]
  = 9.2370 mm.
```

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

```
  = max( ta, tb )
  = max( 6.3439, 9.237 )
  = 9.2370 mm.
```

Available Nozzle Neck Thickness = 16.7640 mm. --> OK

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 = 12.0, tr = 3.237, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.539, Temp. Reduction = 28 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A          -3 °C
Min Metal Temp. at Required thickness (UCS 66.1)       -30 °C
Min Metal Temp. w/o impact per UG-20(f)                -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :   -30 °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)      -104 °C
```

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

```
Design Pressure/Ambient Rating = 8.00/51.10 = 0.157
```

Weld Size Calculations, Description: K05 (2in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          4.2000 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
```

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (1.3753 - 1.0174 + 2 * 10.764 * 1.0 *
    (1.0 * 6.0 - 4.3799 ) )138)
  = 9.74 kN
```

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

Weld Load [W1]:

```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 3.126 + 0.0 + 0.64 - 0.0 * 1.0 ) * 138
= 51.93 kN
```

Weld Load [W2]:

```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 3.126 + 0.0 + 0.64 + ( 1.2917 ) ) * 138
= 69.74 kN
```

Weld Load [W3]:

```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 3.126 + 0.0 + 0.64 + 0.0 + ( 1.2917 ) ) * 138
= 69.74 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 84.328 * 8.0 * 0.49 * 138
= 72. kN
```

Shear, Nozzle Wall [Snw]:

```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 36.782) * ( 16.764 - 6.0 ) * 0.7 * 138
= 120. kN
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 84.328 * ( 12.0 - 6.0 ) * 0.74 * 138
= 81. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 72 + 120 ) = 192 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 72 + 0 + 81 + 0 ) = 153 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 72 + 81 + 0 ) = 153 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 191 kN , must exceed W = 9 kN  or W1 = 51 kN
Path 2-2 = 152 kN , must exceed W = 9 kN  or W2 = 69 kN
Path 3-3 = 152 kN , must exceed W = 9 kN  or W3 = 69 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   15  bars
```

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

```
 Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 1.6186 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 163.6185 mm.

Input, Nozzle Desc: K4B (2in) **From: 30**

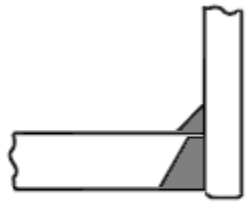
Pressure for Reinforcement Calculations	P	8.039	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1100.00	mm.
Design Length of Section	L	1791.6666	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	6.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Cylinder/Cone Centerline	L1	400.0000	mm.
Distance from Bottom/Left Tangent		2400.00	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		-45.38	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	6.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	250.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: K4B (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)
  = (8.04*556.0)/(138*1.0-0.6*8.04)
  = 3.2529 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)
  = (8.04*31.4)/(138*1.0-0.6*8.04)
  = 0.1837 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.4253 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)          Dl   180.9041  mm.
Parallel to Vessel Wall, opening length            d    90.4520  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp   15.0000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

```
AREA AVAILABLE, A1 to A5     |    Design|  External|     Mapnc|
-------------------------------------------------------------
```

```
Area Required              Ar |     1.471|     1.981|        NA|
Area in Shell              A1 |     3.956|     1.465|        NA|
Area in Nozzle Wall        A2 |     4.247|     4.149|        NA|
Area in Inward Nozzle      A3 |     0.000|     0.000|        NA|
Area in Welds     A41+A42+A43 |     0.640|     0.640|        NA|
Area in Element            A5 |     0.000|     0.000|        NA|
TOTAL AREA AVAILABLE     Atot |     8.843|     6.254|        NA|
```

The External Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                43.97  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:

```
= 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
= 0.5(90.452*4.3799*1+2*10.6*4.3799*1(1-1.0))
= 1.981 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 )
= 90.452( 1.0 * 6.0 - 1.0 * 4.38 ) - 2 * 10.6
  ( 1.0 * 6.0 - 1.0 * 4.3799 ) * ( 1 - 1.0 )
= 1.465 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
= ( 2 * tlnp )( tn - trn )fr2/sin( alpha3 )
= ( 2 * 15.0 )( 10.6 - 0.43 )1.0/sin( 47.4 )
= 4.149 cm²
```

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

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

```
= Wo² * fr2 + ( Wi-can/0.707 )² * fr2
= 8.0² * 1.0 + ( 0.0 )² * 1.0
= 0.640 cm²
```

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 = 12.0, tr = 3.253, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.542, Temp. Reduction = 28 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -3 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -30 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :   -30 °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)        -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
```
Design Pressure/Ambient Rating = 8.04/51.10 = 0.157
```

Weld Size Calculations, Description: K4B (2in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld         4.2000 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
```

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (1.9809 - 1.4654 + 2 * 10.6 * 1.0 *
    (1.0 * 6.0 - 4.3799 ) )138)
  = 11.84 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.1486 + 0.0 + 0.64 - 0.0 * 1.0 ) * 138
  = 66.03 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.1486 + 0.0 + 0.64 + ( 1.272 ) ) * 138
  = 83.57 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.1486 + 0.0 + 0.64 + 0.0 + ( 1.272 ) ) * 138
  = 83.57 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 120.9868 * 8.0 * 0.49 * 138
  = 103. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 52.8597) * ( 16.6 - 6.0 ) * 0.7 * 138
  = 170. kN
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 120.9868 * ( 12.0 - 6.0 ) * 0.74 * 138
= 116. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 103 + 170 ) = 273 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 103 + 0 + 116 + 0 ) = 219 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 103 + 116 + 0 ) = 219 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 272 kN , must exceed W = 11 kN  or W1 = 66 kN
Path 2-2 = 219 kN , must exceed W = 11 kN  or W2 = 83 kN
Path 3-3 = 219 kN , must exceed W = 11 kN  or W3 = 83 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   15  bars
```

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

```
Nozzle is O.K. for the External Pressure           1  bars
```

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

Reinforcement CALCULATION, Description: K4B (2in)

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

```
Actual Inside Diameter Used in Calculation            2.000  in.
Actual Thickness Used in Calculation                  0.654  in.
```

Nozzle input data check completed without errors.

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

```
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (8.04*556.0)/(138*1.0-0.6*8.04)
= 3.2529 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)
= (8.04*31.4)/(138*1.0-0.6*8.04)
= 0.1837 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.4253 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)          Dl   125.6000  mm.
Parallel to Vessel Wall, opening length            d    62.8000  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp   15.0000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	2.043	1.375	NA
Area in Shell	A1	1.725	1.017	NA
Area in Nozzle Wall	A2	3.125	3.052	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	5.490	4.710	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(62.8*4.3799*1+2*10.6*4.3799*1(1-1.0))
= 1.375 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)
= 62.8(1.0 * 6.0 - 1.0 * 4.38) - 2 * 10.6
(1.0 * 6.0 - 1.0 * 4.3799) * (1 - 1.0)
= 1.017 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 15.0)(10.6 - 0.43)1.0
= 3.052 cm²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 8.0² * 1.0 + (0.0)² * 1.0
= 0.640 cm²

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

Wall Thickness for Internal/External pressures ta = 6.4253 mm.
Wall Thickness per UG16(b), tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 9.2529 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 9.2529 mm.
Wall Thickness, shell/head, external pressure trb2 = 6.4171 mm.
Wall Thickness tb2 = max(trb2, tr16b) = 7.5000 mm.
Wall Thickness per table UG-45 tb3 = 10.8000 mm.

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[10.8, max(9.2529, 7.5)]
= 9.2529 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 6.4253, 9.2529 )
  = 9.2529 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Weld Size Calculations, Description: K4B (2in)

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      6.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
 Nozzle Weld          4.2000 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
```

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (1.3753 - 1.0174 + 2 * 10.6 * 1.0 *
    (1.0 * 6.0 - 4.3799 ) )138)
  = 9.67 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.0524 + 0.0 + 0.64 - 0.0 * 1.0 ) * 138
  = 50.91 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.0524 + 0.0 + 0.64 + ( 1.272 ) ) * 138
  = 68.45 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.0524 + 0.0 + 0.64 + 0.0 + ( 1.272 ) ) * 138
  = 68.45 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 84.0 * 8.0 * 0.49 * 138
  = 71. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 36.7) * ( 16.6 - 6.0 ) * 0.7 * 138
  = 118. kN
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 84.0 * ( 12.0 - 6.0 ) * 0.74 * 138
= 81. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 71 + 118 ) = 189 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 71 + 0 + 81 + 0 ) = 152 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 71 + 81 + 0 ) = 152 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 189 kN , must exceed W = 9 kN  or W1 = 50 kN
Path 2-2 = 152 kN , must exceed W = 9 kN  or W2 = 68 kN
Path 3-3 = 152 kN , must exceed W = 9 kN  or W3 = 68 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   15  bars

Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 50.1754 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 317.4545 mm.

Input, Nozzle Desc: K4A (2in) **From: 30**

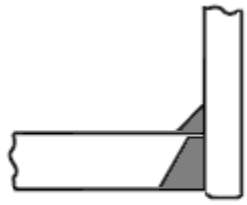
Pressure for Reinforcement Calculations	P	8.014	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1100.00	mm.
Design Length of Section	L	1791.6666	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	6.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Cylinder/Cone Centerline	L1	144.0000	mm.
Distance from Bottom/Left Tangent		2400.00	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		-14.85	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	6.0000	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	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: K4A (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)
= (8.01*556.0)/(138*1.0-0.6*8.01)
= 3.2427 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)
= (8.01*31.4)/(138*1.0-0.6*8.01)
= 0.1831 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   130.0897  mm.
Parallel to Vessel Wall, opening length            d    65.0449  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp   15.0000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.055	1.424	NA
Area in Shell	A1	2.848	1.054	NA
Area in Nozzle Wall	A2	3.205	3.156	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	6.693	4.849	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 74.90 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(65.0449*4.3799*1+2*10.6*4.3799*1(1-1.0))
= 1.424 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)
= 65.045(1.0 * 6.0 - 1.0 * 4.38) - 2 * 10.6
(1.0 * 6.0 - 1.0 * 4.3799) * (1 - 1.0)
= 1.054 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2/sin(alpha3)
= (2 * 15.0)(10.6 - 0.34)1.0/sin(77.2)
= 3.156 cm²

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

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 8.0² * 1.0 + (0.0)² * 1.0
= 0.640 cm²

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 = 12.0, tr = 3.243, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.54, Temp. Reduction = 28 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -3 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -30 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :   -30 °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)      -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
`Design Pressure/Ambient Rating = 8.01/51.10 = 0.157`

Weld Size Calculations, Description: K4A (2in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.0000  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.2000 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.

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

Weld Load [W]:

```
= max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max( 0, (1.4245 - 1.0538 + 2 * 10.6 * 1.0 *
  (1.0 * 6.0 - 4.3799 ) )138)
= 9.85 kN
```

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

Weld Load [W1]:

```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 3.1556 + 0.0 + 0.64 - 0.0 * 1.0 ) * 138
= 52.34 kN
```

Weld Load [W2]:

```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 3.1556 + 0.0 + 0.64 + ( 1.272 ) ) * 138
= 69.88 kN
```

Weld Load [W3]:

```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 3.1556 + 0.0 + 0.64 + 0.0 + ( 1.272 ) ) * 138
= 69.88 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 87.0027 * 8.0 * 0.49 * 138
= 74. kN
```

Shear, Nozzle Wall [Snw]:
```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 38.0119) * ( 16.6 - 6.0 ) * 0.7 * 138
= 122. kN
```

Tension, Shell Groove Weld [Tngw]:
```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 87.0027 * ( 12.0 - 6.0 ) * 0.74 * 138
= 84. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 74 + 122 ) = 196 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 74 + 0 + 84 + 0 ) = 158 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 74 + 84 + 0 ) = 158 kN
```

Summary of Failure Path Calculations:
```
Path 1-1 = 196 kN , must exceed W = 9 kN  or W1 = 52 kN
Path 2-2 = 157 kN , must exceed W = 9 kN  or W2 = 69 kN
Path 3-3 = 157 kN , must exceed W = 9 kN  or W3 = 69 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
Converged Max. Allow. Pressure in Operating case   15  bars
```

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

```
Nozzle is O.K. for the External Pressure          1  bars
```

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

Reinforcement CALCULATION, Description: K4A (2in)

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

```
Actual Inside Diameter Used in Calculation            2.000  in.
Actual Thickness Used in Calculation                  0.654  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (8.01*556.0)/(138*1.0-0.6*8.01)
= 3.2427 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)
= (8.01*31.4)/(138*1.0-0.6*8.01)
= 0.1831 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   125.6000  mm.
Parallel to Vessel Wall, opening length              d    62.8000  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    15.0000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	2.036	1.375	NA
Area in Shell	A1	1.732	1.017	NA
Area in Nozzle Wall	A2	3.125	3.077	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	5.497	4.734	NA

The External Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:

```
= 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
= 0.5(62.8*4.3799*1+2*10.6*4.3799*1(1-1.0))
= 1.375 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 )
= 62.8( 1.0 * 6.0 - 1.0 * 4.38 ) - 2 * 10.6
  ( 1.0 * 6.0 - 1.0 * 4.3799 ) * ( 1 - 1.0 )
= 1.017 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
= ( 2 * tlnp )( tn - trn )fr2
= ( 2 * 15.0 )( 10.6 - 0.34 )1.0
= 3.077 cm²
```

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

```
= Wo² * fr2 + ( Wi-can/0.707 )² * fr2
= 8.0² * 1.0 + ( 0.0 )² * 1.0
= 0.640 cm²
```

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

```
Wall Thickness for Internal/External pressures      ta = 6.3430 mm.
```

```
Wall Thickness per UG16(b),                        tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure       trb1 = 9.2427 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 9.2427 mm.
Wall Thickness, shell/head, external pressure       trb2 = 6.4171 mm.
Wall Thickness                  tb2 = max(trb2, tr16b) = 7.5000 mm.
Wall Thickness per table UG-45                       tb3 = 10.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 10.8, max( 9.2427, 7.5 ) ]
  = 9.2427 mm.
```

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

```
  = max( ta, tb )
  = max( 6.343, 9.2427 )
  = 9.2427 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Weld Size Calculations, Description: K4A (2in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          4.2000 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
```

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (1.3753 - 1.0174 + 2 * 10.6 * 1.0 *
    (1.0 * 6.0 - 4.3799 ) )138)
  = 9.67 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.0771 + 0.0 + 0.64 - 0.0 * 1.0 ) * 138
  = 51.25 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.0771 + 0.0 + 0.64 + ( 1.272 ) ) * 138
  = 68.79 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.0771 + 0.0 + 0.64 + 0.0 + ( 1.272 ) ) * 138
  = 68.79 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 84.0 * 8.0 * 0.49 * 138
= 71. kN
```

Shear, Nozzle Wall [Snw]:
```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 36.7) * ( 16.6 - 6.0 ) * 0.7 * 138
= 118. kN
```

Tension, Shell Groove Weld [Tngw]:
```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 84.0 * ( 12.0 - 6.0 ) * 0.74 * 138
= 81. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 71 + 118 ) = 189 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 71 + 0 + 81 + 0 ) = 152 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 71 + 81 + 0 ) = 152 kN
```

Summary of Failure Path Calculations:
```
Path 1-1 = 189 kN , must exceed W = 9 kN  or W1 = 51 kN
Path 2-2 = 152 kN , must exceed W = 9 kN  or W2 = 68 kN
Path 3-3 = 152 kN , must exceed W = 9 kN  or W3 = 68 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
Converged Max. Allow. Pressure in Operating case   15  bars

Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 13.2200 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 175.6440 mm.

Input, Nozzle Desc: K2B (2in) **From: 30**

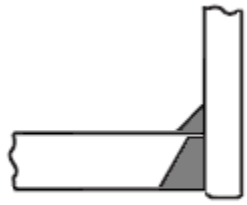
Pressure for Reinforcement Calculations	P	8.015	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1100.00	mm.
Design Length of Section	L	1791.6666	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	6.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Cylinder/Cone Centerline	L1	150.0000	mm.
Distance from Bottom/Left Tangent		2650.00	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		-15.48	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	6.0000	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	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: K2B (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)
= (8.01*556.0)/(138*1.0-0.6*8.01)
= 3.2429 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)
= (8.01*31.4)/(138*1.0-0.6*8.01)
= 0.1831 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   130.4880  mm.
Parallel to Vessel Wall, opening length            d    65.2440  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp   15.0000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.058	1.429	NA
Area in Shell	A1	2.857	1.057	NA
Area in Nozzle Wall	A2	3.213	3.164	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	6.710	4.861	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 74.27 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(65.244*4.3799*1+2*10.6*4.3799*1(1-1.0))
= 1.429 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)
= 65.244(1.0 * 6.0 - 1.0 * 4.38) - 2 * 10.6
(1.0 * 6.0 - 1.0 * 4.3799) * (1 - 1.0)
= 1.057 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2/sin(alpha3)
= (2 * 15.0)(10.6 - 0.34)1.0/sin(76.6)
= 3.164 cm²

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

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 8.0² * 1.0 + (0.0)² * 1.0
= 0.640 cm²

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 = 12.0, tr = 3.243, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.54, Temp. Reduction = 28 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -3 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -30 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C

Gov. MDMT of the nozzle to shell joint welded assembly :   -30 °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)      -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
`Design Pressure/Ambient Rating = 8.01/51.10 = 0.157`

Weld Size Calculations, Description: K2B (2in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.0000  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.2000 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.

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

Weld Load [W]:

```
= max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max( 0, (1.4288 - 1.057 + 2 * 10.6 * 1.0 *
  (1.0 * 6.0 - 4.3799 ) )138)
= 9.86 kN
```

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

Weld Load [W1]:

```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 3.1637 + 0.0 + 0.64 - 0.0 * 1.0 ) * 138
= 52.45 kN
```

Weld Load [W2]:

```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 3.1637 + 0.0 + 0.64 + ( 1.272 ) ) * 138
= 69.99 kN
```

Weld Load [W3]:

```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 3.1637 + 0.0 + 0.64 + 0.0 + ( 1.272 ) ) * 138
= 69.99 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 87.2691 * 8.0 * 0.49 * 138
= 74. kN
```

Shear, Nozzle Wall [Snw]:
```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 38.1283) * ( 16.6 - 6.0 ) * 0.7 * 138
= 123. kN
```

Tension, Shell Groove Weld [Tngw]:
```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 87.2691 * ( 12.0 - 6.0 ) * 0.74 * 138
= 84. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 74 + 123 ) = 197 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 74 + 0 + 84 + 0 ) = 158 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 74 + 84 + 0 ) = 158 kN
```

Summary of Failure Path Calculations:
```
Path 1-1 = 196 kN , must exceed W = 9 kN  or W1 = 52 kN
Path 2-2 = 158 kN , must exceed W = 9 kN  or W2 = 69 kN
Path 3-3 = 158 kN , must exceed W = 9 kN  or W3 = 69 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
Converged Max. Allow. Pressure in Operating case   15  bars
```

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

```
Nozzle is O.K. for the External Pressure          1  bars
```

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

Reinforcement CALCULATION, Description: K2B (2in)

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

```
Actual Inside Diameter Used in Calculation            2.000  in.
Actual Thickness Used in Calculation                  0.654  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (8.01*556.0)/(138*1.0-0.6*8.01)
= 3.2429 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)
= (8.01*31.4)/(138*1.0-0.6*8.01)
= 0.1831 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   125.6000  mm.
Parallel to Vessel Wall, opening length              d    62.8000  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    15.0000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	2.037	1.375	NA
Area in Shell	A1	1.731	1.017	NA
Area in Nozzle Wall	A2	3.125	3.077	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	5.496	4.734	NA

The External Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:

```
= 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
= 0.5(62.8*4.3799*1+2*10.6*4.3799*1(1-1.0))
= 1.375 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 )
= 62.8( 1.0 * 6.0 - 1.0 * 4.38 ) - 2 * 10.6
  ( 1.0 * 6.0 - 1.0 * 4.3799 ) * ( 1 - 1.0 )
= 1.017 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
= ( 2 * tlnp )( tn - trn )fr2
= ( 2 * 15.0 )( 10.6 - 0.34 )1.0
= 3.077 cm²
```

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

```
= Wo² * fr2 + ( Wi-can/0.707 )² * fr2
= 8.0² * 1.0 + ( 0.0 )² * 1.0
= 0.640 cm²
```

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

```
Wall Thickness for Internal/External pressures      ta = 6.3430 mm.
```

```
Wall Thickness per UG16(b),                        tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure       trb1 = 9.2429 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 9.2429 mm.
Wall Thickness, shell/head, external pressure       trb2 = 6.4171 mm.
Wall Thickness                  tb2 = max(trb2, tr16b) = 7.5000 mm.
Wall Thickness per table UG-45                       tb3 = 10.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
= min[ tb3, max( tb1,tb2) ]
= min[ 10.8, max( 9.2429, 7.5 ) ]
= 9.2429 mm.
```

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

```
= max( ta, tb )
= max( 6.343, 9.2429 )
= 9.2429 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Weld Size Calculations, Description: K2B (2in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.0000  mm.
```

Results Per UW-16.1:

```
                        Required Thickness    Actual Thickness
Nozzle Weld           4.2000 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
```

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

Weld Load [W]:

```
= max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max( 0, (1.3753 - 1.0174 + 2 * 10.6 * 1.0 *
  (1.0 * 6.0 - 4.3799 ) )138)
= 9.67 kN
```

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

Weld Load [W1]:

```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 3.0771 + 0.0 + 0.64 - 0.0 * 1.0 ) * 138
= 51.25 kN
```

Weld Load [W2]:

```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 3.0771 + 0.0 + 0.64 + ( 1.272 ) ) * 138
= 68.79 kN
```

Weld Load [W3]:

```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 3.0771 + 0.0 + 0.64 + 0.0 + ( 1.272 ) ) * 138
= 68.79 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 84.0 * 8.0 * 0.49 * 138
= 71. kN
```

Shear, Nozzle Wall [Snw]:
```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 36.7) * ( 16.6 - 6.0 ) * 0.7 * 138
= 118. kN
```

Tension, Shell Groove Weld [Tngw]:
```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 84.0 * ( 12.0 - 6.0 ) * 0.74 * 138
= 81. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 71 + 118 ) = 189 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 71 + 0 + 81 + 0 ) = 152 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 71 + 81 + 0 ) = 152 kN
```

Summary of Failure Path Calculations:
```
Path 1-1 = 189 kN , must exceed W = 9 kN  or W1 = 51 kN
Path 2-2 = 152 kN , must exceed W = 9 kN  or W2 = 68 kN
Path 3-3 = 152 kN , must exceed W = 9 kN  or W3 = 68 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
Converged Max. Allow. Pressure in Operating case   15  bars

Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 13.7514 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 176.2135 mm.

Input, Nozzle Desc: K2A (2in) **From: 30**

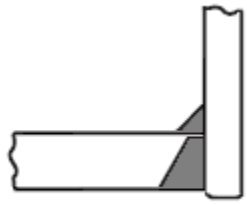
Pressure for Reinforcement Calculations	P	8.000	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1100.00	mm.
Design Length of Section	L	1791.6666	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	6.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Cylinder/Cone Centerline	L1	106.0000	mm.
Distance from Bottom/Left Tangent		2650.00	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		10.87	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	6.0000	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	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: K2A (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)
= (8.0*556.0)/(138*1.0-0.6*8.0)
= 3.2370 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)
= (8.0*31.4)/(138*1.0-0.6*8.0)
= 0.1828 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   128.0058  mm.
Parallel to Vessel Wall, opening length            d    64.0029  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp   15.0000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.036	1.402	NA
Area in Shell	A1	2.804	1.037	NA
Area in Nozzle Wall	A2	3.163	3.114	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	6.607	4.791	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 78.87 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(64.0029*4.3799*1+2*10.6*4.3799*1(1-1.0))
= 1.402 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)
= 64.003(1.0 * 6.0 - 1.0 * 4.38) - 2 * 10.6
(1.0 * 6.0 - 1.0 * 4.3799) * (1 - 1.0)
= 1.037 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2/sin(alpha3)
= (2 * 15.0)(10.6 - 0.34)1.0/sin(81.1)
= 3.114 cm²

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

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 8.0² * 1.0 + (0.0)² * 1.0
= 0.640 cm²

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 = 12.0, tr = 3.237, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.539, Temp. Reduction = 28 °C

Min Metal Temp. w/o impact per UCS-66, Curve A	-3 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-30 °C
Min Metal Temp. w/o impact per UG-20(f)	-29 °C

Gov. MDMT of the nozzle to shell joint welded assembly : -30 °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) -104 °C

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 8.00/51.10 = 0.157

Weld Size Calculations, Description: K2A (2in)

Intermediate Calc. for nozzle/shell Welds Tmin 6.0000 mm.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.2000 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.

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

Weld Load [W]:
= max(0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max(0, (1.4016 - 1.0369 + 2 * 10.6 * 1.0 *
(1.0 * 6.0 - 4.3799))138)
= 9.77 kN

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

Weld Load [W1]:
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= (3.1143 + 0.0 + 0.64 - 0.0 * 1.0) * 138
= 51.77 kN

Weld Load [W2]:
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= (3.1143 + 0.0 + 0.64 + (1.272)) * 138
= 69.31 kN

Weld Load [W3]:
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= (3.1143 + 0.0 + 0.64 + 0.0 + (1.272)) * 138
= 69.31 kN

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
= (pi/2) * Dlo * Wo * 0.49 * Snw
= (3.1416/2.0) * 85.6089 * 8.0 * 0.49 * 138
= 73. kN

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.1416 * 37.403) * (16.6 - 6.0) * 0.7 * 138
= 120. kN

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 85.6089 * ( 12.0 - 6.0 ) * 0.74 * 138
  = 82. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 73 + 120 ) = 193 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 73 + 0 + 82 + 0 ) = 155 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 73 + 82 + 0 ) = 155 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 192 kN , must exceed W = 9 kN  or W1 = 51 kN
 Path 2-2 = 155 kN , must exceed W = 9 kN  or W2 = 69 kN
 Path 3-3 = 155 kN , must exceed W = 9 kN  or W3 = 69 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case   15  bars
```

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

```
 Nozzle is O.K. for the External Pressure           1  bars
```

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

Reinforcement CALCULATION, Description: K2A (2in)

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

```
 Actual Inside Diameter Used in Calculation            2.000  in.
 Actual Thickness Used in Calculation                  0.654  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (8.0*556.0)/(138*1.0-0.6*8.0)
  = 3.2370 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)
  = (8.0*31.4)/(138*1.0-0.6*8.0)
  = 0.1828 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   125.6000  mm.
 Parallel to Vessel Wall, opening length            d    62.8000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad  Tlnp   15.0000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	2.033	1.375	NA
Area in Shell	A1	1.735	1.017	NA
Area in Nozzle Wall	A2	3.125	3.077	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	5.500	4.734	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(62.8*4.3799*1+2*10.6*4.3799*1(1-1.0))
= 1.375 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)
= 62.8(1.0 * 6.0 - 1.0 * 4.38) - 2 * 10.6
(1.0 * 6.0 - 1.0 * 4.3799) * (1 - 1.0)
= 1.017 cm²

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 15.0)(10.6 - 0.34)1.0
= 3.077 cm²

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 8.0² * 1.0 + (0.0)² * 1.0
= 0.640 cm²

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

Wall Thickness for Internal/External pressures ta = 6.3430 mm.
Wall Thickness per UG16(b), tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 9.2370 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 9.2370 mm.
Wall Thickness, shell/head, external pressure trb2 = 6.4171 mm.
Wall Thickness tb2 = max(trb2, tr16b) = 7.5000 mm.
Wall Thickness per table UG-45 tb3 = 10.8000 mm.

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[10.8, max(9.237, 7.5)]
= 9.2370 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 6.343, 9.237 )
  = 9.2370 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Weld Size Calculations, Description: K2A (2in)

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      6.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
 Nozzle Weld          4.2000 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
```

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (1.3753 - 1.0174 + 2 * 10.6 * 1.0 *
    (1.0 * 6.0 - 4.3799 ) )138)
  = 9.67 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.0771 + 0.0 + 0.64 - 0.0 * 1.0 ) * 138
  = 51.25 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.0771 + 0.0 + 0.64 + ( 1.272 ) ) * 138
  = 68.79 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.0771 + 0.0 + 0.64 + 0.0 + ( 1.272 ) ) * 138
  = 68.79 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 84.0 * 8.0 * 0.49 * 138
  = 71. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 36.7) * ( 16.6 - 6.0 ) * 0.7 * 138
  = 118. kN
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 84.0 * ( 12.0 - 6.0 ) * 0.74 * 138
= 81. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 71 + 118 ) = 189 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 71 + 0 + 81 + 0 ) = 152 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 71 + 81 + 0 ) = 152 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 189 kN , must exceed W = 9 kN  or W1 = 51 kN
Path 2-2 = 152 kN , must exceed W = 9 kN  or W2 = 68 kN
Path 3-3 = 152 kN , must exceed W = 9 kN  or W3 = 68 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   15  bars

Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 9.9757 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 172.1999 mm.

Input, Nozzle Desc: K1B (3in) **From: 30**

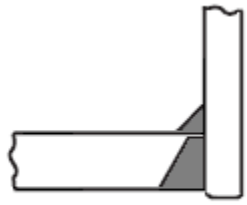
Pressure for Reinforcement Calculations	P	8.039	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1100.00	mm.
Design Length of Section	L	1791.6666	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	6.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Cylinder/Cone Centerline	L1	400.0000	mm.
Distance from Bottom/Left Tangent		3150.00	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		-45.38	deg
Diameter		3.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	6.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	250.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	6.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: K1B (3in)

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

```
Actual Inside Diameter Used in Calculation          2.734   in.
Actual Thickness Used in Calculation                0.383   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)
  = (8.04*556.0)/(138*1.0-0.6*8.04)
  = 3.2529 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)
  = (8.04*40.72)/(118*1.0-0.6*8.04)
  = 0.2788 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.4399 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)          Dl    235.3265  mm.
Parallel to Vessel Wall, opening length            d    117.6632  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp     9.3364  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.931	2.601	NA
Area in Shell	A1	5.099	1.889	NA
Area in Nozzle Wall	A2	0.735	0.701	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.308	0.308	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	6.141	2.897	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 43.79 Degs.

The area available without a pad is Sufficient.

Area Required [A]:

= 0.5(d * tr*F + 2 * tn * tr*F(1-fr1)) per UG-37(d)
= 0.5(117.6632*4.3799*1+2*3.7345*4.3799*1(1-0.86))
= 2.601 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)
= 117.663(1.0 * 6.0 - 1.0 * 4.38) - 2 * 3.735
(1.0 * 6.0 - 1.0 * 4.3799) * (1 - 0.855)
= 1.889 cm²

Area Available in Nozzle Projecting Outward [A2]:

= (2 * tlnp)(tn - trn)fr2/sin(alpha3)
= (2 * 9.34)(3.73 - 0.44) 0.855/sin(48.7)
= 0.701 cm²

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

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

= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 6.0² * 0.855 + (0.0)² * 0.855
= 0.308 cm²

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 9.735, tr = 0.279, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.075, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A              -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -104 °C
Min Metal Temp. w/o impact per UG-20(f)                    -29 °C
```

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

Govrn. thk, tg = 9.735, tr = 0.279, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.075, Temp. Reduction = 78 °C

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

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

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)      -104 °C
```

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

```
Design Pressure/Ambient Rating = 8.04/51.10 = 0.157
```

Weld Size Calculations, Description: K1B (3in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      3.7345  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          2.6142 = 0.7 * tmin.  4.2420 = 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, (2.6005 - 1.8887 + 2 * 3.7345 * 0.855 *
    (1.0 * 6.0 - 4.3799 ) )138)
  = 11.24 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.7007 + 0.0 + 0.3078 - 0.0 * 0.86 ) * 138
  = 13.91 kN
```

Weld Load [W2]:

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

```
  = ( 0.7007 + 0.0 + 0.3078 + ( 0.3832 ) ) * 138
  = 19.19 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = (  0.7007 + 0.0 + 0.3078 + 0.0 + ( 0.3832 ) ) * 138
  = 19.19 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 128.4557 * 6.0 * 0.49 * 118
  = 70. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 61.5297) * ( 9.7345 - 6.0 ) * 0.7 * 118
  = 60. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 128.4557 * ( 12.0 - 6.0 ) * 0.74 * 138
  = 124. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 70 + 60 ) = 130 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 70 + 0 + 124 + 0 ) = 193 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 70 + 124 + 0 ) = 193 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 129 kN , must exceed W = 11 kN  or W1 = 13 kN
 Path 2-2 = 193 kN , must exceed W = 11 kN  or W2 = 19 kN
 Path 3-3 = 193 kN , must exceed W = 11 kN  or W3 = 19 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case   9  bars
```

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

```
 Nozzle is O.K. for the External Pressure           1  bars
```

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

Reinforcement CALCULATION, Description: K1B (3in)

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

```
 Actual Inside Diameter Used in Calculation            2.734  in.
 Actual Thickness Used in Calculation                  0.383  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (8.04*556.0)/(138*1.0-0.6*8.04)
= 3.2529 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)
= (8.04*40.72)/(118*1.0-0.6*8.04)
= 0.2788 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.4399 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	162.8618	mm.
Parallel to Vessel Wall, opening length	d	81.4309	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	9.3364	mm.

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	2.684	1.807	NA
Area in Shell	A1	2.207	1.302	NA
Area in Nozzle Wall	A2	0.552	0.526	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.308	0.308	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	3.067	2.135	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
```
= 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
= 0.5(81.4309*4.3799*1+2*3.7345*4.3799*1(1-0.86))
= 1.807 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 )
= 81.431( 1.0 * 6.0 - 1.0 * 4.38 ) - 2 * 3.735
  ( 1.0 * 6.0 - 1.0 * 4.3799 ) * ( 1 - 0.855 )
= 1.302 cm²
```

Area Available in Nozzle Projecting Outward [A2]:
```
= ( 2 * tlnp )( tn - trn )fr2
= ( 2 * 9.34 )( 3.73 - 0.44 ) 0.855
= 0.526 cm²
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo^2 * fr2 + (Wi-can/0.707)^2 * fr2
= 6.0^2 * 0.855 + (0.0)^2 * 0.855
= 0.308 cm^2

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

```
Wall Thickness for Internal/External pressures      ta = 6.4399 mm.
Wall Thickness per UG16(b),                      tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 9.2529 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 9.2529 mm.
Wall Thickness, shell/head, external pressure     trb2 = 6.4171 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 7.5000 mm.
Wall Thickness per table UG-45                    tb3 = 10.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[10.8, max(9.2529, 7.5)]
= 9.2529 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(6.4399, 9.2529)
= 9.2529 mm.

Available Nozzle Neck Thickness = 9.7345 mm. --> OK

Weld Size Calculations, Description: K1B (3in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      3.7345  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	2.6142 = 0.7 * tmin.	4.2420 = 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, (1.807 - 1.3017 + 2 * 3.7345 * 0.855 *
(1.0 * 6.0 - 4.3799))138)
= 8.39 kN

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

Weld Load [W1]:
= (A2+A5+A4-(Wi-Can/.707)^2*fr2)*Sv
= (0.526 + 0.0 + 0.3078 - 0.0 * 0.86) * 138
= 11.50 kN

Weld Load [W2]:
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= (0.526 + 0.0 + 0.3078 + (0.3832)) * 138
= 16.78 kN

Weld Load [W3]:
```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= (  0.526 + 0.0 + 0.3078 + 0.0 + ( 0.3832 ) ) * 138
= 16.78 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 88.9 * 6.0 * 0.49 * 118
= 48. kN
```

Shear, Nozzle Wall [Snw]:
```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 42.5827) * ( 9.7345 - 6.0 ) * 0.7 * 118
= 41. kN
```

Tension, Shell Groove Weld [Tngw]:
```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 88.9 * ( 12.0 - 6.0 ) * 0.74 * 138
= 85. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 48 + 41 ) = 90 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 48 + 0 + 85 + 0 ) = 134 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 48 + 85 + 0 ) = 134 kN
```

Summary of Failure Path Calculations:
```
Path 1-1 = 89 kN , must exceed W = 8 kN  or W1 = 11 kN
Path 2-2 = 133 kN , must exceed W = 8 kN  or W2 = 16 kN
Path 3-3 = 133 kN , must exceed W = 8 kN  or W3 = 16 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
Converged Max. Allow. Pressure in Operating case   9  bars

Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 53.5099 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 320.7890 mm.

Input, Nozzle Desc: K1A (3in) **From: 30**

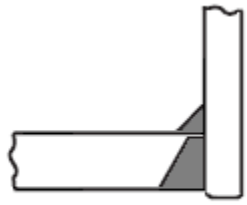
Pressure for Reinforcement Calculations	P	8.000	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	100	°C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm²
Shell Allowable Stress At Ambient	Sva	137.90	N./mm²
Inside Diameter of Cylindrical Shell	D	1100.00	mm.
Design Length of Section	L	1791.6666	mm.
Shell Finished (Minimum) Thickness	t	12.0000	mm.
Shell Internal Corrosion Allowance	c	6.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Cylinder/Cone Centerline	L1	150.0000	mm.
Distance from Bottom/Left Tangent		3150.00	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		15.48	deg
Diameter		3.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	6.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	6.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	12.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: K1A (3in)

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

```
Actual Inside Diameter Used in Calculation          2.734   in.
Actual Thickness Used in Calculation                0.383   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)
  = (8.0*556.0)/(138*1.0-0.6*8.0)
  = 3.2370 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)
  = (8.0*40.72)/(118*1.0-0.6*8.0)
  = 0.2774 mm.
```

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

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

```
Parallel to Vessel Wall (Diameter Limit)          Dl   169.2813  mm.
Parallel to Vessel Wall, opening length            d    84.6406  mm.
Normal to Vessel Wall (Thickness Limit), no pad  Tlnp     9.3364  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

```
AREA AVAILABLE, A1 to A5     |    Design|  External|     Mapnc|
-------------------------------------------------------------
```

```
Area Required              Ar |     1.387|     1.877|        NA|
Area in Shell              A1 |     3.661|     1.354|        NA|
Area in Nozzle Wall        A2 |     0.565|     0.545|        NA|
Area in Inward Nozzle      A3 |     0.000|     0.000|        NA|
Area in Welds     A41+A42+A43 |     0.308|     0.308|        NA|
Area in Element            A5 |     0.000|     0.000|        NA|
TOTAL AREA AVAILABLE     Atot |     4.534|     2.207|        NA|
```

The External Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                74.17  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:

```
= 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
= 0.5(84.6406*4.3799*1+2*3.7345*4.3799*1(1-0.86))
= 1.877 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 )
= 84.641( 1.0 * 6.0 - 1.0 * 4.38 ) - 2 * 3.735
  ( 1.0 * 6.0 - 1.0 * 4.3799 ) * ( 1 - 0.855 )
= 1.354 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
= ( 2 * tlnp )( tn - trn )fr2/sin( alpha3 )
= ( 2 * 9.34 )( 3.73 - 0.4 ) 0.855/sin( 77.5 )
= 0.545 cm²
```

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

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

```
= Wo² * fr2 + ( Wi-can/0.707 )² * fr2
= 6.0² * 0.855 + ( 0.0 )² * 0.855
= 0.308 cm²
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 9.735, tr = 0.277, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.074, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve A          -8 °C
Min Metal Temp. at Required thickness (UCS 66.1)      -104 °C
Min Metal Temp. w/o impact per UG-20(f)                -29 °C
```

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

Govrn. thk, tg = 9.735, tr = 0.277, c = 6.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.074, Temp. Reduction = 78 °C

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

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

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)      -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
```
Design Pressure/Ambient Rating = 8.00/51.10 = 0.157
```

Weld Size Calculations, Description: K1A (3in)

```
Intermediate Calc. for nozzle/shell Welds   Tmin      3.7345  mm.
```

Results Per UW-16.1:

```
                        Required Thickness    Actual Thickness
Nozzle Weld          2.6142 = 0.7 * tmin.  4.2420 = 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, (1.8773 - 1.3537 + 2 * 3.7345 * 0.855 *
    (1.0 * 6.0 - 4.3799 ) )138)
  = 8.65 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.5454 + 0.0 + 0.3078 - 0.0 * 0.86 ) * 138
  = 11.76 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.5454 + 0.0 + 0.3078 + ( 0.3832 ) ) * 138
  = 17.05 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = (  0.5454 + 0.0 + 0.3078 + 0.0 + ( 0.3832 ) ) * 138
  = 17.05 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 92.4041 * 6.0 * 0.49 * 118
  = 50. kN
```

Shear, Nozzle Wall [Snw]:
```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 44.2612) * ( 9.7345 - 6.0 ) * 0.7 * 118
= 43. kN
```

Tension, Shell Groove Weld [Tngw]:
```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 92.4041 * ( 12.0 - 6.0 ) * 0.74 * 138
= 89. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 50 + 43 ) = 93 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 50 + 0 + 89 + 0 ) = 139 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 50 + 89 + 0 ) = 139 kN
```

Summary of Failure Path Calculations:
```
Path 1-1 = 93 kN , must exceed W = 8 kN  or W1 = 11 kN
Path 2-2 = 139 kN , must exceed W = 8 kN  or W2 = 17 kN
Path 3-3 = 139 kN , must exceed W = 8 kN  or W3 = 17 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
Converged Max. Allow. Pressure in Operating case   9  bars
```

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

```
Nozzle is O.K. for the External Pressure           1  bars
```

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

Reinforcement CALCULATION, Description: K1A (3in)

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

```
Actual Inside Diameter Used in Calculation            2.734  in.
Actual Thickness Used in Calculation                  0.383  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (8.0*556.0)/(138*1.0-0.6*8.0)
= 3.2370 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)
= (8.0*40.72)/(118*1.0-0.6*8.0)
= 0.2774 mm.
```

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

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl    162.8618  mm.
Parallel to Vessel Wall, opening length              d     81.4309  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp      9.3364  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm²)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	2.671	1.807	NA
Area in Shell	A1	2.220	1.302	NA
Area in Nozzle Wall	A2	0.552	0.533	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.308	0.308	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	3.080	2.142	NA

The External Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:

```
= 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
= 0.5(81.4309*4.3799*1+2*3.7345*4.3799*1(1-0.86))
= 1.807 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 )
= 81.431( 1.0 * 6.0 - 1.0 * 4.38 ) - 2 * 3.735
  ( 1.0 * 6.0 - 1.0 * 4.3799 ) * ( 1 - 0.855 )
= 1.302 cm²
```

Area Available in Nozzle Projecting Outward [A2]:

```
= ( 2 * tlnp )( tn - trn )fr2
= ( 2 * 9.34 )( 3.73 - 0.4 ) 0.855
= 0.533 cm²
```

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

```
= Wo² * fr2 + ( Wi-can/0.707 )² * fr2
= 6.0² * 0.855 + ( 0.0 )² * 0.855
= 0.308 cm²
```

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

```
Wall Thickness for Internal/External pressures      ta = 6.3989 mm.
Wall Thickness per UG16(b),                      tr16b = 7.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 9.2370 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 9.2370 mm.
Wall Thickness, shell/head, external pressure     trb2 = 6.4171 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 7.5000 mm.
Wall Thickness per table UG-45                    tb3 = 10.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 10.8, max( 9.237, 7.5 ) ]
  = 9.2370 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 6.3989, 9.237 )
  = 9.2370 mm.
```

Available Nozzle Neck Thickness = 9.7345 mm. --> OK

Weld Size Calculations, Description: K1A (3in)

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      3.7345  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
 Nozzle Weld          2.6142 = 0.7 * tmin.  4.2420 = 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, (1.807 - 1.3017 + 2 * 3.7345 * 0.855 *
    (1.0 * 6.0 - 4.3799 ) )138)
  = 8.39 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.5325 + 0.0 + 0.3078 - 0.0 * 0.86 ) * 138
  = 11.59 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.5325 + 0.0 + 0.3078 + ( 0.3832 ) ) * 138
  = 16.87 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = (  0.5325 + 0.0 + 0.3078 + 0.0 + ( 0.3832 ) ) * 138
  = 16.87 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 88.9 * 6.0 * 0.49 * 118
  = 48. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
```

```
= (3.1416 * 42.5827) * ( 9.7345 - 6.0 ) * 0.7 * 118
= 41. kN
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 88.9 * ( 12.0 - 6.0 ) * 0.74 * 138
= 85. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 48 + 41 ) = 90 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 48 + 0 + 85 + 0 ) = 134 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 48 + 85 + 0 ) = 134 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 89 kN , must exceed W = 8 kN  or W1 = 11 kN
Path 2-2 = 133 kN , must exceed W = 8 kN  or W2 = 16 kN
Path 3-3 = 133 kN , must exceed W = 8 kN  or W3 = 16 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
Converged Max. Allow. Pressure in Operating case   9  bars

Nozzle is O.K. for the External Pressure           1  bars
```

The Drop for this Nozzle is : 14.6707 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 227.1328 mm.