PPI / NARGAN	DEHDASHT PETROCHEMICAL INDUSTRY COMPANY DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT	PGPIC
	DOCUMENT TITLE: Mechanical Calculation for K.O. Drum	POI: IFA
Contract No.: DPIC/98-12	DOCUMENT NUMBER: DPIC9812-000-VD-1002-ME-CLN-0095	Rev. No.: D0

DOCUMENT TITLE:

Mechanical Calculation for K.O. Drum (D-PK6101-3)

PURCHASER'S COMMENT/APPROVAL STATUS		Purchaser: NARGAN
1	AP: Approved (Released for Manufacturing)	Requisition No.: DPIC98-12-001-000-ME-MR-4150-0001-D1
2	AN: Approved With Minor Comments (Fabrication may Proceed)	
3	NF: Approved With Comments (Fabrication not Proceed)	Item No. (Tag No.): PK-6101
4	RJ: Rejected	
5	NR: Not be Returned	Vendor Doc. No.: DPIC9812-000-VD-1002-ME-CLN-0095-D0
Date:	Signature:	

REV	DATE ISSUE	PREPARED	CHECKED	APPROVED
D0	23.Dec.21	A.VOSOUGH	DR.A.NEJATI	DR.A.NEJATI

KASRAVAND Engineering & Construction

PPI / NARGAN	**DEHDASHT PETROCHEMICAL INDUSTRY COMPANY** **DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT**	PGPIC
	DOCUMENT TITLE: Mechanical Calculation for K.O. Drum	**POI: IFA**
Contract No.: DPIC/98-12	**DOCUMENT NUMBER: DPIC9812-000-VD-1002-ME-CLN-0095**	**Rev. No.: D0**

Page	Rev-D0	Rev-D1	Rev-D2	Rev-D3	Rev-D4
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				

Page	Rev-D0	Rev-D1	Rev-D2	Rev-D3	Rev-D4
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				
66	x				
67	x				
68	x				
69	x				
70	x				

PPI / NARGAN	**DEHDASHT PETROCHEMICAL INDUSTRY COMPANY** **DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT**	PGPIC
	DOCUMENT TITLE: Mechanical Calculation for K.O. Drum	**POI: IFA**
Contract No.: DPIC/98-12	**DOCUMENT NUMBER: DPIC9812-000-VD-1002-ME-CLN-0095**	**Rev. No.: D0**

Page	Rev-D0	Rev-D1	Rev-D2	Rev-D3	Rev-D4
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				

Page	Rev-D0	Rev-D1	Rev-D2	Rev-D3	Rev-D4
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				
131	x				
132	x				
133	x				
134	x				
135	x				
136	x				
137	x				
138	x				
139	x				
140	x				

PPI / NARGAN	**DEHDASHT PETROCHEMICAL INDUSTRY COMPANY** **DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT**	PGPIC
	DOCUMENT TITLE: Mechanical Calculation for K.O. Drum	**POI: IFA**
Contract No.: DPIC/98-12	**DOCUMENT NUMBER: DPIC9812-000-VD-1002-ME-CLN-0095**	**Rev. No.: D0**

Page	Rev-D0	Rev-D1	Rev-D2	Rev-D3	Rev-D4
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					
163					
164					
165					
166					
167					
168					
169					
170					
171					
172					
173					
174					
175					

Page	Rev-D0	Rev-D1	Rev-D2	Rev-D3	Rev-D4
176					
177					
178					
179					
180					
181					
182					
183					
184					
185					
186					
187					
188					
189					
190					
191					
192					
193					
194					
195					
196					
197					
198					
199					
200					
201					
202					
203					
204					
205					
206					
207					
208					
209					
210					

Table of Contents

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no: K.O. Drum (D-PK6101-3)

DESIGN CALCULATION

In Accordance with ASME Section VIII Division 1

ASME Code Version : 2017

Analysis Performed by : SPLM Licensed User

Job File :

Date of Analysis : Dec 24,2021 8:44pm

PV Elite 2018 SP2, June 2018

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

```
 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

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no: K.O. Drum (D-PK6101-3)

Design Internal Pressure (for Hydrotest)	23	bars
Design Internal Temperature	125.0	°C
Type of Hydrotest	UG-99(b) Note [36]	
Hydrotest Position	Vertical	
Projection of Nozzle from Vessel Top	0	mm.
Projection of Nozzle from Vessel Bottom	0	mm.
Minimum Design Metal Temperature	-45.0	°C
Type of Construction	Welded	
Special Service	None	
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	N	
Perform a Corroded Hydrotest	Y	
Is this a Heat Exchanger	No	
User Defined Hydro. Press. (Used if > 0)	0	bars
User defined MAWP	0	bars
User defined MAPnc	0	bars

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]	195	Km/hr
Surface Roughness Category		C: Open Terrain	
Importance Factor		1.0	
Type of Surface		Moderately Smooth	
Base Elevation		123000	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		1.500
Table Value Fa		1.000
Table Value Fv		1.300
Short Period Acceleration value Ss		1.163
Long Period Acceleration Value Sl		0.600
Moment Reduction Factor Tau		1.000
Force Modification Factor R		2.000
Site Class		C
Component Elevation Ratio	z/h	0.000
Amplification Factor	Ap	1.000
Force Factor		0.000
Consider Vertical Acceleration		No
Minimum Acceleration Multiplier		0.000
User Value of Sds (used if > 0)		0.000
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

Complete Listing of Vessel Elements and Details:

Element From Node	10	
Element To Node	20	
Element Type	Elliptical	
Description	HEAD 001	
Distance "FROM" to "TO"	50	mm.
Inside Diameter	1800	mm.
Element Thickness	18.5	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	22	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	23	bars
Design Temperature Internal Pressure	125	°C
Design External Pressure	1.1	bars
Design Temperature External Pressure	125	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	[Impact Tested]
Allowable Stress, Ambient	137.9	N./mm^2
Allowable Stress, Operating	137.9	N./mm^2
Allowable Stress, Hydrotest	235.8	N./mm^2

Material Density	0.00775	kg./cm^3
P Number Thickness	29.997	mm.
Yield Stress, Operating	235.2	N./mm^2
UCS-66 Chart Curve Designation	Impact Tested	
External Pressure Chart Name	CS-2	
UNS Number	K02700	
Product Form	Plate	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	0.85	
Elliptical Head Factor	2.0	
Weld is pre-Heated	No	
Element From Node	10	
Detail Type	Liquid	
Detail ID	VAM + HQ	
Dist. from "FROM" Node / Offset dist	-450	mm.
Height/Length of Liquid	500	mm.
Liquid Density	0	kg./cm^3
Element From Node	10	
Detail Type	Insulation	
Detail ID	Ins: 20	
Dist. from "FROM" Node / Offset dist	-450	mm.
Height/Length of Insulation	500	mm.
Thickness of Insulation	100	mm.
Density	0.00012	kg./cm^3
Element From Node	10	
Detail Type	Nozzle	
Detail ID	D	
Dist. from "FROM" Node / Offset dist	0	mm.
Nozzle Diameter	2	in.
Nozzle Schedule	160	
Nozzle Class	300	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.1909	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6 [Impact Tested]	
Element From Node	10	
Detail Type	Nozzle	
Detail ID	LG1	
Dist. from "FROM" Node / Offset dist	500	mm.
Nozzle Diameter	2	in.
Nozzle Schedule	None	
Nozzle Class	300	
Layout Angle	180.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.09794	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-350 LF2 [Impact Tested]	
Element From Node	10	
Detail Type	Nozzle	
Detail ID	LT2	
Dist. from "FROM" Node / Offset dist	500	mm.
Nozzle Diameter	2	in.
Nozzle Schedule	None	
Nozzle Class	300	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.09794	kN

Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-350 LF2 [Impact Tested]	

Element From Node	20	
Element To Node	30	
Element Type	Cylinder	
Description	SHELL	
Distance "FROM" to "TO"	2900	mm.
Inside Diameter	1800	mm.
Element Thickness	22	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	22	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	23	bars
Design Temperature Internal Pressure	125	°C
Design External Pressure	1.1	bars
Design Temperature External Pressure	125	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70 [Impact Tested]	
Efficiency, Longitudinal Seam	0.85	
Efficiency, Circumferential Seam	0.85	
Weld is pre-Heated	No	

Element From Node	20	
Detail Type	Liquid	
Detail ID	VAM + HQ	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	2900	mm.
Liquid Density	0	kg./cm^3

Element From Node	20	
Detail Type	Insulation	
Detail ID	Ins: 20	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	2900	mm.
Thickness of Insulation	100	mm.
Density	0.00012	kg./cm^3

Element From Node	20	
Detail Type	Nozzle	
Detail ID	A1	
Dist. from "FROM" Node / Offset dist	500	mm.
Nozzle Diameter	10	in.
Nozzle Schedule	80	
Nozzle Class	300	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	1.0482	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6 [Impact Tested]	

Element From Node	20	
Detail Type	Nozzle	
Detail ID	A2	
Dist. from "FROM" Node / Offset dist	1100	mm.
Nozzle Diameter	8	in.
Nozzle Schedule	80	
Nozzle Class	300	
Layout Angle	45.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.755	kN

Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6	[Impact Tested]
Element From Node	20	
Detail Type	Nozzle	
Detail ID	B	
Dist. from "FROM" Node / Offset dist	2250	mm.
Nozzle Diameter	12	in.
Nozzle Schedule	80	
Nozzle Class	300	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	1.4197	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6	[Impact Tested]
Element From Node	20	
Detail Type	Nozzle	
Detail ID	LG2	
Dist. from "FROM" Node / Offset dist	200	mm.
Nozzle Diameter	2	in.
Nozzle Schedule	None	
Nozzle Class	300	
Layout Angle	180.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.09794	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-350 LF2	[Impact Tested]
Element From Node	20	
Detail Type	Nozzle	
Detail ID	LT2	
Dist. from "FROM" Node / Offset dist	200	mm.
Nozzle Diameter	2	in.
Nozzle Schedule	None	
Nozzle Class	300	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.09794	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-350 LF2	[Impact Tested]
Element From Node	20	
Detail Type	Nozzle	
Detail ID	SV	
Dist. from "FROM" Node / Offset dist	1500	mm.
Nozzle Diameter	2	in.
Nozzle Schedule	None	
Nozzle Class	300	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.09794	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-350 LF2	[Impact Tested]
Element From Node	20	
Detail Type	Nozzle	
Detail ID	M2	
Dist. from "FROM" Node / Offset dist	2250	mm.
Nozzle Diameter	6	in.
Nozzle Schedule	80	
Nozzle Class	300	
Layout Angle	90.0	

Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.5268	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6 [Impact Tested]	
Element From Node	20	
Detail Type	Nozzle	
Detail ID	T1	
Dist. from "FROM" Node / Offset dist	700	mm.
Nozzle Diameter	1.5	in.
Nozzle Schedule	None	
Nozzle Class	300	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.07803	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-350 LF2 [Impact Tested]	
Element From Node	20	
Detail Type	Nozzle	
Detail ID	M1	
Dist. from "FROM" Node / Offset dist	700	mm.
Nozzle Diameter	20	in.
Nozzle Schedule	None	
Nozzle Class	300	
Layout Angle	0.0	
Blind Flange (Y/N)	Y	
Weight of Nozzle (Used if > 0)	5.2309	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-516 70 [Impact Tested]	
Element From Node	20	
Detail Type	Leg	
Detail ID	LEGS	
Dist. from "FROM" Node / Offset dist	300	mm.
Diameter at Leg Centerline	1844	mm.
Leg Orientation	1	
Number of Legs	4	

Element From Node	30	
Element To Node	40	
Element Type	Elliptical	
Description	HEAD 002	
Distance "FROM" to "TO"	50	mm.
Inside Diameter	1800	mm.
Element Thickness	18.5	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	22	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	23	bars
Design Temperature Internal Pressure	125	°C
Design External Pressure	1.1	bars
Design Temperature External Pressure	125	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70 [Impact Tested]	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	0.85	
Elliptical Head Factor	2.0	
Weld is pre-Heated	No	
Element From Node	30	

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no: K.O. Drum (D-PK6101-3)
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for K.O. Drum (D-PK6101-3)
Input Echo: Step: 1 8:44pm Dec 24,2021

Detail Type	Liquid	
Detail ID	VAM + HQ	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	500	mm.
Liquid Density	0	kg./cm^3
Element From Node	30	
Detail Type	Insulation	
Detail ID	Ins: 20	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	500	mm.
Thickness of Insulation	100	mm.
Density	0.00012	kg./cm^3
Element From Node	30	
Detail Type	Nozzle	
Detail ID	V	
Dist. from "FROM" Node / Offset dist	0	mm.
Nozzle Diameter	2	in.
Nozzle Schedule	160	
Nozzle Class	300	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.103	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6	[Impact Tested]

XY Coordinate Calculations:

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
HEAD 001		...	50	...	50
SHELL		...	2950	...	2900
HEAD 002		...	3000	...	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./mm^2
HEAD 001		23.002	22	3	1800	137.9
SHELL		23.002	22	3	1800	117.21
HEAD 002		23	22	3	1800	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.
HEAD 001		23	23.7308	28.2863	18.5	18.0219
SHELL		23	24.3523	28.2368	22	20.9324
HEAD 002		23	23.7328	28.2863	18.5	18.0206
Minimum			23.731	28.237		

MAWP: 23.176 bars, limited by: Nozzle Reinforcement.

Internal Pressure Calculation Results :

ASME Code, Section VIII Division 1, 2017

Elliptical Head From 10 To 20 SA-516 70 at 125 °C

HEAD 001

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
= (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
= (23*1806*0.996)/(2*137.9*1-0.2*23)
= 15.0219 + 3.0000 = 18.0219 mm.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.002 bars
= (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
= (2*137.9*1*15.5)/(0.996*1806+0.2*15.5)
= 23.733 - 0.002 = 23.731 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*18.5)/(1*1800+0.2*18.5)
= 28.286 bars

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(Kcor*D+0.2*t))/(2*E*t)
= (23*(0.996*1806+0.2*15.5))/(2*1*15.5)
= 133.654 N./mm^2

Straight Flange Required Thickness:
= (P*R)/(S*E-0.6*P) + c per UG-27 (c)(1)
= (23*903)/(137.9*1-0.6*23)+3
= 18.216 mm.

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.002 bars
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (137.9 * 1 * 19)/(903 + 0.6 * 19)
= 28.652 - 0.002 = 28.650 bars

Factor K, corroded condition [Kcor]:
= (2 + (Inside Diameter/(2 * Inside Head Depth))^2)/6
= (2 + (1806/(2 * 453))^2)/6
= 0.995592

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 5.205 %
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

Note: This Element/Detail was specified as being Impact Tested.

MDMT Calculations in the Head Straight Flange:

Note: This Element/Detail was specified as being Impact Tested.

Cylindrical Shell **From 20 To 30 SA-516 70 at 125 °C**

SHELL

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
= (23*903)/(137.9*0.85-0.6*23)
= 17.9324 + 3.0000 = 20.9324 mm.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.002 bars
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (137.9*0.85*19)/(903+0.6*19)
= 24.354 - 0.002 = 24.352 bars

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (137.9*0.85*22)/(900+0.6*22)
= 28.237 bars

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(R+0.6*t))/(E*t)
= (23*(903+0.6*19))/(0.85*19)
= 130.243 N./mm^2

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.207 %

Minimum Design Metal Temperature Results:

Note: This Element/Detail was specified as being Impact Tested.

Elliptical Head From 30 To 40 SA-516 70 at 125 °C

HEAD 002

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
= (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
= (23*1806*0.996)/(2*137.9*1-0.2*23)
= 15.0206 + 3.0000 = 18.0206 mm.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.000 bars
= (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
= (2*137.9*1*15.5)/(0.996*1806+0.2*15.5)
= 23.733 - 0.000 = 23.733 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*18.5)/(1*1800+0.2*18.5)
= 28.286 bars

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(Kcor*D+0.2*t))/(2*E*t)
= (23*(0.996*1806+0.2*15.5))/(2*1*15.5)
= 133.642 N./mm^2

Straight Flange Required Thickness:
= (P*R)/(S*E-0.6*P) + c per UG-27 (c)(1)
= (23*903)/(137.9*1-0.6*23)+3
= 18.214 mm.

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.000 bars
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (137.9 * 1 * 19)/(903 + 0.6 * 19)
= 28.652 - 0.000 = 28.652 bars

Factor K, corroded condition [Kcor]:
= (2 + (Inside Diameter/(2 * Inside Head Depth))^2)/6
= (2 + (1806/(2 * 453))^2)/6
= 0.995592

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 5.205 %
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

Note: This Element/Detail was specified as being Impact Tested.

MDMT Calculations in the Head Straight Flange:

Note: This Element/Detail was specified as being Impact Tested.

Hydrostatic Test Pressure Results:

Pressure per UG99b	= 1.30 * M.A.W.P. * Sa/S	30.129	bars
Pressure per UG99b[36]	= 1.30 * Design Pres * Sa/S	29.900	bars
Pressure per UG99c	= 1.30 * M.A.P. - Head(Hyd)	36.374	bars
Pressure per UG100	= 1.10 * M.A.W.P. * Sa/S	25.493	bars

```
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)    32.775  bars
Pressure per App 27-4  = 1.30 * M.A.W.P. * Sa/S         30.129  bars
```

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

```
  = Test Factor * Design Pressure * Stress Ratio
  = 1.3 * 23 * 1
  = 29.900 bars
```

Vertical 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./mm^2 & bars):

From To	Stress	Allowable	Ratio	Pressure
HEAD 001	176.0	235.8	0.746	30.28
SHELL	171.2	235.8	0.726	30.23
HEAD 002	174.0	235.8	0.738	29.95

Stress ratios for Nozzle and Pad Materials (N./mm^2):

Description	Pad/Nozzle	Ambient	Operating	Ratio
D	Nozzle	117.90	117.90	1.000
D	Pad	137.90	137.90	1.000
LG1	Nozzle	137.90	137.90	1.000
LT2	Nozzle	137.90	137.90	1.000
A1	Nozzle	117.90	117.90	1.000
A1	Pad	137.90	137.90	1.000
A2	Nozzle	117.90	117.90	1.000
A2	Pad	137.90	137.90	1.000
B	Nozzle	117.90	117.90	1.000
B	Pad	137.90	137.90	1.000
LG2	Nozzle	137.90	137.90	1.000
LT2	Nozzle	137.90	137.90	1.000
SV	Nozzle	137.90	137.90	1.000
M2	Nozzle	117.90	117.90	1.000
M2	Pad	137.90	137.90	1.000
T1	Nozzle	137.90	137.90	1.000
M1	Nozzle	137.90	137.90	1.000
M1	Pad	137.90	137.90	1.000
V	Nozzle	117.90	117.90	1.000
V	Pad	137.90	137.90	1.000
Minimum				1.000

Stress ratios for Pressurized Vessel Elements (N./mm^2):

Description	Ambient	Operating	Ratio
HEAD 001	137.90	137.90	1.000
SHELL	137.90	137.90	1.000
HEAD 002	137.90	137.90	1.000
Minimum			1.000

Hoop Stress in Nozzle Wall during Pressure Test (N./mm^2):

Description	Ambient	Operating	Ratio
D	18.45	217.19	0.085
LG1	8.14	223.40	0.036
LT2	8.14	223.40	0.036
A1	39.19	217.19	0.180
A2	39.47	217.19	0.182
B	38.41	217.19	0.177
LG2	8.12	223.40	0.036
LT2	8.12	223.40	0.036
SV	8.09	223.40	0.036
M2	37.06	217.19	0.171
T1	6.95	223.40	0.031
M1	39.12	235.80	0.166
V	18.25	217.19	0.084

Elements Suitable for Internal Pressure.

External Pressure Calculation Results :

External Pressure Calculations:

From	To	Section Length mm.	Outside Diameter mm.	Corroded Thickness mm.	Factor A	Factor B N./mm^2
10	20	No Calc	1837	15.5	0.0011719	90.0274
20	30	3300	1844	19	0.00075914	75.8969
30	40	No Calc	1837	15.5	0.0011719	90.0274

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	18.5	7.90534	1.1	8.43975
20	30	22	10.7157	1.1	10.4263
30	40	18.5	7.90534	1.1	8.43975
Minimum					8.440

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	3300	75873.1	No Calc	No Calc
30	40	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

ASME Code, Section VIII Division 1, 2017

Elliptical Head From 10 to 20 Ext. Chart: CS-2 at 125 °C

HEAD 001

Elastic Modulus from Chart: CS-2 at 125 °C : 0.200E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	D/t	Factor A	B
15.500	1837.00	118.52	0.0011719	90.03

EMAP = B/(K0*D/t) = 90.03/(0.9 *118.5) = 8.44 bars

Results for Required Thickness (Tca):

Tca	OD	D/t	Factor A	B
4.905	1837.00	374.49	0.0003709	37.08

EMAP = B/(K0*D/t) = 37.08/(0.9 *374.5) = 1.1 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)
  = (1.837*1806*0.996)/(2*137.9*1-0.2*1.837)
  = 1.1978 + 3.0000 = 4.1978 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*15.5)/(0.996*1806+0.2*15.5))/1.67
  = 14.211 bars
```

Maximum Allowable External Pressure [MAEP]:
```
  = min( MAEP, MAWP )
  = min( 8.44, 14.21 )
  = 8.440 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 125 °C**

SHELL

Elastic Modulus from Chart: CS-2 at 125 °C : 0.200E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):
```
     Tca          OD          SLEN         D/t         L/D    Factor A         B
  19.000     1844.00      3300.00      97.05     1.7896   0.0007591     75.90
 EMAP = (4*B)/(3*(D/t)) = (4*75.9 )/(3*97.05 ) = 10.43 bars
```

Results for Required Thickness (Tca):
```
     Tca          OD          SLEN         D/t         L/D    Factor A         B
   7.716     1844.00      3300.00     238.99     1.7896   0.0001972     19.72
 EMAP = (4*B)/(3*(D/t)) = (4*19.72 )/(3*239 ) = 1.1 bars
```

Results for Maximum Stiffened Length (Slen):
```
     Tca          OD          SLEN         D/t         L/D    Factor A         B
  19.000     1844.00     75873.15      97.05    41.1460   0.0001180     11.79
 EMAP = (4*B)/(3*(D/t)) = (4*11.79 )/(3*97.05 ) = 1.62 bars
```

Elliptical Head From 30 to 40 Ext. Chart: CS-2 at 125 °C

HEAD 002

Elastic Modulus from Chart: CS-2 at 125 °C : 0.200E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):
```
     Tca          OD          D/t     Factor A          B
  15.500     1837.00       118.52    0.0011719      90.03
 EMAP = B/(K0*D/t) = 90.03/(0.9 *118.5 ) = 8.44 bars
```

Results for Required Thickness (Tca):
```
     Tca          OD          D/t     Factor A          B
   4.905     1837.00       374.49    0.0003709      37.08
 EMAP = B/(K0*D/t) = 37.08/(0.9 *374.5 ) = 1.1 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)
= (1.837*1806*0.996)/(2*137.9*1-0.2*1.837)
= 1.1978 + 3.0000 = 4.1978 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*15.5)/(0.996*1806+0.2*15.5))/1.67
= 14.211 bars
```

Maximum Allowable External Pressure [MAEP]:

```
= min( MAEP, MAWP )
= min( 8.44, 14.21 )
= 8.440 bars
```

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

Element and Detail Weights:

From	To	Element Metal Wgt. kg.	Element ID Volume Cm3	Corroded Metal Wgt. kg.	Corroded ID Volume Cm3	Extra due Misc % kg.
10	20	726.27	890801	627.233	899312	...
20	30	2830.41	7380924	2448.47	7430211	...
30	40	726.27	890801	627.233	899312	...
Total		4282	9162526.00	3702	9228836.00	0

Weight of Details:

From	Type	Weight of Detail kg.	X Offset, Dtl. Cent. mm.	Y Offset, Dtl. Cent. mm.	Description
10	Liqd	5.16349	...	-225	VAM + HQ
10	Insl	64.819	...	-200	Ins: 20
10	Nozl	19.4686	...	-1057.08	D
10	Nozl	9.98809	-500	-524.166	LG1
10	Nozl	9.98809	...	-524.166	LT2
20	Liqd	42.7832	...	1450	VAM + HQ
20	Insl	212.781	...	1450	Ins: 20
20	Nozl	106.891	1036.53	500	A1
20	Nozl	76.9905	1009.54	1100	A2
20	Nozl	144.778	1061.92	2250	B
20	Nozl	9.98809	925.4	200	LG2
20	Nozl	9.98809	925.4	200	LT2
20	Nozl	9.98809	925.4	1500	SV
20	Nozl	53.7219	984.138	2250	M2
20	Nozl	7.95779	919.05	700	T1
20	Nozl	533.436	1154	700	M1
20	Legs	436.745	...	-600	LEGS
30	Liqd	5.16349	...	275	VAM + HQ
30	Insl	64.819	...	250	Ins: 20
30	Nozl	10.5041	...	600	V

Total Weight of Each Detail Type

Total Weight of Liquid	53.1
Total Weight of Insulation	342.4
Total Weight of Nozzles	1003.7
Total Weight of Legs	436.7
Sum of the Detail Weights	1836.0 kg.

Weight Summation: kg.

Fabricated	Shop Test	Shipping	Erected	Empty	Operating
4282.9	5723.4	4282.9	5723.4	4282.9	6065.8
...	9156.9	...	...	...	53.1
1003.7	...	1003.7	...	...	...
436.7	...	436.7	342.4	...	...
...	...	...	...	342.4	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	1003.7	...
...	...	...	...	436.7	...

5723.4	14880.3	5723.4	6065.8	6065.8	6118.9

Weight Summary

Fabricated Wt.	- Bare Weight W/O Removable Internals	5723.4 kg.
Shop Test Wt.	- Fabricated Weight + Water (Full)	14880.3 kg.
Shipping Wt.	- Fab. Wt + Rem. Intls.+ Shipping App.	5723.4 kg.
Erected Wt.	- Fab. Wt + Rem. Intls.+ Insul. (etc)	6065.8 kg.
Ope. Wt. no Liq	- Fab. Wt + Intls. + Details + Wghts.	6065.8 kg.
Operating Wt.	- Empty Wt + Operating Liq. Uncorroded	6118.9 kg.
Field Test Wt.	- Empty Weight + Water (Full)	14709.0 kg.
Mass of the Upper 1/3 of the Vertical Vessel		1812.0 kg.

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

Outside Surface Areas of Elements:

From	To	Surface Area cm^2
10	20	39755.7
20	30	168000
30	40	39755.7
Total		247511.203 cm^2

Element and Detail Weights:

From	To	Total Ele. Empty Wgt. kg.	Total. Ele. Oper. Wgt. kg.	Total. Ele. Hydro. Wgt. kg.	Total Dtl. Offset Mom. N-m	Oper. Wgt. No Liquid kg.
10	20	765.715	835.697	1630.26	48.9914	830.534
20	Legs	391.463	417.901	1142.14	1061.26	413.475
Legs	30	3392.68	3621.81	9898.53	9197.62	3583.45
30	40	736.774	806.757	1601.32	...	801.593

Cumulative Vessel Weight

From	To	Cumulative Ope Wgt. No Liquid kg.	Cumulative Oper. Wgt. kg.	Cumulative Hydro. Wgt. kg.
10	20	...	...	...
20	Legs	-830.534	-835.697	-1630.26
Legs	30	4385.04	4428.56	11499.8
30	40	801.593	806.757	1601.32

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

Cumulative Vessel Moment

From	To	Cumulative Empty Mom. N-m	Cumulative Oper. Mom. N-m	Cumulative Hydro. Mom. N-m

10	20	48.9914	48.9914	48.9914
20	Legs	1110.26	1110.26	1110.26
Legs	30	9197.62	9197.62	9197.62
30	40	...	...	...

Nozzle Flange MAWP Results:

Nozzle Description	Flange Rating Ope. bars	Ambient bars	Design Temp °C	Class	Grade/ Group	Equiv. Press	Max Pressure PVP	50%	DNV bars
D	45.8	51.1	125	300	GR 1.1	...	...	...	...
LG1	45.8	51.1	125	300	GR 1.1	...	...	...	...
LT2	45.8	51.1	125	300	GR 1.1	...	...	...	...
A1	45.8	51.1	125	300	GR 1.1	...	...	...	...
A2	45.8	51.1	125	300	GR 1.1	...	...	...	...
B	45.8	51.1	125	300	GR 1.1	...	...	...	...
LG2	45.8	51.1	125	300	GR 1.1	...	...	...	...
LT2	45.8	51.1	125	300	GR 1.1	...	...	...	...
SV	45.8	51.1	125	300	GR 1.1	...	...	...	...
M2	45.8	51.1	125	300	GR 1.1	...	...	...	...
T1	45.8	51.1	125	300	GR 1.1	...	...	...	...
M1	45.8	51.1	125	300	GR 1.1	...	...	...	...
V	45.8	51.1	125	300	GR 1.1	...	...	...	...
Min Rating	45.850	51.100 bars [for Core Elements]					0.000	0.000	0.000

Selected Method for Derating ANSI Flange MAWP: None Selected

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

The PVP Method is based on the paper PVP 2013-97814. PV Elite uses the maximum loads from each load category to determine ME and FE. In many cases, the computed maximum allowable pressure will be greater than the flange rating. In these cases, the minimum of the rating from the table and the PVP method will be used. SA-193 B8 Cl. 2 bolts or ones with higher allowable stresses at the specified bolt size shall be used. Note that ANSI pipe nominal sizes up to 24 inch (600mm) are addressed.

How the 50% Stress Method Works:
If the computed stress/allowable stress is < 0.5 on the pipe wall, then the allowable pressure is the table rating from the ANSI/ASME standard. If the stress ratio is >= 0.5, then the full equivalent pressure is subtracted from the flange rating.

The DNV Method:
minimum(table rating, 1.5 * Operating rating - equivalent pressure)

The Natural Frequencies for the vessel have been computed iteratively by solving a system of matrices. These matrices describe the mass and the stiffness of the vessel. This is the generalized eigenvalue/ eigenvector problem and is referenced in some mathematical texts.

The Natural Frequency for the Vessel (Empty.) is 23.7922 Hz.

The Natural Frequency for the Vessel (Ope...) is 23.68 Hz.

The Natural Frequency for the Vessel (Filled) is 14.9266 Hz.

Input Values:

Wind Design Code		ASCE-7 2010	
Wind Load Reduction Scale Factor		0.600	
Basic Wind Speed	[V]	195	Km/hr
Surface Roughness Category		C: Open Terrain	
Importance Factor		1.0	
Type of Surface		Moderately Smooth	
Base Elevation		123000	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*0.962)/(1+1.7*3.4*0.228)))
= min(0.85, 0.905 )
= 0.850
```

Natural Frequency of Vessel (Operating)		23.680 Hz
Natural Frequency of Vessel (Empty)		23.792 Hz
Natural Frequency of Vessel (Test)		14.927 Hz
Force Coefficient	[Cf]	0.513
Structure Height to Diameter ratio		1.809
Height to top of Structure		3568.500 mm.

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
= 354 + 123000 = 123354 mm.
= 404.7 ft. Imperial Units
```

Velocity Pressure coefficient evaluated at height z [Kz]:

```
Because z (404.7 ft.) > 15 ft.
= 2.01 * ( z / Zg ) 2 / Alpha
= 2.01 * ( 404.7/900 )2/9.5
= 1.699
```

Type of Hill: No Hill

Wind Directionality Factor [Kd]:

```
= 0.95 per Table 26.6-1
```

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

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

Velocity Pressure evaluated at height z, Imperial Units [qz]:
= max(16, 0.00256 * Kz * Kzt * Kd * V(mph)²)
= max(16, 0.00256 * 1.699 * 1 * 0.95 * 121.2²)
= 60.66 psf [296.2] Kgs/m^2

Force on the first element [F]:
= qz * G * Cf * WindArea
= 60.66 * 0.85 * 0.513 * 13.06
= 345.8 lbs. [1.538] kN

Element	Hgt (z) mm.	K1	K2	K3	Kz	Kzt	qz Kgs/m^2
HEAD 001	*******	0.000	0.000	0.000	1.699	1.000	296.157
SHELL	*******	0.000	0.000	0.000	1.703	1.000	296.960
HEAD 002	*******	0.000	0.000	0.000	1.708	1.000	297.813

Wind Vibration Calculations

This evaluation is based on work by Kanti Mahajan and Ed Zorilla

Nomenclature

Cf - Correction factor for natural frequency
D - Average internal diameter of vessel mm.
Df - Damping Factor < 0.75 Unstable, > 0.95 Stable
Dr - Average internal diameter of top half of vessel mm.
f - Natural frequency of vibration (Hertz)
f1 - Natural frequency of bare vessel based on a unit value of $(D/L^2)(10^4)$
L - Total height of structure mm.
Lc - Total length of conical section(s) of vessel mm.
tb - Uncorroded plate thickness at bottom of vessel mm.
V30 - Design Wind Speed provided by user Km/hr
Vc - Critical wind velocity Km/hr
Vw - Maximum wind speed at top of structure Km/hr
W - Total corroded weight of structure kN
Ws - Cor. vessel weight excl. weight of parts which do not effect stiff. kN
Z - Maximum amplitude of vibration at top of vessel mm.
Dl - Logarithmic decrement (taken as 0.03 for Welded Structures)
Vp - Vib. Chance, <= 0.000 (High); 0.000 < 0.000 (Probable)
P30 - wind pressure 30 feet above the base

Check other Conditions and Basic Assumptions:
#1 - Total Cone Length / Total Length < 0.5
0/3000 = 0

#2 - (D / L²) * 10^4 < 8.0 (English Units)
- (6.705/9.843²) * 10^4 = 692.2 [Geometry Violation]

Compute the vibration possibility. If Vp > 0.000 no chance. [Vp]:
= W / (L * Dr²)
= 54.31/(3000 * 1806²)

= 0.55508E-08

Since Vp is > 0.000 no further vibration analysis is required !

The Natural Frequency for the Vessel (Ope...) is 23.68 Hz.

Wind Load Calculation:

From	To	Wind Height mm.	Wind Diameter mm.	Wind Area cm^2	Wind Pressure Kgs/m^2	Element Wind Load kN
10	20	123354	2444.4	12136.4	296.157	0.92299
20	30	124950	2452.8	71131.2	296.96	5.42428
30	40	126664	2444.4	12136.4	297.813	0.92815

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		1.500
Table Value Fa		1.000
Table Value Fv		1.300
Short Period Acceleration value Ss		1.163
Long Period Acceleration Value Sl		0.600
Moment Reduction Factor Tau		1.000
Force Modification Factor R		2.000
Site Class		C
Component Elevation Ratio	z/h	0.000
Amplification Factor	Ap	1.000
Force Factor		0.000
Consider Vertical Acceleration		No
Minimum Acceleration Multiplier		0.000
User Value of Sds (used if > 0)		0.000

Seismic Analysis Results:

```
Sms = Fa * Ss = 1 * 1.163 = 1.163
Sm1 = Fv * S1 = 1.3 * 0.6 = 0.78
Sds = 2/3 * Sms = 2/3 * 1.163 = 0.775
Sd1 = 2/3 * Sm1 = 2/3 * 0.78 = 0.52
```

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

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

$= 0.020 * (16.08^{0.75})$

= 0.161 seconds

The Coefficient Cu from Table 12.8-1 is : 1.400

Fundamental Period (1/Frequency) [T]:

= (1/Natural Frequency) = (1/23.68)

= 0.042

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

= Minimum Value of (1.4 * 0.161, 0.0422) per 12.8.2

= 0.042

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 * 0.775 * 55.72 * 1.5
= 19.440 kN
```

```
Final Base Shear,      V = 13.61 kN
```

Distribute the Base shear force to each element according to the equations
Fx = Cvx * V (eqn. 12.8-11) and the vertical distribution factor
Cvx = $Wx*hx^{k}/($ Sum of $Wi*hi^{k}$) and k is an exponent which is related
to the period of Vibration.

In this case, the value of k was 1

The Natural Frequency for the Vessel (Ope...) is 23.68 Hz.

Earthquake Load Calculation:

From	To	Earthquake Height mm.	Earthquake Weight kN	Element Ope Load kN	Element Emp Load kN
10	20	25	8.19485	0.033279	0.030502
20	Legs	350	4.09793	0.23298	0.21831
Legs	30	1650	35.5154	9.519	8.91968
30	40	2975	7.91105	3.82306	3.49256

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.

The following table is for the Operating Case.

Wind/Earthquake Shear, Bending:

From	To	Distance to Support mm.	Cumulative Wind Shear kN	Earthquake Shear kN	Wind Bending N-m	Earthquake Bending N-m
10	20	564.463	...	...	...	...
20	Legs	150	0.92299	0.033279	244.196	8.80465
Legs	30	1300	6.71428	13.3753	8378.97	23281.4
30	40	2864.46	0.92815	3.82306	245.561	1011.47

Note:
The Wind Shears/Moments and the Earthquake Shears/Moments calculated and printed in the Wind/Earthquake Shear and Bending report have been factored by the input Scalar/Load reductions factors of;
Wind: 0.600; Earthquake: 0.700.

Note:
Review the Vessel Design Summary for the cumulative shear force and bending moment on the support.

Wind Deflection Calculations:

The following table is for the Operating Case.

Wind Deflection:

From	To	Cumulative Wind Shear kN	Centroid Deflection mm.	Elem. End Deflection mm.	Elem. Ang. Rotation
10	20	...	0.53169	0.53169	0.00044281
20	Legs	0.92299	0.5317	0.53174	0.00044312
Legs	30	6.71428	0.53286	0.53466	0.00044427
30	40	0.92815	0.5347	0.53474	0.00044427

Critical Wind Velocity for Tower Vibration:

From	To	1st Crit. Wind Speed Km/hr	2nd Crit. Wind Speed Km/hr
10	20	1039.09	6494.34
20	30	1042.67	6516.66
30	40	1039.09	6494.34

Allowable deflection at the Tower Top (Ope)(6.000"/100ft. Criteria)
Allowable deflection : 15.000 Actual Deflection : 0.535 mm.

Longitudinal Stress Constants:

From	To	Metal Area New cm^2	Metal Area Corroded cm^2	Section Modulus New mm.³	Section Modulus Corroded mm.³
10	20	1056.9	886.976	47570540	40052732
20	30	1259.28	1089.35	56683988	49194728
30	40	1056.9	886.976	47570540	40052732

Longitudinal Allowable Stresses:

From	To	Tensile N./mm^2	Hydrotest Tensile N./mm^2	Compressive N./mm^2	Hydrotest Compressive N./mm^2
10	20	140.658	240.516	-125.926	-125.926
20	Legs	140.658	240.516	-130.886	-130.886
Legs	30	140.658	240.516	-130.886	-130.886
30	40	140.658	240.516	-125.926	-125.926

Longitudinal Stress Report

Note: Longitudinal Operating and Empty Stresses are computed in the corroded condition. Stresses due to loads in the hydrostatic test cases have also been computed in the corroded condition.

Longitudinal Pressure Stresses due to:

From	To	Longitudinal Stress Internal Pressure N./mm^2	Longitudinal Stress External Pressure N./mm^2	Longitudinal Stress Hydrotest Pressure N./mm^2
10	20	66.5406	-3.28711	86.5028
20	30	54.1984	-2.69689	70.4579
30	40	66.5406	-3.28711	86.5028

Longitudinal Stresses due to Weight Loads for these Conditions:

From	To	Wght. Str. Empty N./mm^2	Wght. Str. Operating N./mm^2	Wght. Str. Hydrotest N./mm^2	Wght. Str. Emp. Mom. N./mm^2	Wght. Str. Opr. Mom. N./mm^2
10	20	...	...	...	0.0012228	0.0012228
20	Legs	0.074769	0.075233	0.14676	0.022561	0.022561
Legs	30	-0.39476	-0.39436	-0.39476	0.1869	0.1869
30	40	-0.088628	-0.088628	-0.088628	...	...

Longitudinal Stresses due to Weight Loads and Bending for these Conditions:

From	To	Wght. Str. Hyd. Mom. N./mm^2	Bend. Str. Oper. Wind N./mm^2	Bend. Str. Oper. Equ. N./mm^2	Bend. Str. Hyd. Wind N./mm^2	Bend. Str. Hyd. Equ. N./mm^2
10	20	0.0012228	...	...	...	...
20	Legs	0.022561	0.0049623	0.00017892	0.0016375	...
Legs	30	0.1869	0.17027	0.4731	0.056188	...
30	40	...	0.006129	0.025245	0.0020226	...

Longitudinal Stresses due to these Conditions:

From	To	Vortex Shedding Operating Case N./mm^2	Vortex Shedding Empty Case N./mm^2	Vortex Shedding Test Case N./mm^2	Earthquake Empty Case N./mm^2
10	20	...	...	...	...
20	Legs	...	...	...	0.00016399
Legs	30	...	...	...	0.43809
30	40	...	...	...	0.023063

Longitudinal Stresses due to Applied Axial Forces:

From	To	Longitudinal Stress Y Forces Wind N./mm^2	Longitudinal Stress Y Forces Seismic N./mm^2
10	20	...	...
20	Legs	...	...

Legs	30	...	...
30	40	...	...

Longitudinal Stresses due to User Forces and Moments:

From	To	Wind For/Mom Corroded N./mm^2	Earthquake For/Mom Corroded N./mm^2	Wind For/Mom No Corrosion N./mm^2	Earthquake For/Mom No Corrosion N./mm^2
10	20	...	...	...	...
20	Legs	...	...	...	...
Legs	30	...	...	...	...
30	40	...	...	...	...

Stress Combination Load Cases for Vertical Vessels:

Load Case Definition Key

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

General Notes:

Case types HI and HE are in the Corroded condition.

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

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

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

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	140.66	-0.00	125.93	0.0000	0.0000
20	0.10	140.66		130.89	0.0007	
20		140.66	-0.75	130.89		0.0057
30		140.66	-0.09	125.93		0.0008

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	140.66	-0.00	125.93	0.0000	0.0000
20	0.10	140.66		130.89	0.0007	
20	0.23	140.66	-1.02	130.89	0.0016	0.0078
30		140.66	-0.11	125.93		0.0009

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

From	Tensile	All. Tens.	Comp.	All. Comp.	Tens.	Comp.

Node	Stress	Stress	Stress	Stress	Ratio	Ratio
10	0.00	140.66	-0.00	125.93	0.0000	0.0000
20	0.10	140.66		130.89	0.0007	
20		140.66	-0.75	130.89		0.0057
30		140.66	-0.09	125.93		0.0008

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	140.66	-0.00	125.93	0.0000	0.0000
20	0.10	140.66		130.89	0.0007	
20	0.27	140.66	-1.05	130.89	0.0019	0.0081
30		140.66	-0.11	125.93		0.0009

Analysis of Load Case 5 : NP+HW+HI

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	240.52	-0.00	125.93	0.0000	0.0000
20	0.17	240.52		130.89	0.0007	
20		240.52	-0.64	130.89		0.0049
30		240.52	-0.09	125.93		0.0007

Analysis of Load Case 6 : NP+HW+HE

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	240.52	-0.00	125.93	0.0000	0.0000
20	0.17	240.52		130.89	0.0007	
20		240.52	-0.58	130.89		0.0044
30		240.52	-0.09	125.93		0.0007

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	66.54	140.66		125.93	0.4731	
20	54.30	140.66		130.89	0.3861	
20	54.16	140.66		130.89	0.3851	
30	66.46	140.66		125.93	0.4725	

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	66.54	140.66		125.93	0.4731	
20	54.30	140.66		130.89	0.3860	
20	54.46	140.66		130.89	0.3872	
30	66.48	140.66		125.93	0.4726	

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		140.66	-3.29	125.93		0.0261
20		140.66	-2.65	130.89		0.0202
20		140.66	-3.45	130.89		0.0263
30		140.66	-3.38	125.93		0.0269

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		140.66	-3.29	125.93		0.0261
20		140.66	-2.64	130.89		0.0202
20		140.66	-3.75	130.89		0.0287
30		140.66	-3.40	125.93		0.0270

Analysis of Load Case 11 : HP+HW+HI

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	86.50	240.52		125.93	0.3597	
20	70.63	240.52		130.89	0.2937	
20	70.31	240.52		130.89	0.2923	
30	86.42	240.52		125.93	0.3593	

Analysis of Load Case 12 : HP+HW+HE

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	86.50	240.52		125.93	0.3597	
20	70.63	240.52		130.89	0.2936	
20	70.25	240.52		130.89	0.2921	
30	86.41	240.52		125.93	0.3593	

Analysis of Load Case 13 : IP+WE+EW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	66.54	140.66		125.93	0.4731	
20	54.30	140.66		130.89	0.3860	
20	53.99	140.66		130.89	0.3838	
30	66.45	140.66		125.93	0.4724	

Analysis of Load Case 14 : IP+WF+CW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	66.54	140.66		125.93	0.4731	
20	54.26	140.66		130.89	0.3858	
20	53.86	140.66		130.89	0.3829	
30	66.47	140.66		125.93	0.4725	

Analysis of Load Case 15 : IP+VO+OW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	66.54	140.66		125.93	0.4731	
20	54.30	140.66		130.89	0.3860	
20	53.99	140.66		130.89	0.3838	
30	66.45	140.66		125.93	0.4724	

Analysis of Load Case 16 : IP+VE+EW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	66.54	140.66		125.93	0.4731	
20	54.30	140.66		130.89	0.3860	
20	53.99	140.66		130.89	0.3838	
30	66.45	140.66		125.93	0.4724	

Analysis of Load Case 17 : NP+VO+OW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	140.66	-0.00	125.93	0.0000	0.0000
20	0.10	140.66		130.89	0.0007	
20		140.66	-0.58	130.89		0.0044
30		140.66	-0.09	125.93		0.0007

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	66.54	140.66		125.93	0.4731	
20	54.30	140.66		130.89	0.3860	
20	53.99	140.66		130.89	0.3838	

30	66.45	140.66		125.93	0.4724

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		140.66	-3.29	125.93		0.0261
20		140.66	-2.64	130.89		0.0202
20		140.66	-3.28	130.89		0.0250
30		140.66	-3.38	125.93		0.0268

Absolute Maximum of the all of the Stress Ratio's 0.4731

Governing Element: HEAD 001
Governing Load Case 7 : IP+OW+WI+FW+BW

Shop/Field Installation Options :

Insulation is installed in the Field.

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

Center of Gravity of Liquid	1500.000 mm.
Center of Gravity of Insulation	1500.000 mm.
Center of Gravity of Nozzles	1032.829 mm.
Center of Gravity of Legs	-550.000 mm.
Center of Gravity of Bare Shell New and Cold	1500.000 mm.
Center of Gravity of Bare Shell Corroded	1500.000 mm.
Vessel CG in the Operating Condition	1253.702 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition	1261.641 mm.
Vessel CG in the Test Condition	1408.321 mm.

RESULTS FOR LEGS : Operating Case Description: LEGS

Legs attached to: SHELL

Section Properties : Circular Steel Pipe: PIPE

USA AISC 1989 Steel Table

Overall Leg Length		1800.000	mm.
Effective Leg Length	Leglen	1500.000	mm.
Distance Leg Up Side of Vessel		300.000	mm.
Number of Legs	Nleg	4	
Cross Sectional Area for PIPE	Aleg	54.190	cm^2
Section Inertia (strong axis)		3017.292	cm**4
Section Inertia (weak axis)		3017.292	cm**4
Section Modulus (strong axis)		275457.688	mm.³
Section Modulus (weak axis)		275457.688	mm.³
Radius of Gyration (strong axis)		74.619	mm.
Radius of Gyration (weak axis)		74.619	mm.

Leg Orientation - Strong Axis

Overturning Moment at top of Legs		23281.4	N-m
Total Weight Load at top of Legs	W	55.7	kN
Total Shear force at top of Legs		13.6	kN
Additional force in Leg due to Bracing	Fadd	5.5	kN
Occasional Load Factor	Occfac	1.333	
Effective Leg End Condition Factor	k	1.000	
Pipe Leg Inside Diameter (Pid)		202.717	mm.
Pipe Leg Outside Diameter (Pod)		219.075	mm.

Note: The Legs Are Cross Braced
The Leg Shear Force includes Wind and Seismic Effects

Pad Width along Circumference	C11P	300.000	mm.
Pad Length along Vessel Axis	C22P	400.000	mm.
Pad Thickness	Tpad	15.000	mm.

Maximum Shear at top of one Leg [Vleg]:
= (max(Wind, Seismic) + applied forces)(Imax / Itot)
= (13.61)(3017/12069)
= 3.40 kN

Axial Compression, Leg furthest from the Neutral Axis [Sma]:
= W/Nleg + (Mleg/(Nlegm*Rn))/Aleg
= 55722/4 + (23272148/(2 * 922))/5419
= 4.90 N./mm^2

Axial Compression, Leg closest to the Neutral Axis [Sva]:
= (W / Nleg + Fadd) / Aleg
= (55.72/4 + 5.535)/54.19
= 3.59 N./mm^2

Allowable Comp. for the Selected Leg (KL/r < Cc) [Sa]:
= Occfac * (1-(kl/r)²/(2*Cc²))*Fy /
(5/3+3*(Kl/r)/(8*Cc)-(Kl/r³)/(8*Cc³)
= 1.333 * (1-(20.1)²/(2 * 127.2²)) * 248.2/
(5/3+3*(20.1)/(8* 127.2)-(20.1³)/(8* 127.2³)
= 189.37 N./mm^2

Bending at the Bottom of the Leg closest to the N.A. [S]:

```
  = ( Vleg * Leglen / Smdsa )
  = ( 3.402 * 1500/275458 )
  = 0 since the legs are Cross Braced
```

Allowable Bending Stress[Sb]:

```
  = ( 0.6 * Fy * Occfac )
  = ( 0.6 * 248.2 * 1.333 )
  = 198.53 N./mm^2
```

AISC Unity Check [Sc](must be < or = to 1.00) :

```
  = (Sma/Sa)+(0.85*S)/((1-Sma/Spex)*Sb)
  = (4.9/189.4 )+( 0.85 *0 )/(( 1 -4.9/3455 ) *198.5 )
  = 0.0259
```

Bolting Size Requirement for Leg Baseplates :

Baseplate Material		SA-516 70	
Baseplate Allowable Stress	SBA	137.90	N./mm^2
Baseplate Length	B	350.0000	mm.
Baseplate Width	D	350.0000	mm.
Baseplate Thickness	BTHK	35.0000	mm.
Leg Dimension Along Baseplate Length	d	219.0750	mm.
Leg Dimension Along Baseplate Width	b	219.0750	mm.
Dist. from the Leg Edge to Bolt Hole Center	z	25.0000	mm.
Bolt Material		SA-193 B7	
Bolt Allowable Stress	STBA	172.38	N./mm^2
Anchor Bolt Nominal Diameter	BOD	30.0000	mm.
Number of Anchor Bolts in Tension per Leg	NB	2	
Total Number of Anchors Bolt per Leg	NBT	4	
Ultimate 28-day Concrete Strength	FCPRIME	20.685	N./mm^2

LEG BASEPLATE and BOLTING Analysis, including Moments

Pipe Leg

Base Plate Available Area (AA):

```
    = B * D
    = 350 * 350
    = 1225.00  cm^2
```

Clearance Between The Bolt And The Leg Edge (BCL):

```
    = z - BOD / 2
    = 25 - 30/2
    = 10.00  mm.
```

Moment at Baseplate (MOMENT):

```
    = Vleg * Lleg
    = 3.402 * 1800
    = 6126.23  N-m
```

Axial Load on the baseplate (P):

```
    = Operating Weight per leg  (as Seismic + Operating case is controlling)
    = 13.93  kN
```

Eccentricity (e):

```
    = MOMENT * Conv_Factor / P
    = 6126 *999.68/13.93
    = 439.61 mm. > D/6 [Plate Uplift Condition]

 a  = (MAX[B,D] - 0.707 * Pod) / 2
```

```
    = (350 - 0.707 * 219.1 )/2
    = 97.56  mm.
```

Modular Ratio Of Steel/Concrete (n):

```
    = ES / EC
    = 203402/21526
    = 9.45

 F  = 0.5 * d + z
    = 0.5 * 219.1 + 25
    = 134.54  mm.

 K1 = 3.0 (e - 0.5*D)
    = 3.0 (439.6 - 0.5*350 )
    = 793.84

 K2 = 6 * n * Ast / B * (F + e)
    = 6 * 9.449 * 10.06/350 * (134.5 + 439.6 )
    = 935.54

 K3 = -K2 * (0.5 * D + F)
    = -935.5 * (0.5 * 350 + 134.5 )
    = -289585.77
```

Solving For The Effective Bearing Length Using Iteration:

```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + 31.25 * Y² + 145 * Y - 1767 = 0
 Y  = 133.34  mm.

 NUM = (D / 2 - Y / 3 - e)
     = (350/2 - 133.3/3 - 439.6 )
     = -309.06

 DENOM = (D / 2 - Y / 3 + F)
       = (350/2 - 133.3/3 + 134.5 )
       = 265.09
```

Total Bolt Tension Force (T):

```
    = - P * NUM / DENOM
    = - 13.93 * -309.1/265.1
    = 16.24  kN
```

Overturning Moment Due To Bolt In Tension (Mt):

```
    = T * (0.5 * D + F - Y)
    = 16.24 * (0.5 * 350 + 134.5 - 133.3 )
    = 2862.69  N-m
```

Bearing Pressure (FC):

```
    = 2 * (P + T) / (Y * B)
    = 2 * (13.93 + 16.24 )/(133.3 * 350 )
    = 12.93 bars [ <= FCPRIME ( 206.84)]
```

Equivalent Bearing Pressure (f1):

```
    = FC * (Y - a) / Y
    = 12.93 * (133.3 - 97.56 )/133.3
    = 3.47  bars
```

Overturning Moment Due To Bearing Pressure (Mc):

```
    = (a² * B / 6) * (f1 + 2 * FC)
    = (97.56² * 350/6) * (3.47 + 2 * 12.93 )
    = 1628.94  N-m
```

The Baseplate Required Thickness (TREQ):

```
    = (6 * MAX(Mt,Mc) / (B * 1.5 * SBA))½
    = (6 * 2863/(350 * 206.9 ))½
    = 15.40  mm.
```

Required bolt area (ABREQM): per D. Moss

```
    = T / STBA
    = 16.24/172.4
    = 0.9422 cm^2 [ < Ast ( 10.06) --> PASSED]
```

Distance from Top of Legs to Vessel CG (CD_DIST):

```
    = 903.7 mm.
```

Total Overturning Moment at Baseplate (Mbb):

```
    = ( Mleg / max([CD_DIST], minDist) )* ( CD_DIST + Lleg )
    = ( 23281/max( 903.7, 38.1 ) ) * ( 903.7 + 1800 )
    = 69653.50  N-m
```

Required Total Bolt Area per Leg (ABREQB): per H. Bednar

```
    = (1 / (Nleg * STBA)) * ((4 * Mbb / (Rn * 2) ) - W )
    = (1/(4 * 172.4 )) * ((4 * 69654/(1844 )) - 55.72 )
    = 1.3824 cm^2
```

Available Total Bolt Corr. Area per Leg (ABAVL):

```
    = As * NBT
    = 5.03 * 4
    = 20.1186 cm^2 [ > ABREQB ( 1.38) --> PASSED]
```

Summary of Results:

		Actual	Required	Pass/Fail
Baseplate Thickness	(mm.):	35.000	15.400	Pass
Bolt Root Area (Bednar)	(cm^2):	20.12	1.38	Pass
Bolt Root Area (D. Moss)	(cm^2):	10.06	0.94	Pass

Note: The required thickness calculation is performed based on:
Beam leg analysis per Moss.
Even number of bolts installed only on the B dimension sides

RESULTS FOR LEGS : HydroTest Case Description: LEGS

Legs attached to: SHELL

Section Properties : Circular Steel Pipe: PIPE

USA AISC 1989 Steel Table

Overall Leg Length		1800.000	mm.
Effective Leg Length	Leglen	1500.000	mm.
Distance Leg Up Side of Vessel		300.000	mm.
Number of Legs	Nleg	4	
Cross Sectional Area for PIPE	Aleg	54.190	cm^2
Section Inertia (strong axis)		3017.292	cm**4
Section Inertia (weak axis)		3017.292	cm**4
Section Modulus (strong axis)		275457.688	mm.³
Section Modulus (weak axis)		275457.688	mm.³
Radius of Gyration (strong axis)		74.619	mm.
Radius of Gyration (weak axis)		74.619	mm.

Leg Orientation - Strong Axis

Overturning Moment at top of Legs		2765.1	N-m
Total Weight Load at top of Legs	W	141.6	kN
Total Shear force at top of Legs		2.4	kN
Additional force in Leg due to Bracing	Fadd	1.0	kN
Occasional Load Factor	Occfac	1.333	
Effective Leg End Condition Factor	k	1.000	
Pipe Leg Inside Diameter (Pid)		202.717	mm.
Pipe Leg Outside Diameter (Pod)		219.075	mm.

Note: The Legs Are Cross Braced
The Leg Shear Force includes Wind and Seismic Effects

Pad Width along Circumference	C11P	300.000	mm.
Pad Length along Vessel Axis	C22P	400.000	mm.
Pad Thickness	Tpad	15.000	mm.

Maximum Shear at top of one Leg [Vleg]:
= (max(Wind, Seismic) + applied forces)(Imax / Itot)
= (2.401)(3017/12069)
= 0.60 kN

Axial Compression, Leg furthest from the Neutral Axis [Sma]:
= W/Nleg + (Mleg/(Nlegm*Rn))/Aleg
= 141641/4 + (2763959/(2 * 922))/5419
= 6.81 N./mm^2

Axial Compression, Leg closest to the Neutral Axis [Sva]:
= (W / Nleg + Fadd) / Aleg
= (141.6/4 + 0.976)/54.19
= 6.71 N./mm^2

Allowable Comp. for the Selected Leg (KL/r < Cc) [Sa]:
= Occfac * (1-(kl/r)²/(2*Cc²))*Fy /
(5/3+3*(Kl/r)/(8*Cc)-(Kl/r³)/(8*Cc³)
= 1.333 * (1-(20.1)²/(2 * 127.2²)) * 248.2/
(5/3+3*(20.1)/(8* 127.2)-(20.1³)/(8* 127.2³)
= 189.37 N./mm^2

Bending at the Bottom of the Leg closest to the N.A. [S]:

```
  = ( Vleg * Leglen / Smdsa )
  = ( 0.6 * 1500/275458 )
  = 0 since the legs are Cross Braced
```

Allowable Bending Stress[Sb]:
```
  = ( 0.6 * Fy * Occfac )
  = ( 0.6 * 248.2 * 1.333 )
  = 198.53 N./mm^2
```

AISC Unity Check [Sc](must be < or = to 1.00) :
```
  = (Sma/Sa)+(0.85*S)/((1-Sma/Spex)*Sb)
  = (6.811/189.4 )+( 0.85 *0 )/(( 1 -6.811/3455 ) *198.5 )
  = 0.0360
```

Bolting Size Requirement for Leg Baseplates :

Baseplate Material		SA-516 70	
Baseplate Allowable Stress	SBA	137.90	N./mm^2
Baseplate Length	B	350.0000	mm.
Baseplate Width	D	350.0000	mm.
Baseplate Thickness	BTHK	35.0000	mm.
Leg Dimension Along Baseplate Length	d	219.0750	mm.
Leg Dimension Along Baseplate Width	b	219.0750	mm.
Dist. from the Leg Edge to Bolt Hole Center	z	25.0000	mm.
Bolt Material		SA-193 B7	
Bolt Allowable Stress	STBA	172.38	N./mm^2
Anchor Bolt Nominal Diameter	BOD	30.0000	mm.
Number of Anchor Bolts in Tension per Leg	NB	2	
Total Number of Anchors Bolt per Leg	NBT	4	
Ultimate 28-day Concrete Strength	FCPRIME	20.685	N./mm^2

LEG BASEPLATE and BOLTING Analysis, including Moments

Pipe Leg

Base Plate Available Area (AA):
```
    = B * D
    = 350 * 350
    = 1225.00  cm^2
```

Clearance Between The Bolt And The Leg Edge (BCL):
```
    = z - BOD / 2
    = 25 - 30/2
    = 10.00  mm.
```

Moment at Baseplate (MOMENT):
```
    = Vleg * Lleg
    = 0.6 * 1800
    = 1080.84  N-m
```

Axial Load on the baseplate (P):
```
    = Operating Weight per leg  (as Seismic + Operating case is controlling)
    = 13.93  kN
```

Eccentricity (e):
```
    = MOMENT * Conv_Factor / P
    = 1081 *999.68/13.93
    = 77.56 mm. > D/6 [Plate Uplift Condition]

 a  = (MAX[B,D] - 0.707 * Pod) / 2
```

```
    = (350 - 0.707 * 219.1 )/2
    = 97.56  mm.
```

Modular Ratio Of Steel/Concrete (n):

```
    = ES / EC
    = 203402/21526
    = 9.45

 F  = 0.5 * d + z
    = 0.5 * 219.1 + 25
    = 134.54  mm.

 K1 = 3.0 (e - 0.5*D)
    = 3.0 (77.56 - 0.5*350 )
    = -292.32

 K2 = 6 * n * Ast / B * (F + e)
    = 6 * 9.449 * 10.06/350 * (134.5 + 77.56 )
    = 345.60

 K3 = -K2 * (0.5 * D + F)
    = -345.6 * (0.5 * 350 + 134.5 )
    = -106976.09
```

Solving For The Effective Bearing Length Using Iteration:

```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + -11.51 * Y² + 53.57 * Y - 652.8 = 0
 Y  = 297.16  mm.

 NUM = (D / 2 - Y / 3 - e)
     = (350/2 - 297.2/3 - 77.56 )
     = -1.61

 DENOM = (D / 2 - Y / 3 + F)
       = (350/2 - 297.2/3 + 134.5 )
       = 210.48
```

Total Bolt Tension Force (T):

```
    = - P * NUM / DENOM
    = - 13.93 * -1.614/210.5
    = 0.11  kN
```

Overturning Moment Due To Bolt In Tension (Mt):

```
    = T * (0.5 * D + F - Y)
    = 0.107 * (0.5 * 350 + 134.5 - 297.2 )
    = 1.32  N-m
```

Bearing Pressure (FC):

```
    = 2 * (P + T) / (Y * B)
    = 2 * (13.93 + 0.107 )/(297.2 * 350 )
    = 2.70 bars [ <= FCPRIME ( 206.84)]
```

Equivalent Bearing Pressure (f1):

```
    = FC * (Y - a) / Y
    = 2.699 * (297.2 - 97.56 )/297.2
    = 1.81  bars
```

Overturning Moment Due To Bearing Pressure (Mc):

```
    = (a² * B / 6) * (f1 + 2 * FC)
    = (97.56² * 350/6) * (1.813 + 2 * 2.699 )
    = 400.53  N-m
```

The Baseplate Required Thickness (TREQ):

```
    = (6 * MAX(Mt,Mc) / (B * 1.5 * SBA))½
    = (6 * 400.5/(350 * 206.9 ))½
    = 5.76  mm.
```

Required bolt area (ABREQM): per D. Moss

```
    = T / STBA
    = 0.107/172.4
    = 0.0062 cm^2 [ < Ast ( 10.06) --> PASSED]
```

Distance from Top of Legs to Vessel CG (CD_DIST):

```
    = 1058 mm.
```

Total Overturning Moment at Baseplate (Mbb):

```
    = ( Mleg / max([CD_DIST], minDist) )* ( CD_DIST + Lleg )
    = ( 2765/max( 1058, 38.1 ) ) * ( 1058 + 1800 )
    = 7467.90  N-m
```

Required Total Bolt Area per Leg (ABREQB): per H. Bednar

```
    = (1 / (Nleg * STBA)) * ((4 * Mbb / (Rn * 2) ) - W )
    = (1/(4 * 172.4 )) * ((4 * 7468/(1844 )) - 55.72 )
    = -0.5733 cm^2 --> (No tension in bolts)
```

Summary of Results:

		Actual	Required	Pass/Fail
Baseplate Thickness	(mm.):	35.000	5.760	Pass
Bolt Root Area (D. Moss)	(cm^2):	10.06	0.01	Pass

Note: The required thickness calculation is performed based on:
Beam leg analysis per Moss.
Even number of bolts installed only on the B dimension sides

Nozzle Calculation Summary:

Description	MAWP bars	Ext	MAPNC bars	UG-45	[tr] mm.	Weld Path	Areas or Stresses
D	23.18	OK	...	OK	6.42	OK	Passed
LG1	23.73	OK	...	OK	7.80	OK	Passed
LG1	23.73	OK	...	OK	7.80	OK	Passed
LT2	23.73	OK	...	OK	7.80	OK	Passed
LT2	23.73	OK	...	OK	7.80	OK	Passed
A1	23.32	OK	...	OK	11.10	OK	Passed
A2	23.66	OK	...	OK	10.16	OK	Passed
B	23.50	OK	...	OK	11.33	OK	Passed
LG2	24.35	OK	...	OK	7.80	OK	Passed
LT2	24.35	OK	...	OK	7.80	OK	Passed
SV	24.35	OK	...	OK	7.80	OK	Passed
M2	24.35	OK	...	OK	9.22	OK	Passed
T1	24.35	OK	...	OK	7.52	OK	Passed
M1	24.35	OK	...	...		OK	Passed
V	23.18	OK	...	OK	6.42	OK	Passed

MAWP Summary:

Minimum MAWP Nozzles	:	23.176	Nozzle : D
Minimum MAWP Shells/Flanges	:	23.731	Element : HEAD 001
Minimum MAPnc Shells/Flanges	:	28.237	Element : SHELL
Computed Vessel M.A.W.P.	:	23.176	bars

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

Warning: A Nozzle Reinforcement is governing the MAWP of this Vessel.

Check the Spatial Relationship between the Nozzles

From Node	Nozzle Description	Y Coordinate mm.	Layout Angle deg	Dia. Limit mm.
10	D	0.000	0.000	102.068
10	LG1	0.000	180.000	115.000
10	LT2	0.000	270.000	115.000
20	A1	550.000	90.000	505.293
20	A2	1150.000	45.000	405.700
20	B	2300.000	270.000	598.626
20	LG2	250.000	180.000	122.000
20	LT2	250.000	270.000	122.000
20	SV	1550.000	0.000	122.000
20	M2	2300.000	90.000	310.145
20	T1	750.000	270.000	108.000
20	M1	750.000	0.000	940.000
30	V	0.000	0.000	102.068

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

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

INPUT VALUES, Nozzle Description: D From : 10

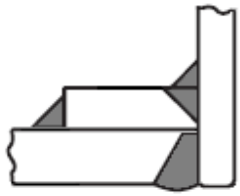
Pressure for Reinforcement Calculations	P	23.002	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Elliptical Head	D	1800.00	mm.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	18.5000	mm.
Head Internal Corrosion Allowance	c	3.0000	mm.
Head External Corrosion Allowance	co	0.0000	mm.
Distance from Head Centerline	L1	0.0000	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type		Smls. & wld. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
Diameter Basis (for tr calc only)		OD	
Layout Angle		0.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.5000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
Diameter of Pad along vessel surface	Dp	190.0000	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	10.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		64.8375	mm.
Class of attached Flange		300	
Grade of attached Flange		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: D

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation	2.375	in.
Actual Thickness Used in Calculation	0.301	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)
= (23*0.897*1806)/(2 *137.9*1-0.2*23)
= 13.5366 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)
= (23*30.16)/(117.9*1+0.4*23)
= 0.5839 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.3261 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	102.0684	mm.
Parallel to Vessel Wall, opening length	d	51.0342	mm.
Normal to Vessel Wall (Thickness Limit), pad side	Tlwp	21.6135	mm.

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

Weld Strength Reduction Factor [fr1]:
= min(1, Sn/Sv)
= min(1, 117.9/137.9)
= 0.855

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 117.9/137.9)
= 0.855

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( 0.855, 1 )
  = 0.855
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.091	1.285	NA
Area in Shell	A1	0.976	5.264	NA
Area in Nozzle Wall	A2	1.501	1.596	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.547	0.547	NA
Area in Element	A5	4.174	4.174	NA
TOTAL AREA AVAILABLE	Atot	7.198	11.582	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Insufficient.
The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	100.9934	10.0000	mm.
Based on given Pad Diameter:	190.0000	9.7425	mm.
Based on the Estimated Diameter Limit:	100.4809	10.1276	mm.

Area Required [A]:

```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (51.03*13.54*1+2*4.645*13.54*1*(1-0.855))
  = 7.091 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 )
  = 51.03 ( 1 * 15.5 - 1 * 13.54 ) - 2 * 4.645
    ( 1 * 15.5 - 1 * 13.54 ) * ( 1 - 0.855 )
  = 0.976 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 21.61 ) * ( 4.645 - 0.584 ) * 0.855
  = 1.501 cm^2
```

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

```
  = Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
  = 8² * 0.855 + (0 )² * 0.855 + 0² * 1
  = 0.547 cm^2
```

Area Available in Element [A5]:

```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 102.1 - 60.33 ) * 10 * 1
  = 4.174 cm^2
```

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

```
Wall Thickness for Internal/External pressures      ta = 3.5839 mm.
Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 18.0219 mm.
Wall Thickness                tb1 = max(trb1, tr16b) = 18.0219 mm.
Wall Thickness, shell/head, external pressure     trb2 = 3.7172 mm.
Wall Thickness                tb2 = max(trb2, tr16b) = 4.5000 mm.
```

Wall Thickness per table UG-45 tb3 = 6.4200 mm.

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[6.42, max(18.02, 4.5)]
= 6.4200 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(3.584, 6.42)
= 6.4200 mm.

Available Nozzle Neck Thickness = 7.6454 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

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

Impact Test Temperature provided per Specification -46 °C

Calculated Minimum Design Metal Temperature -104 °C

Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :

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

Impact Test Temperature provided per Specification -46 °C

Calculated Minimum Design Metal Temperature -104 °C

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

Govrn. thk, tg = 7.645, tr = 0.584, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.126, Temp. Reduction = 78 °C

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

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

Govrn. thk, tg = 10, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.873, Temp. Reduction = 7 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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

Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :

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

Impact Test Temperature provided per Specification -46 °C

Calculated Minimum Design Metal Temperature -104 °C

Governing MDMT of the Nozzle : -104 °C
Governing MDMT of the Reinforcement Pad : -48 °C
Governing MDMT of all the sub-joints of this Junction : -48 °C

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ANSI B16.5/47 flange per Matl. Specification       -18 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)           -48 °C
Flange MDMT with Temp reduction per UCS-66(i)(3)           -96 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
```
Design Pressure/Ambient Rating = 23.00/51.10 = 0.450
```

Note:
Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.

Weld Size Calculations, Description: D

```
Intermediate Calc. for nozzle/shell Welds   Tmin      4.6454  mm.
Intermediate Calc. for pad/shell Welds   TminPad     10.0000  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	3.2518 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.
Pad Weld	5.0000 = 0.5*TminPad	7.0700 = 0.7 * Wp mm.

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

Weld Load [W]:
```
= max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max( 0, (7.091 - 0.976 + 2 * 4.645 * 0.855 *
  (1 * 15.5 - 13.54 ) )137.9 )
= 86.47 kN
```

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

Weld Load [W1]:
```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 1.501 + 4.174 + 0.547 - 0 * 0.855 ) * 137.9
= 85.80 kN
```

Weld Load [W2]:
```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 1.501 + 0 + 0.547 + ( 1.231 ) ) * 137.9
= 45.22 kN
```

Weld Load [W3]:
```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 1.501 + 0 + 0.547 + 4.174 + ( 1.231 ) ) * 137.9
= 102.78 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.142/2.0 ) * 60.33 * 8 * 0.49 * 117.9
= 44. kN
```

Shear, Pad Element Weld [Spew]:
```
= (pi/2) * DP * WP * 0.49 * SEW
= ( 3.142/2.0 ) * 190 * 10 * 0.49 * 137.9
= 202. kN
```

Shear, Nozzle Wall [Snw]:
```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
```

```
  = (3.142 * 27.84 ) * ( 7.645 - 3 ) * 0.7 * 117.9
  = 34. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.142/2 ) * 60.33 * 10 * 0.74 * 137.9
  = 97. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.142/2.0 ) * 60.33 * ( 18.5 - 3 ) * 0.74 * 137.9
  = 150. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 201.6 + 33.53 ) = 235.2 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 43.79 + 96.69 + 149.9 + 0 ) = 290.3 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 201.6 + 149.9 + 0 ) = 351.5 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 235 kN , must exceed W = 86 kN  or W1 = 85 kN
 Path 2-2 = 290 kN , must exceed W = 86 kN  or W2 = 45 kN
 Path 3-3 = 351 kN , must exceed W = 86 kN  or W3 = 102 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case       23.178  bars

 Nozzle is O.K. for the External Pressure                1.100  bars
```

The Drop for this Nozzle is : 0.2783 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 218.7783 mm.

INPUT VALUES, Nozzle Description: LG1 From : 10

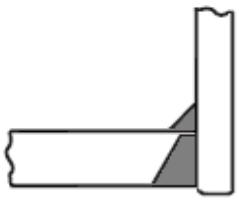
Pressure for Reinforcement Calculations	P	23.002	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Elliptical Head	D	1800.00	mm.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	18.5000	mm.
Head Internal Corrosion Allowance	c	3.0000	mm.
Head External Corrosion Allowance	co	0.0000	mm.
Distance from Head Centerline	L1	500.0000	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm^2
Allowable Stress At Ambient	Sna	137.90	N./mm^2
Diameter Basis (for tr calc only)		ID	
Layout Angle		180.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.5000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		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 in the Meridional direction.

Reinforcement CALCULATION, Description: LG1

ASME Code, Section VIII, Div. 1, 2017, 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 Elliptical Head, Tr [Int. Press]
= (P*K1*D))/(2*Sv*E-0.2*P) per UG-37(a)(3)
= (23*0.897*1806)/(2 *137.9*1-0.2*23)
= 13.5366 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)
= (23*28.4)/(137.9*1-0.6*23)
= 0.4785 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.3963 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	119.7360	mm.
Parallel to Vessel Wall, opening length	d	59.8680	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	34.0000	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, 1)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	8.104	1.468	NA

Area in Shell	A1	1.175	6.343	NA
Area in Nozzle Wall	A2	9.313	9.372	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	11.489	16.715	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 71.58 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (59.87*13.54*1+2*13.6*13.54*1*(1-1))
= 8.104 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)
= 59.87 (1 * 15.5 - 1 * 13.54) - 2 * 13.6
(1 * 15.5 - 1 * 13.54) * (1 - 1)
= 1.175 cm^2

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2/sin(alpha3)
= (2 * 34)(13.6 - 0.479)1/sin(73.34)
= 9.313 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]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 10² * 1 + (0)² * 1
= 1.000 cm^2

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :

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

Impact Test Temperature provided per Specification -46 °C

Calculated Minimum Design Metal Temperature -104 °C

Governing MDMT of all the sub-joints of this Junction : -104 °C

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

MDMT of ANSI B16.5/47 flange per Matl. Specification -18 °C
Flange MDMT with Temp reduction per UCS-66(i)(2) -48 °C

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
Design Pressure/Ambient Rating = 23.00/51.10 = 0.450

Weld Size Calculations, Description: LG1

Intermediate Calc. for nozzle/shell Welds Tmin 13.6000 mm.

Results Per UW-16.1:

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

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

Weld Load [W]:
= max(0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max(0, (8.104 - 1.175 + 2 * 13.6 * 1 *
(1 * 15.5 - 13.54))137.9)
= 102.90 kN

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

Weld Load [W1]:
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= (9.313 + 0 + 1 - 0 * 1) * 137.9
= 142.21 kN

Weld Load [W2]:
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= (9.313 + 0 + 1 + (4.216)) * 137.9
= 200.34 kN

Weld Load [W3]:
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= (9.313 + 0 + 1 + 0 + (4.216)) * 137.9
= 200.34 kN

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
= (pi/2) * Dlo * Wo * 0.49 * Snw
= (3.142/2.0) * 88.54 * 10 * 0.49 * 137.9
= 94. kN

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.142 * 37.1) * (16.6 - 3) * 0.7 * 137.9
= 153. kN

Tension, Shell Groove Weld [Tngw]:
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= (3.142/2.0) * 88.54 * (18.5 - 3) * 0.74 * 137.9
= 220. kN

Strength of Failure Paths:

PATH11 = (SONW + SNW) = (93.97 + 153) = 247 kN
PATH22 = (Sonw + Tpgw + Tngw + Sinw)
= (93.97 + 0 + 220 + 0) = 313.9 kN
PATH33 = (Sonw + Tngw + Sinw)
= (93.97 + 220 + 0) = 313.9 kN

Summary of Failure Path Calculations:
Path 1-1 = 246 kN , must exceed W = 102 kN or W1 = 142 kN
Path 2-2 = 313 kN , must exceed W = 102 kN or W2 = 200 kN
Path 3-3 = 313 kN , must exceed W = 102 kN or W3 = 200 kN

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 23.733 bars

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

```
Nozzle is O.K. for the External Pressure               1.100  bars
```

Note : Checking Nozzle in the Latitudinal direction.

Reinforcement CALCULATION, Description: LG1

ASME Code, Section VIII, Div. 1, 2017, 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 Elliptical Head, Tr [Int. Press]
```
= (P*K1*D))/(2*Sv*E-0.2*P) per UG-37(a)(3)
= (23*0.897*1806)/(2 *137.9*1-0.2*23)
= 13.5366 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)
= (23*28.4)/(137.9*1-0.6*23)
= 0.4785 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3963 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl   115.0000  mm.
Parallel to Vessel Wall                          Rn+tn+t    57.5000  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    34.0000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.689	1.393	NA
Area in Shell	A1	1.143	6.166	NA
Area in Nozzle Wall	A2	8.923	8.979	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	11.065	16.145	NA

The Internal Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations               90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
= ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
= (56.8*13.54*1+2*13.6*13.54*1*(1-1))
= 7.689 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 )
= 58.2 ( 1 * 15.5 - 1 * 13.54 ) - 2 * 13.6
  ( 1 * 15.5 - 1 * 13.54 ) * ( 1 - 1 )
```

= 1.143 cm^2

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 34)(13.6 - 0.479)1
= 8.923 cm^2

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 10² * 1 + (0)² * 1
= 1.000 cm^2

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

```
Wall Thickness for Internal/External pressures      ta = 3.4785 mm.
Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 18.0219 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 18.0219 mm.
Wall Thickness, shell/head, external pressure     trb2 = 3.7172 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                    tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[7.8, max(18.02, 4.5)]
= 7.8000 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(3.479, 7.8)
= 7.8000 mm.

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Weld Size Calculations, Description: LG1

```
Intermediate Calc. for nozzle/shell Welds   Tmin     13.6000  mm.
```

Results Per UW-16.1:

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

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

Weld Load [W]:
= max(0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max(0, (7.689 - 1.143 + 2 * 13.6 * 1 *
(1 * 15.5 - 13.54))137.9)
= 97.63 kN

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

Weld Load [W1]:
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= (8.923 + 0 + 1 - 0 * 1) * 137.9
= 136.82 kN

Weld Load [W2]:
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= (8.923 + 0 + 1 + (4.216)) * 137.9
= 194.95 kN

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.923 + 0 + 1 + 0 + ( 4.216 ) ) * 137.9
  = 194.95 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.142/2.0 ) * 84 * 10 * 0.49 * 137.9
  = 89. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.142 * 35.2 ) * ( 16.6 - 3 ) * 0.7 * 137.9
  = 145. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.142/2.0 ) * 84 * ( 18.5 - 3 ) * 0.74 * 137.9
  = 209. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89.15 + 145.2 ) = 234.3 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89.15 + 0 + 208.7 + 0 ) = 297.8 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89.15 + 208.7 + 0 ) = 297.8 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 234 kN , must exceed W = 97 kN  or W1 = 136 kN
 Path 2-2 = 297 kN , must exceed W = 97 kN  or W2 = 194 kN
 Path 3-3 = 297 kN , must exceed W = 97 kN  or W3 = 194 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case       23.733  bars
```

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

```
 Nozzle is O.K. for the External Pressure                1.100  bars
```

The Drop for this Nozzle is : 14.1229 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 233.5428 mm.

INPUT VALUES, Nozzle Description: LT2 From : 10

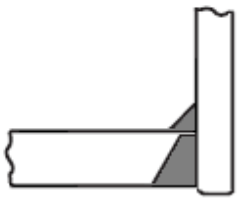
Pressure for Reinforcement Calculations	P	23.002	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Elliptical Head	D	1800.00	mm.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	18.5000	mm.
Head Internal Corrosion Allowance	c	3.0000	mm.
Head External Corrosion Allowance	co	0.0000	mm.
Distance from Head Centerline	L1	500.0000	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm^2
Allowable Stress At Ambient	Sna	137.90	N./mm^2
Diameter Basis (for tr calc only)		ID	
Layout Angle		270.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.5000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		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 in the Meridional direction.

Reinforcement CALCULATION, Description: LT2

ASME Code, Section VIII, Div. 1, 2017, 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 Elliptical Head, Tr [Int. Press]
= (P*K1*D))/(2*Sv*E-0.2*P) per UG-37(a)(3)
= (23*0.897*1806)/(2 *137.9*1-0.2*23)
= 13.5366 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)
= (23*28.4)/(137.9*1-0.6*23)
= 0.4785 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.3963 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	119.7360	mm.
Parallel to Vessel Wall, opening length	d	59.8680	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	34.0000	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, 1)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	8.104	1.468	NA

Area in Shell	A1	1.175	6.343	NA
Area in Nozzle Wall	A2	9.313	9.372	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	11.489	16.715	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 71.58 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (59.87*13.54*1+2*13.6*13.54*1*(1-1))
= 8.104 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)
= 59.87 (1 * 15.5 - 1 * 13.54) - 2 * 13.6
(1 * 15.5 - 1 * 13.54) * (1 - 1)
= 1.175 cm^2

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2/sin(alpha3)
= (2 * 34)(13.6 - 0.479)1/sin(73.34)
= 9.313 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]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 10² * 1 + (0)² * 1
= 1.000 cm^2

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :

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

Impact Test Temperature provided per Specification -46 °C

Calculated Minimum Design Metal Temperature -104 °C

Governing MDMT of all the sub-joints of this Junction : -104 °C

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

MDMT of ANSI B16.5/47 flange per Matl. Specification -18 °C
Flange MDMT with Temp reduction per UCS-66(i)(2) -48 °C

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
Design Pressure/Ambient Rating = 23.00/51.10 = 0.450

Weld Size Calculations, Description: LT2

Intermediate Calc. for nozzle/shell Welds Tmin 13.6000 mm.

Results Per UW-16.1:

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

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

Weld Load [W]:
= max(0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max(0, (8.104 - 1.175 + 2 * 13.6 * 1 *
(1 * 15.5 - 13.54))137.9)
= 102.90 kN

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

Weld Load [W1]:
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= (9.313 + 0 + 1 - 0 * 1) * 137.9
= 142.21 kN

Weld Load [W2]:
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= (9.313 + 0 + 1 + (4.216)) * 137.9
= 200.34 kN

Weld Load [W3]:
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= (9.313 + 0 + 1 + 0 + (4.216)) * 137.9
= 200.34 kN

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
= (pi/2) * Dlo * Wo * 0.49 * Snw
= (3.142/2.0) * 88.54 * 10 * 0.49 * 137.9
= 94. kN

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.142 * 37.1) * (16.6 - 3) * 0.7 * 137.9
= 153. kN

Tension, Shell Groove Weld [Tngw]:
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= (3.142/2.0) * 88.54 * (18.5 - 3) * 0.74 * 137.9
= 220. kN

Strength of Failure Paths:

PATH11 = (SONW + SNW) = (93.97 + 153) = 247 kN
PATH22 = (Sonw + Tpgw + Tngw + Sinw)
= (93.97 + 0 + 220 + 0) = 313.9 kN
PATH33 = (Sonw + Tngw + Sinw)
= (93.97 + 220 + 0) = 313.9 kN

Summary of Failure Path Calculations:
Path 1-1 = 246 kN , must exceed W = 102 kN or W1 = 142 kN
Path 2-2 = 313 kN , must exceed W = 102 kN or W2 = 200 kN
Path 3-3 = 313 kN , must exceed W = 102 kN or W3 = 200 kN

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 23.733 bars

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

```
Nozzle is O.K. for the External Pressure                1.100  bars
```

Note : Checking Nozzle in the Latitudinal direction.

Reinforcement CALCULATION, Description: LT2

ASME Code, Section VIII, Div. 1, 2017, 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 Elliptical Head, Tr [Int. Press]
```
= (P*K1*D))/(2*Sv*E-0.2*P) per UG-37(a)(3)
= (23*0.897*1806)/(2 *137.9*1-0.2*23)
= 13.5366 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)
= (23*28.4)/(137.9*1-0.6*23)
= 0.4785 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3963 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl    115.0000  mm.
Parallel to Vessel Wall                          Rn+tn+t   57.5000  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    34.0000  mm.
```

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.689	1.393	NA
Area in Shell	A1	1.143	6.166	NA
Area in Nozzle Wall	A2	8.923	8.979	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	11.065	16.145	NA

The Internal Pressure Case Governs the Analysis.

```
Nozzle Angle Used in Area Calculations                 90.00  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
= ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
= (56.8*13.54*1+2*13.6*13.54*1*(1-1))
= 7.689 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 )
= 58.2 ( 1 * 15.5 - 1 * 13.54 ) - 2 * 13.6
  ( 1 * 15.5 - 1 * 13.54 ) * ( 1 - 1 )
```

= 1.143 cm^2

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 34)(13.6 - 0.479)1
= 8.923 cm^2

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 10² * 1 + (0)² * 1
= 1.000 cm^2

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

```
Wall Thickness for Internal/External pressures      ta = 3.4785 mm.
Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure     trb1 = 18.0219 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 18.0219 mm.
Wall Thickness, shell/head, external pressure     trb2 = 3.7172 mm.
Wall Thickness                 tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                    tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[7.8, max(18.02, 4.5)]
= 7.8000 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(3.479, 7.8)
= 7.8000 mm.

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Weld Size Calculations, Description: LT2

```
Intermediate Calc. for nozzle/shell Welds   Tmin     13.6000  mm.
```

Results Per UW-16.1:

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

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

Weld Load [W]:
= max(0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max(0, (7.689 - 1.143 + 2 * 13.6 * 1 *
(1 * 15.5 - 13.54))137.9)
= 97.63 kN

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

Weld Load [W1]:
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= (8.923 + 0 + 1 - 0 * 1) * 137.9
= 136.82 kN

Weld Load [W2]:
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= (8.923 + 0 + 1 + (4.216)) * 137.9
= 194.95 kN

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.923 + 0 + 1 + 0 + ( 4.216 ) ) * 137.9
  = 194.95 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.142/2.0 ) * 84 * 10 * 0.49 * 137.9
  = 89. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.142 * 35.2 ) * ( 16.6 - 3 ) * 0.7 * 137.9
  = 145. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.142/2.0 ) * 84 * ( 18.5 - 3 ) * 0.74 * 137.9
  = 209. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89.15 + 145.2 ) = 234.3 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89.15 + 0 + 208.7 + 0 ) = 297.8 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89.15 + 208.7 + 0 ) = 297.8 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 234 kN , must exceed W = 97 kN  or W1 = 136 kN
 Path 2-2 = 297 kN , must exceed W = 97 kN  or W2 = 194 kN
 Path 3-3 = 297 kN , must exceed W = 97 kN  or W3 = 194 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case       23.733  bars
```

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

```
 Nozzle is O.K. for the External Pressure                1.100  bars
```

The Drop for this Nozzle is : 14.1229 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 233.5428 mm.

INPUT VALUES, Nozzle Description: A1 From : 20

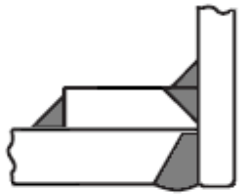
Pressure for Reinforcement Calculations	P	23.002	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1800.00	mm.
Design Length of Section	L	3299.9998	mm.
Shell Finished (Minimum) Thickness	t	22.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		550.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type		Smls. & wld. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		10.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	22.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
Diameter of Pad along vessel surface	Dp	473.0500	mm.
Thickness of Pad	te	15.0000	mm.
Weld leg size between Pad and Shell	Wp	14.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	15.0000	mm.
Reinforcing Pad Width		100.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		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: A1

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation	10.750	in.
Actual Thickness Used in Calculation	0.520	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)
= (23*903)/(137.9*1-0.6*23)
= 15.2152 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)
= (23*136.5)/(117.9*1+0.4*23)
= 2.6430 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.7856 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	505.2934	mm.
Parallel to Vessel Wall, opening length	d	252.6467	mm.
Normal to Vessel Wall (Thickness Limit), pad side	Tlwp	40.5041	mm.

Weld Strength Reduction Factor [fr1]:
= min(1, Sn/Sv)
= min(1, 117.9/137.9)
= 0.855

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 117.9/137.9)
= 0.855

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(0.855, 1)
= 0.855

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	38.891	9.861	NA
Area in Shell	A1	9.450	28.176	NA
Area in Nozzle Wall	A2	5.235	6.522	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	2.815	2.815	NA
Area in Element	A5	22.500	22.500	NA
TOTAL AREA AVAILABLE	Atot	40.001	60.012	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Insufficient.
The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	463.1841	15.0000	mm.
Based on given Pad Diameter:	473.0500	14.2601	mm.
Based on Shell or Nozzle Thickness:	489.0845	13.2016	mm.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (252.6*15.22*1+2*10.2*15.22*1*(1-0.855))
= 38.891 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)
= 252.6 (1 * 19 - 1 * 15.22) - 2 * 10.2
(1 * 19 - 1 * 15.22) * (1 - 0.855)
= 9.450 cm^2

Area Available in Nozzle Wall Projecting Outward [A2]:
= (2 * Tlwp) * (tn - trn) * fr2
= (2 * 40.5) * (10.2 - 2.643) * 0.855
= 5.235 cm^2

Area Available in Welds [A41 + A42 + A43]:
= Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
= 10² * 0.855 + (0)² * 0.855 + 14² * 1
= 2.815 cm^2

Area Available in Element, also see UG-37(h) [A5]:
= (min(Dp,DL)-(Nozzle OD))(min(tp,Tlwp,te)) * fr4 * 0.75
= (473 - 273)15 * 1 * 0.75
= 22.500 cm^2

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

Wall Thickness for Internal/External pressures ta = 5.6430 mm.
Wall Thickness per UG16(b), tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 18.2152 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 18.2152 mm.
Wall Thickness, shell/head, external pressure trb2 = 3.7207 mm.
Wall Thickness tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45 tb3 = 11.1026 mm.

Determine Nozzle Thickness candidate [tb]:

```
= min[ tb3, max( tb1,tb2) ]
= min[ 11.1, max( 18.22, 4.5 ) ]
= 11.1026 mm.
```

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

```
= max( ta, tb )
= max( 5.643, 11.1 )
= 11.1026 mm.
```

Available Nozzle Neck Thickness = 13.2016 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):

```
Sustained  :     43.0,  Allowable :    117.9 N./mm^2  Passed
Expansion  :      0.0,  Allowable :    251.8 N./mm^2  Passed
Occasional :     13.7,  Allowable :    156.8 N./mm^2  Passed
Shear      :     16.3,  Allowable :     82.5 N./mm^2  Passed
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

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

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

Calculated Minimum Design Metal Temperature               -104 °C
```

Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :

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

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

Calculated Minimum Design Metal Temperature               -104 °C
```

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

Govrn. thk, tg = 13.2, tr = 2.643, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.259, Temp. Reduction = 78 °C

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

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

Govrn. thk, tg = 15, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.801, Temp. Reduction = 11 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

```
Min Metal Temp. w/o impact per UCS-66, Curve D             -47 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -48 °C
```

Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :

Note:

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

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

Calculated Minimum Design Metal Temperature               -104 °C

Governing MDMT of the Nozzle                          :   -104 °C
Governing MDMT of the Reinforcement Pad               :    -48 °C
Governing MDMT of all the sub-joints of this Junction :    -48 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ANSI B16.5/47 flange per Matl. Specification       -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)           -48 °C
Flange MDMT with Temp reduction per UCS-66(i)(3)          -104 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
`Design Pressure/Ambient Rating = 23.00/51.10 = 0.450`

Note:
Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.

Weld Size Calculations, Description: A1

```
Intermediate Calc. for nozzle/shell Welds   Tmin     10.2016  mm.
Intermediate Calc. for pad/shell Welds   TminPad     15.0000  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	7.0700 = 0.7 * Wo mm.
Pad Weld	7.5000 = 0.5*TminPad	9.8980 = 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, (38.89 - 9.45 + 2 * 10.2 * 0.855 *
  (1 * 19 - 15.22 ) )137.9 )
= 415.05 kN
```

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

Weld Load [W1]:
```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 5.235 + 22.5 + 2.815 - 0 * 0.855 ) * 137.9
= 421.25 kN
```

Weld Load [W2]:
```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 5.235 + 0 + 0.855 + ( 3.315 ) ) * 137.9
= 129.68 kN
```

Weld Load [W3]:
```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 5.235 + 0 + 2.815 + 22.5 + ( 3.315 ) ) * 137.9
= 466.96 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.142/2.0 ) * 273 * 10 * 0.49 * 117.9
```

= 248. kN

Shear, Pad Element Weld [Spew]:
= (pi/2) * DP * WP * 0.49 * SEW
= (3.142/2.0) * 473 * 14 * 0.49 * 137.9
= 703. kN

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.142 * 131.4) * (13.2 - 3) * 0.7 * 117.9
= 348. kN

Tension, Pad Groove Weld [Tpgw]:
= (pi/2) * Dlo * Wgpn * 0.74 * Seg
= (3.142/2) * 273 * 15 * 0.74 * 137.9
= 656. kN

Tension, Shell Groove Weld [Tngw]:
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= (3.142/2.0) * 273 * (22 - 3) * 0.74 * 137.9
= 832. kN

Strength of Failure Paths:

PATH11 = (SPEW + SNW) = (702.9 + 347.6) = 1050 kN
PATH22 = (Sonw + Tpgw + Tngw + Sinw)
= (247.8 + 656.5 + 831.5 + 0) = 1736 kN
PATH33 = (Spew + Tngw + Sinw)
= (702.9 + 831.5 + 0) = 1534 kN

Summary of Failure Path Calculations:
Path 1-1 = 1050 kN , must exceed W = 415 kN or W1 = 421 kN
Path 2-2 = 1735 kN , must exceed W = 415 kN or W2 = 129 kN
Path 3-3 = 1534 kN , must exceed W = 415 kN or W3 = 466 kN

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 23.323 bars

Nozzle is O.K. for the External Pressure 1.100 bars

The Drop for this Nozzle is : 10.4153 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 232.4153 mm.

Input Echo, WRC107/537 Item 1, Description: A1 :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1800.000	mm.
Vessel Thickness	Tv	22.000	mm.
Design Temperature		125.00	°C
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	137.90	N./mm^2
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	273.050	mm.
Nozzle Thickness	Tn	13.202	mm.

Nozzle Material		SA-333 6	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm^2
Thickness of Reinforcing Pad	Tpad	15.000	mm.
Diameter of Reinforcing Pad	Dpad	473.050	mm.
Design Internal Pressure	Dp	23.002	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	10.0	kN
Longitudinal Shear	(SUS)	Vl	10.0	kN
Circumferential Shear	(SUS)	Vc	10.0	kN
Circumferential Moment	(SUS)	Mc	10600.0	N-m
Longitudinal Moment	(SUS)	Ml	10600.0	N-m
Torsional Moment	(SUS)	Mt	13100.0	N-m

Use Interactive Control		No
WRC107 Version	Version	March 1979
Include Pressure Stress Indices per Div. 2		No
Compute Pressure Stress per WRC-368		No
Local Loads applied at end of Nozzle/Attachment		No

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

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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 273.05 + 2 * 1.65 * sqrt( 912.5 ( 22.0 - 3.0 ) )
  = 707.567 mm.
```

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	10.0	kN
Circumferential Shear	VC	10.0	kN
Longitudinal Shear	VL	10.0	kN
Circumferential Moment	MC	10600.0	N-m
Longitudinal Moment	ML	10600.0	N-m
Torsional Moment	MT	13100.0	N-m

Dimensionless Parameters used : Gamma = 27.06

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.130	4C	4.639	(A,B)
N(PHI) / (P/Rm)	0.130	3C	3.874	(C,D)
M(PHI) / (P)	0.130	2C1	0.082	(A,B)
M(PHI) / (P)	0.130	1C	0.117	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.130	3A	0.857	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.130	1A	0.095	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.130	3B	2.821	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.130	1B	0.044	(A,B,C,D)
N(x) / (P/Rm)	0.130	3C	3.874	(A,B)
N(x) / (P/Rm)	0.130	4C	4.639	(C,D)

M(x) / (P)	0.130	1C1	0.120	(A,B)
M(x) / (P)	0.130	2C	0.082	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.130	4A	1.302	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.130	2A	0.051	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.130	4B	0.829	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.130	2B	0.071	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-1.5	-1.5	-1.5	-1.5	-1.2	-1.2	-1.2	-1.2
Circ. Bend. P	-4.2	4.2	-4.2	4.2	-6.1	6.1	-6.1	6.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	-2.4	-2.4	2.4	2.4
Circ. Memb. MC	0.0	0.0	0.0	0.0	-43.6	43.6	43.6	-43.6
Circ. Memb. ML	-8.0	-8.0	8.0	8.0	0.0	0.0	0.0	0.0
Circ. Bend. ML	-20.0	20.0	20.0	-20.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-33.8	14.8	22.3	-9.3	-53.3	46.0	38.7	-36.3
Long. Memb. P	-1.2	-1.2	-1.2	-1.2	-1.5	-1.5	-1.5	-1.5
Long. Bend. P	-6.2	6.2	-6.2	6.2	-4.3	4.3	-4.3	4.3
Long. Memb. MC	0.0	0.0	0.0	0.0	-3.7	-3.7	3.7	3.7
Long. Bend. MC	0.0	0.0	0.0	0.0	-23.6	23.6	23.6	-23.6
Long. Memb. ML	-2.3	-2.3	2.3	2.3	0.0	0.0	0.0	0.0
Long. Bend. ML	-32.9	32.9	32.9	-32.9	0.0	0.0	0.0	0.0
Tot. Long. Str.	-42.7	35.5	27.7	-25.5	-33.0	22.7	21.6	-17.1
Shear VC	0.7	0.7	-0.7	-0.7	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Shear MT	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Tot. Shear	4.0	4.0	2.6	2.6	2.6	2.6	4.0	4.0
Str. Int.	44.2	36.2	28.8	25.9	53.7	46.3	39.6	37.1

Dimensionless Parameters used : Gamma = 48.03

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure		Value	Location
N(PHI) / (P/Rm)	0.227	4C		6.119	(A,B)
N(PHI) / (P/Rm)	0.227	3C		3.439	(C,D)
M(PHI) / (P)	0.227	2C1		0.024	(A,B)
M(PHI) / (P)	0.227	1C	!	0.065	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.227	3A		1.872	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.227	1A		0.067	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.227	3B		4.299	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.227	1B		0.018	(A,B,C,D)
N(x) / (P/Rm)	0.227	3C		3.439	(A,B)
N(x) / (P/Rm)	0.227	4C		6.119	(C,D)
M(x) / (P)	0.227	1C1		0.052	(A,B)
M(x) / (P)	0.227	2C	!	0.033	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.227	4A		4.122	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.227	2A		0.030	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.227	4B		1.917	(A,B,C,D)

M(x) / (ML/(Rm * Beta)) 0.227 2B 0.026 (A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-3.5	-3.5	-3.5	-3.5	-2.0	-2.0	-2.0	-2.0
Circ. Bend. P	-4.0	4.0	-4.0	4.0	-10.7	10.7	-10.7	10.7
Circ. Memb. MC	0.0	0.0	0.0	0.0	-5.5	-5.5	5.5	5.5
Circ. Memb. MC	0.0	0.0	0.0	0.0	-56.6	56.6	56.6	-56.6
Circ. Memb. ML	-12.7	-12.7	12.7	12.7	0.0	0.0	0.0	0.0
Circ. Bend. ML	-14.9	14.9	14.9	-14.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-35.2	2.7	20.1	-1.7	-74.9	59.8	49.4	-42.3
Long. Memb. P	-2.0	-2.0	-2.0	-2.0	-3.5	-3.5	-3.5	-3.5
Long. Bend. P	-8.7	8.7	-8.7	8.7	-5.5	5.5	-5.5	5.5
Long. Memb. MC	0.0	0.0	0.0	0.0	-12.2	-12.2	12.2	12.2
Long. Bend. MC	0.0	0.0	0.0	0.0	-25.7	25.7	25.7	-25.7
Long. Memb. ML	-5.7	-5.7	5.7	5.7	0.0	0.0	0.0	0.0
Long. Bend. ML	-22.1	22.1	22.1	-22.1	0.0	0.0	0.0	0.0
Tot. Long. Str.	-38.4	23.1	17.1	-9.7	-46.9	15.5	28.8	-11.5
Shear VC	0.7	0.7	-0.7	-0.7	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Shear MT	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Tot. Shear	2.7	2.7	1.3	1.3	1.3	1.3	2.7	2.7
Str. Int.	39.9	23.4	20.5	9.9	74.9	59.9	49.7	42.5

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	60.0	62.3	60.0	62.3	60.0	62.3	60.0	62.3
Circ. Pl (SUS)	-9.5	-9.5	6.5	6.5	-3.7	-3.7	1.2	1.2
Circ. Q (SUS)	-24.3	24.3	15.8	-15.8	-49.7	49.7	37.5	-37.5
Long. Pm (SUS)	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Long. Pl (SUS)	-3.6	-3.6	1.1	1.1	-5.2	-5.2	2.2	2.2
Long. Q (SUS)	-39.1	39.1	26.6	-26.6	-27.9	27.9	19.3	-19.3
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.7	0.7	-0.7	-0.7	-0.7	-0.7	0.7	0.7
Shear Q (SUS)	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Pm (SUS)	60.0	62.3	60.0	62.3	60.0	62.3	60.0	62.3

Pm+Pl (SUS)	50.5	52.8	66.5	68.8	56.3	58.6	61.2	63.5
Pm+Pl+Q (Total)	39.7	78.3	82.6	53.1	11.0	108.4	99.0	27.0

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	62.26	137.90	Passed
Pm+Pl (SUS)	68.79	206.85	Passed
Pm+Pl+Q (TOTAL)	108.38	413.70	Passed

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Circ. Pl (SUS)	-16.2	-16.2	9.2	9.2	-7.5	-7.5	3.5	3.5
Circ. Q (SUS)	-18.9	18.9	10.9	-10.9	-67.3	67.3	45.9	-45.9
Long. Pm (SUS)	54.1	54.1	54.1	54.1	54.1	54.1	54.1	54.1
Long. Pl (SUS)	-7.6	-7.6	3.7	3.7	-15.7	-15.7	8.6	8.6
Long. Q (SUS)	-30.7	30.7	13.4	-13.4	-31.2	31.2	20.2	-20.2
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.7	0.7	-0.7	-0.7	-0.7	-0.7	0.7	0.7
Shear Q (SUS)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Pm (SUS)	108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Pm+Pl (SUS)	92.0	94.3	117.4	119.7	100.7	103.0	111.7	114.0
Pm+Pl+Q (Total)	73.2	113.4	128.3	108.8	33.4	170.3	157.7	68.5

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	110.49	137.90	Passed
Pm+Pl (SUS)	119.66	206.85	Passed
Pm+Pl+Q (TOTAL)	170.33	413.70	Passed

INPUT VALUES, Nozzle Description: A2 From : 20

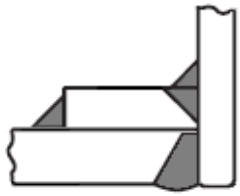
Pressure for Reinforcement Calculations	P	23.001	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1800.00	mm.
Design Length of Section	L	3299.9998	mm.
Shell Finished (Minimum) Thickness	t	22.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1150.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type		Smls. & wld. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
Diameter Basis (for tr calc only)		OD	
Layout Angle		45.00	deg
Diameter		8.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	22.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
Diameter of Pad along vessel surface	Dp	419.0750	mm.
Thickness of Pad	te	15.0000	mm.
Weld leg size between Pad and Shell	Wp	14.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	15.0000	mm.
Reinforcing Pad Width		100.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		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: A2

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation	8.625	in.
Actual Thickness Used in Calculation	0.438	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)
= (23*903)/(137.9*1-0.6*23)
= 15.2149 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)
= (23*109.5)/(117.9*1+0.4*23)
= 2.1205 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.6930 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	405.7000	mm.
Parallel to Vessel Wall, opening length	d	202.8500	mm.
Normal to Vessel Wall (Thickness Limit), pad side	Tlwp	35.2813	mm.

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

Weld Strength Reduction Factor [fr1]:
= min(1, Sn/Sv)
= min(1, 117.9/137.9)
= 0.855

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 117.9/137.9)
= 0.855

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(0.855, 1)
= 0.855

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	31.221	7.916	NA
Area in Shell	A1	7.589	22.625	NA
Area in Nozzle Wall	A2	3.615	4.476	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.855	0.855	NA
Area in Element	A5	20.995	20.995	NA
TOTAL AREA AVAILABLE	Atot	33.054	48.951	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Insufficient.
The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	389.4074	15.0000	mm.
Based on given Pad Diameter:	419.0750	13.6905	mm.
Based on the Estimated Diameter Limit:	404.1125	13.8079	mm.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (202.8*15.21*1+2*8.113*15.21*1*(1-0.855))
= 31.221 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)
= 202.8 (1 * 19 - 1 * 15.21) - 2 * 8.113
(1 * 19 - 1 * 15.21) * (1 - 0.855)
= 7.589 cm^2

Area Available in Nozzle Wall Projecting Outward [A2]:
= (2 * Tlwp) * (tn - trn) * fr2
= (2 * 35.28) * (8.113 - 2.12) * 0.855
= 3.615 cm^2

Area Available in Welds [A41 + A42 + A43]:
= Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
= 10² * 0.855 + (0)² * 0.855 + 0² * 1
= 0.855 cm^2

Area Available in Element, also see UG-37(h) [A5]:
= (min(Dp,DL)-(Nozzle OD))(min(tp,Tlwp,te)) * fr4 * 0.75
= (405.7 - 219.1)15 * 1 * 0.75
= 20.995 cm^2

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

Wall Thickness for Internal/External pressures ta = 5.1205 mm.
Wall Thickness per UG16(b), tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 18.2149 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 18.2149 mm.
Wall Thickness, shell/head, external pressure trb2 = 3.7207 mm.
Wall Thickness tb2 = max(trb2, tr16b) = 4.5000 mm.

Wall Thickness per table UG-45 tb3 = 10.1600 mm.

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[10.16, max(18.21, 4.5)]
= 10.1600 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(5.12, 10.16)
= 10.1600 mm.

Available Nozzle Neck Thickness = 11.1125 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained :	50.5,	Allowable :	117.9 N./mm^2	Passed
Expansion :	0.0,	Allowable :	244.3 N./mm^2	Passed
Occasional :	13.8,	Allowable :	156.8 N./mm^2	Passed
Shear :	20.4,	Allowable :	82.5 N./mm^2	Passed

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

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

Impact Test Temperature provided per Specification -46 °C

Calculated Minimum Design Metal Temperature -104 °C

Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :

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

Impact Test Temperature provided per Specification -46 °C

Calculated Minimum Design Metal Temperature -104 °C

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

Govrn. thk, tg = 11.11, tr = 2.12, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.261, Temp. Reduction = 78 °C

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

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

Govrn. thk, tg = 15, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.801, Temp. Reduction = 11 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

Min Metal Temp. w/o impact per UCS-66, Curve D -47 °C
Min Metal Temp. at Required thickness (UCS 66.1) -48 °C

Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :

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

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

Calculated Minimum Design Metal Temperature               -104 °C

Governing MDMT of the Nozzle                          :   -104 °C
Governing MDMT of the Reinforcement Pad               :    -48 °C
Governing MDMT of all the sub-joints of this Junction :    -48 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ANSI B16.5/47 flange per Matl. Specification       -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)           -48 °C
Flange MDMT with Temp reduction per UCS-66(i)(3)          -104 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
`Design Pressure/Ambient Rating = 23.00/51.10 = 0.450`

Note:
Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.

Weld Size Calculations, Description: A2

```
Intermediate Calc. for nozzle/shell Welds   Tmin      8.1125  mm.
Intermediate Calc. for pad/shell Welds   TminPad     15.0000  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	5.6788 = 0.7 * tmin.	7.0700 = 0.7 * Wo mm.
Pad Weld	7.5000 = 0.5*TminPad	9.8980 = 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, (31.22 - 7.589 + 2 * 8.113 * 0.855 *
    (1 * 19 - 15.21 ) )137.9 )
  = 333.10 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.615 + 21 + 0.855 - 0 * 0.855 ) * 137.9
  = 351.14 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.615 + 0 + 0.855 + ( 2.636 ) ) * 137.9
  = 97.98 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.615 + 0 + 0.855 + 21 + ( 2.636 ) ) * 137.9
  = 387.48 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.142/2.0 ) * 219.1 * 10 * 0.49 * 117.9
  = 199. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.142/2.0 ) * 419.1 * 14 * 0.49 * 137.9
  = 623. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.142 * 105.5 ) * ( 11.11 - 3 ) * 0.7 * 117.9
  = 222. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.142/2 ) * 219.1 * 15 * 0.74 * 137.9
  = 527. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.142/2.0 ) * 219.1 * ( 22 - 3 ) * 0.74 * 137.9
  = 667. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 622.7 + 221.9 ) = 844.5 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 198.8 + 526.7 + 667.2 + 0 ) = 1393 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 622.7 + 667.2 + 0 ) = 1290 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 844 kN , must exceed W = 333 kN  or W1 = 351 kN
 Path 2-2 = 1392 kN , must exceed W = 333 kN  or W2 = 97 kN
 Path 3-3 = 1289 kN , must exceed W = 333 kN  or W3 = 387 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case       23.664  bars

 Nozzle is O.K. for the External Pressure                1.100  bars
```

The Drop for this Nozzle is : 6.6907 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 228.6907 mm.

Input Echo, WRC107/537 Item 1, Description: A2 :

```
 Diameter Basis for Vessel                Vbasis      ID
 Cylindrical or Spherical Vessel          Cylsph      Cylindrical
 Internal Corrosion Allowance                Cas      3.0000  mm.
 Vessel Diameter                              Dv    1800.000  mm.
 Vessel Thickness                             Tv      22.000  mm.

 Design Temperature                                   125.00  °C
 Vessel Material                                   SA-516 70
 Vessel Cold S.I. Allowable                  Smc      137.90  N./mm^2
 Vessel Hot  S.I. Allowable                  Smh      137.90  N./mm^2

 Attachment Type                            Type      Round

 Diameter Basis for Nozzle                Nbasis      OD
 Corrosion Allowance for Nozzle              Can      3.0000  mm.
```

Nozzle Diameter	Dn	219.075	mm.
Nozzle Thickness	Tn	11.113	mm.
Nozzle Material		SA-333 6	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm^2
Thickness of Reinforcing Pad	Tpad	15.000	mm.
Diameter of Reinforcing Pad	Dpad	419.075	mm.
Design Internal Pressure	Dp	23.001	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	8.0	kN
Longitudinal Shear	(SUS)	Vl	8.0	kN
Circumferential Shear	(SUS)	Vc	8.0	kN
Circumferential Moment	(SUS)	Mc	6800.0	N-m
Longitudinal Moment	(SUS)	Ml	6800.0	N-m
Torsional Moment	(SUS)	Mt	8400.0	N-m

Use Interactive Control		No
WRC107 Version	Version	March 1979
Include Pressure Stress Indices per Div. 2		No
Compute Pressure Stress per WRC-368		No
Local Loads applied at end of Nozzle/Attachment		No

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

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

```
= NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
= 219.075 + 2 * 1.65 * sqrt( 912.5 ( 22.0 - 3.0 ) )
= 653.592 mm.
```

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	8.0	kN
Circumferential Shear	VC	8.0	kN
Longitudinal Shear	VL	8.0	kN
Circumferential Moment	MC	6800.0	N-m
Longitudinal Moment	ML	6800.0	N-m
Torsional Moment	MT	8400.0	N-m

Dimensionless Parameters used : Gamma = 27.06

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.104	4C	4.888	(A,B)
N(PHI) / (P/Rm)	0.104	3C	4.306	(C,D)
M(PHI) / (P)	0.104	2C1	0.102	(A,B)
M(PHI) / (P)	0.104	1C	0.139	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.104	3A	0.729	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.104	1A	0.099	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.104	3B	2.502	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.104	1B	0.048	(A,B,C,D)

N(x) / (P/Rm)	0.104	3C	4.306	(A,B)
N(x) / (P/Rm)	0.104	4C	4.888	(C,D)
M(x) / (P)	0.104	1C1	0.142	(A,B)
M(x) / (P)	0.104	2C	0.102	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.104	4A	1.017	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.104	2A	0.055	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.104	4B	0.696	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.104	2B	0.080	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-1.3	-1.3	-1.3	-1.3	-1.1	-1.1	-1.1	-1.1
Circ. Bend. P	-4.3	4.3	-4.3	4.3	-5.8	5.8	-5.8	5.8
Circ. Memb. MC	0.0	0.0	0.0	0.0	-1.7	-1.7	1.7	1.7
Circ. Memb. MC	0.0	0.0	0.0	0.0	-36.4	36.4	36.4	-36.4
Circ. Memb. ML	-5.7	-5.7	5.7	5.7	0.0	0.0	0.0	0.0
Circ. Bend. ML	-17.8	17.8	17.8	-17.8	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-29.0	15.2	18.0	-9.1	-44.9	39.4	31.1	-30.0
Long. Memb. P	-1.1	-1.1	-1.1	-1.1	-1.3	-1.3	-1.3	-1.3
Long. Bend. P	-5.9	5.9	-5.9	5.9	-4.3	4.3	-4.3	4.3
Long. Memb. MC	0.0	0.0	0.0	0.0	-2.3	-2.3	2.3	2.3
Long. Bend. MC	0.0	0.0	0.0	0.0	-20.3	20.3	20.3	-20.3
Long. Memb. ML	-1.6	-1.6	1.6	1.6	0.0	0.0	0.0	0.0
Long. Bend. ML	-29.5	29.5	29.5	-29.5	0.0	0.0	0.0	0.0
Tot. Long. Str.	-38.0	32.7	24.0	-23.1	-28.1	21.0	17.1	-15.0
Shear VC	0.7	0.7	-0.7	-0.7	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Shear MT	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Tot. Shear	4.0	4.0	2.6	2.6	2.6	2.6	4.0	4.0
Str. Int.	39.5	33.5	25.0	23.6	45.3	39.7	32.2	31.0

Dimensionless Parameters used : Gamma = 48.03

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure		Value	Location
N(PHI) / (P/Rm)	0.201	4C		6.492	(A,B)
N(PHI) / (P/Rm)	0.201	3C		4.028	(C,D)
M(PHI) / (P)	0.201	2C1		0.030	(A,B)
M(PHI) / (P)	0.201	1C	!	0.066	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.201	3A		1.928	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.201	1A		0.071	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.201	3B		4.656	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.201	1B		0.022	(A,B,C,D)
N(x) / (P/Rm)	0.201	3C		4.028	(A,B)
N(x) / (P/Rm)	0.201	4C		6.492	(C,D)
M(x) / (P)	0.201	1C1		0.061	(A,B)
M(x) / (P)	0.201	2C	!	0.034	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.201	4A		3.867	(A,B,C,D)

M(x) / (MC/(Rm * Beta))	0.201	2A	0.033	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.201	4B	1.945	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.201	2B	0.031	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-3.0	-3.0	-3.0	-3.0	-1.9	-1.9	-1.9	-1.9
Circ. Bend. P	-4.0	4.0	-4.0	4.0	-8.7	8.7	-8.7	8.7
Circ. Memb. MC	0.0	0.0	0.0	0.0	-4.1	-4.1	4.1	4.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	-43.9	43.9	43.9	-43.9
Circ. Memb. ML	-10.0	-10.0	10.0	10.0	0.0	0.0	0.0	0.0
Circ. Bend. ML	-13.3	13.3	13.3	-13.3	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-30.3	4.4	16.3	-2.4	-58.5	46.6	37.4	-32.9
Long. Memb. P	-1.9	-1.9	-1.9	-1.9	-3.0	-3.0	-3.0	-3.0
Long. Bend. P	-8.1	8.1	-8.1	8.1	-4.5	4.5	-4.5	4.5
Long. Memb. MC	0.0	0.0	0.0	0.0	-8.3	-8.3	8.3	8.3
Long. Bend. MC	0.0	0.0	0.0	0.0	-20.6	20.6	20.6	-20.6
Long. Memb. ML	-4.2	-4.2	4.2	4.2	0.0	0.0	0.0	0.0
Long. Bend. ML	-19.3	19.3	19.3	-19.3	0.0	0.0	0.0	0.0
Tot. Long. Str.	-33.4	21.4	13.5	-8.9	-36.4	13.8	21.4	-10.8
Shear VC	0.6	0.6	-0.6	-0.6	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.6	-0.6	0.6	0.6
Shear MT	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Tot. Shear	2.2	2.2	1.0	1.0	1.0	1.0	2.2	2.2
Str. Int.	34.6	21.7	16.6	9.0	58.6	46.6	37.7	33.1

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	60.0	62.3	60.0	62.3	60.0	62.3	60.0	62.3
Circ. Pl (SUS)	-6.9	-6.9	4.4	4.4	-2.8	-2.8	0.6	0.6
Circ. Q (SUS)	-22.1	22.1	13.6	-13.6	-42.1	42.1	30.6	-30.6
Long. Pm (SUS)	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Long. Pl (SUS)	-2.7	-2.7	0.5	0.5	-3.6	-3.6	1.1	1.1
Long. Q (SUS)	-35.4	35.4	23.6	-23.6	-24.6	24.6	16.0	-16.0
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.7	0.7	-0.7	-0.7	-0.7	-0.7	0.7	0.7
Shear Q (SUS)	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3

Pm (SUS)	60.0	62.3	60.0	62.3	60.0	62.3	60.0	62.3
Pm+Pl (SUS)	53.1	55.4	64.4	66.7	57.2	59.5	60.5	62.8
Pm+Pl+Q (Total)	39.8	78.4	78.2	53.3	15.6	101.8	91.5	33.1

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	62.26	137.90	Passed
Pm+Pl (SUS)	66.70	206.85	Passed
Pm+Pl+Q (TOTAL)	101.77	413.70	Passed

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Circ. Pl (SUS)	-13.0	-13.0	7.0	7.0	-6.0	-6.0	2.3	2.3
Circ. Q (SUS)	-17.3	17.3	9.3	-9.3	-52.6	52.6	35.1	-35.1
Long. Pm (SUS)	54.1	54.1	54.1	54.1	54.1	54.1	54.1	54.1
Long. Pl (SUS)	-6.0	-6.0	2.3	2.3	-11.3	-11.3	5.3	5.3
Long. Q (SUS)	-27.4	27.4	11.2	-11.2	-25.1	25.1	16.1	-16.1
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.6	0.6	-0.6	-0.6	-0.6	-0.6	0.6	0.6
Shear Q (SUS)	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Pm (SUS)	108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Pm+Pl (SUS)	95.2	97.5	115.2	117.5	102.2	104.5	110.5	112.8
Pm+Pl+Q (Total)	78.0	115.0	124.5	108.1	49.7	157.1	145.7	77.8

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	110.49	137.90	Passed
Pm+Pl (SUS)	117.45	206.85	Passed
Pm+Pl+Q (TOTAL)	157.08	413.70	Passed

INPUT VALUES, Nozzle Description: B From : 20

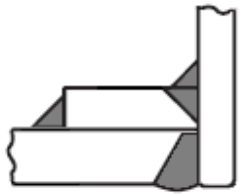
Pressure for Reinforcement Calculations	P	23.001	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1800.00	mm.
Design Length of Section	L	3299.9998	mm.
Shell Finished (Minimum) Thickness	t	22.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		2300.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type		Smls. & wld. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
Diameter Basis (for tr calc only)		OD	
Layout Angle		270.00	deg
Diameter		12.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	22.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
Diameter of Pad along vessel surface	Dp	563.8500	mm.
Thickness of Pad	te	15.0000	mm.
Weld leg size between Pad and Shell	Wp	14.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	15.0000	mm.
Reinforcing Pad Width		120.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		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: B

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation	12.750	in.
Actual Thickness Used in Calculation	0.601	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)
= (23*903)/(137.9*1-0.6*23)
= 15.2145 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)
= (23*161.9)/(117.9*1+0.4*23)
= 3.1345 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.8692 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	598.6257	mm.
Parallel to Vessel Wall, opening length	d	299.3128	mm.
Normal to Vessel Wall (Thickness Limit), pad side	Tlwp	45.6714	mm.

Weld Strength Reduction Factor [fr1]:
= min(1, Sn/Sv)
= min(1, 117.9/137.9)
= 0.855

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 117.9/137.9)
= 0.855

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(0.855, 1)
= 0.855

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	46.080	11.684	NA
Area in Shell	A1	11.196	33.374	NA
Area in Nozzle Wall	A2	7.134	8.903	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	2.815	2.815	NA
Area in Element	A5	27.000	27.000	NA
TOTAL AREA AVAILABLE	Atot	48.144	72.092	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Insufficient.
The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	545.5021	15.0000	mm.
Based on given Pad Diameter:	563.8500	13.8533	mm.
Based on Shell or Nozzle Thickness:	541.6033	15.2686	mm.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (299.3*15.21*1+2*12.27*15.21*1*(1-0.855))
= 46.080 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)
= 299.3 (1 * 19 - 1 * 15.21) - 2 * 12.27
(1 * 19 - 1 * 15.21) * (1 - 0.855)
= 11.196 cm^2

Area Available in Nozzle Wall Projecting Outward [A2]:
= (2 * Tlwp) * (tn - trn) * fr2
= (2 * 45.67) * (12.27 - 3.135) * 0.855
= 7.134 cm^2

Area Available in Welds [A41 + A42 + A43]:
= Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
= 10² * 0.855 + (0)² * 0.855 + 14² * 1
= 2.815 cm^2

Area Available in Element, also see UG-37(h) [A5]:
= (min(Dp,DL)-(Nozzle OD))(min(tp,Tlwp,te)) * fr4 * 0.75
= (563.8 - 323.9)15 * 1 * 0.75
= 27.000 cm^2

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

Wall Thickness for Internal/External pressures ta = 6.1345 mm.
Wall Thickness per UG16(b), tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 18.2145 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 18.2145 mm.
Wall Thickness, shell/head, external pressure trb2 = 3.7207 mm.
Wall Thickness tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45 tb3 = 11.3312 mm.

Determine Nozzle Thickness candidate [tb]:

```
= min[ tb3, max( tb1,tb2) ]
= min[ 11.33, max( 18.21, 4.5 ) ]
= 11.3312 mm.
```

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

```
= max( ta, tb )
= max( 6.135, 11.33 )
= 11.3312 mm.
```

Available Nozzle Neck Thickness = 15.2686 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):

```
Sustained  :     38.5,  Allowable :    117.9 N./mm^2  Passed
Expansion  :      0.0,  Allowable :    256.3 N./mm^2  Passed
Occasional :     13.5,  Allowable :    156.8 N./mm^2  Passed
Shear      :     13.9,  Allowable :     82.5 N./mm^2  Passed
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

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

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

Calculated Minimum Design Metal Temperature               -104 °C
```

Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :

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

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

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

Govrn. thk, tg = 15, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.801, Temp. Reduction = 11 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

```
Min Metal Temp. w/o impact per UCS-66, Curve D             -47 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -48 °C
```

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

Govrn. thk, tg = 15, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.801, Temp. Reduction = 11 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

```
Min Metal Temp. w/o impact per UCS-66, Curve D             -47 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -48 °C
```

Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :

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

Impact Test Temperature provided per Specification -46 °C

Calculated Minimum Design Metal Temperature -104 °C

Governing MDMT of the Nozzle : -46 °C
Governing MDMT of the Reinforcement Pad : -48 °C
Governing MDMT of all the sub-joints of this Junction : -46 °C

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

MDMT of ANSI B16.5/47 flange per Matl. Specification -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2) -48 °C
Flange MDMT with Temp reduction per UCS-66(i)(3) -104 °C

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
Design Pressure/Ambient Rating = 23.00/51.10 = 0.450

Note:
Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.

Weld Size Calculations, Description: B

Intermediate Calc. for nozzle/shell Welds Tmin 12.2686 mm.
Intermediate Calc. for pad/shell Welds TminPad 15.0000 mm.

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	7.0700 = 0.7 * Wo mm.
Pad Weld	7.5000 = 0.5*TminPad	9.8980 = 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, (46.08 - 11.2 + 2 * 12.27 * 0.855 *
(1 * 19 - 15.21))137.9)
= 491.97 kN

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

Weld Load [W1]:
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= (7.134 + 27 + 2.815 - 0 * 0.855) * 137.9
= 509.48 kN

Weld Load [W2]:
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= (7.134 + 0 + 0.855 + (3.986)) * 137.9
= 165.12 kN

Weld Load [W3]:
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= (7.134 + 0 + 2.815 + 27 + (3.986)) * 137.9
= 564.44 kN

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
= (pi/2) * Dlo * Wo * 0.49 * Snw
= (3.142/2.0) * 323.9 * 10 * 0.49 * 117.9
= 294. kN

Shear, Pad Element Weld [Spew]:
= (pi/2) * DP * WP * 0.49 * SEW
= (3.142/2.0) * 563.8 * 14 * 0.49 * 137.9
= 838. kN

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.142 * 155.8) * (15.27 - 3) * 0.7 * 117.9
= 496. kN

Tension, Pad Groove Weld [Tpgw]:
= (pi/2) * Dlo * Wgpn * 0.74 * Seg
= (3.142/2) * 323.9 * 15 * 0.74 * 137.9
= 779. kN

Tension, Shell Groove Weld [Tngw]:
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= (3.142/2.0) * 323.9 * (22 - 3) * 0.74 * 137.9
= 986. kN

Strength of Failure Paths:

PATH11 = (SPEW + SNW) = (837.8 + 495.5) = 1333 kN
PATH22 = (Sonw + Tpgw + Tngw + Sinw)
= (293.9 + 778.6 + 986.2 + 0) = 2059 kN
PATH33 = (Spew + Tngw + Sinw)
= (837.8 + 986.2 + 0) = 1824 kN

Summary of Failure Path Calculations:

Path 1-1 = 1333 kN , must exceed W = 491 kN or W1 = 509 kN
Path 2-2 = 2058 kN , must exceed W = 491 kN or W2 = 165 kN
Path 3-3 = 1824 kN , must exceed W = 491 kN or W3 = 564 kN

Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 23.503 bars

Nozzle is O.K. for the External Pressure 1.100 bars

The Drop for this Nozzle is : 14.6863 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 236.6863 mm.

Input Echo, WRC107/537 Item 1, Description: B :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1800.000	mm.
Vessel Thickness	Tv	22.000	mm.
Design Temperature		125.00	°C
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	137.90	N./mm^2
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	323.850	mm.
Nozzle Thickness	Tn	15.269	mm.
Nozzle Material		SA-333 6	

Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm^2
Thickness of Reinforcing Pad	Tpad	15.000	mm.
Diameter of Reinforcing Pad	Dpad	563.850	mm.
Design Internal Pressure	Dp	23.001	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	12.0	kN
Longitudinal Shear	(SUS)	Vl	12.0	kN
Circumferential Shear	(SUS)	Vc	12.0	kN
Circumferential Moment	(SUS)	Mc	15300.0	N-m
Longitudinal Moment	(SUS)	Ml	15300.0	N-m
Torsional Moment	(SUS)	Mt	18900.0	N-m

Use Interactive Control		No
WRC107 Version	Version	March 1979
Include Pressure Stress Indices per Div. 2		No
Compute Pressure Stress per WRC-368		No
Local Loads applied at end of Nozzle/Attachment		No

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

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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 323.85 + 2 * 1.65 * sqrt( 912.5 ( 22.0 - 3.0 ) )
  = 758.367 mm.
```

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	12.0	kN
Circumferential Shear	VC	12.0	kN
Longitudinal Shear	VL	12.0	kN
Circumferential Moment	MC	15300.0	N-m
Longitudinal Moment	ML	15300.0	N-m
Torsional Moment	MT	18900.0	N-m

Dimensionless Parameters used : Gamma = 27.06

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.154	4C	4.373	(A,B)
N(PHI) / (P/Rm)	0.154	3C	3.492	(C,D)
M(PHI) / (P)	0.154	2C1	0.067	(A,B)
M(PHI) / (P)	0.154	1C	0.099	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.154	3A	0.959	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.154	1A	0.091	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.154	3B	2.978	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.154	1B	0.039	(A,B,C,D)
N(x) / (P/Rm)	0.154	3C	3.492	(A,B)
N(x) / (P/Rm)	0.154	4C	4.373	(C,D)
M(x) / (P)	0.154	1C1	0.104	(A,B)

M(x) / (P)	0.154	2C 0.067	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.154	4A 1.498	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.154	2A 0.048	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.154	4B 0.933	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.154	2B 0.064	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.3	-1.3	-1.3	-1.3
Circ. Bend. P	-4.2	4.2	-4.2	4.2	-6.2	6.2	-6.2	6.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	-3.3	-3.3	3.3	3.3
Circ. Memb. MC	0.0	0.0	0.0	0.0	-51.1	51.1	51.1	-51.1
Circ. Memb. ML	-10.3	-10.3	10.3	10.3	0.0	0.0	0.0	0.0
Circ. Bend. ML	-21.9	21.9	21.9	-21.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-38.0	14.1	26.3	-9.1	-61.9	52.6	46.9	-42.9
Long. Memb. P	-1.3	-1.3	-1.3	-1.3	-1.7	-1.7	-1.7	-1.7
Long. Bend. P	-6.5	6.5	-6.5	6.5	-4.2	4.2	-4.2	4.2
Long. Memb. MC	0.0	0.0	0.0	0.0	-5.2	-5.2	5.2	5.2
Long. Bend. MC	0.0	0.0	0.0	0.0	-26.8	26.8	26.8	-26.8
Long. Memb. ML	-3.2	-3.2	3.2	3.2	0.0	0.0	0.0	0.0
Long. Bend. ML	-35.7	35.7	35.7	-35.7	0.0	0.0	0.0	0.0
Tot. Long. Str.	-46.7	37.6	31.0	-27.3	-37.8	24.1	26.1	-19.1
Shear VC	0.7	0.7	-0.7	-0.7	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Shear MT	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Tot. Shear	4.1	4.1	2.7	2.7	2.7	2.7	4.1	4.1
Str. Int.	48.3	38.3	32.2	27.7	62.2	52.9	47.6	43.6

Dimensionless Parameters used : Gamma = 48.03

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.270	4C	5.493	(A,B)
N(PHI) / (P/Rm)	0.270	3C	2.725	(C,D)
M(PHI) / (P)	0.270	2C1	0.017	(A,B)
M(PHI) / (P)	0.270	1C !	0.065	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.270	3A	1.698	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.270	1A	0.063	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.270	3B	3.658	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.270	1B	0.013	(A,B,C,D)
N(x) / (P/Rm)	0.270	3C	2.725	(A,B)
N(x) / (P/Rm)	0.270	4C	5.493	(C,D)
M(x) / (P)	0.270	1C1	0.040	(A,B)
M(x) / (P)	0.270	2C !	0.033	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.270	4A	4.431	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.270	2A	0.026	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.270	4B	1.802	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.270	2B	0.020	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-3.8	-3.8	-3.8	-3.8	-1.9	-1.9	-1.9	-1.9
Circ. Bend. P	-3.4	3.4	-3.4	3.4	-12.9	12.9	-12.9	12.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	-6.1	-6.1	6.1	6.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	-64.9	64.9	64.9	-64.9
Circ. Memb. ML	-13.1	-13.1	13.1	13.1	0.0	0.0	0.0	0.0
Circ. Bend. ML	-13.1	13.1	13.1	-13.1	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-33.4	-0.4	19.0	-0.5	-85.8	69.9	56.2	-47.9
Long. Memb. P	-1.9	-1.9	-1.9	-1.9	-3.8	-3.8	-3.8	-3.8
Long. Bend. P	-8.1	8.1	-8.1	8.1	-6.6	6.6	-6.6	6.6
Long. Memb. MC	0.0	0.0	0.0	0.0	-15.8	-15.8	15.8	15.8
Long. Bend. MC	0.0	0.0	0.0	0.0	-27.0	27.0	27.0	-27.0
Long. Memb. ML	-6.4	-6.4	6.4	6.4	0.0	0.0	0.0	0.0
Long. Bend. ML	-20.1	20.1	20.1	-20.1	0.0	0.0	0.0	0.0
Tot. Long. Str.	-36.5	19.8	16.6	-7.5	-53.3	14.0	32.4	-8.3
Shear VC	0.7	0.7	-0.7	-0.7	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Shear MT	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Tot. Shear	2.7	2.7	1.3	1.3	1.3	1.3	2.7	2.7
Str. Int.	38.1	20.9	19.6	7.7	85.8	69.9	56.5	48.0

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	60.0	62.3	60.0	62.3	60.0	62.3	60.0	62.3
Circ. Pl (SUS)	-12.0	-12.0	8.6	8.6	-4.6	-4.6	2.0	2.0
Circ. Q (SUS)	-26.0	26.0	17.7	-17.7	-57.3	57.3	44.9	-44.9
Long. Pm (SUS)	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Long. Pl (SUS)	-4.6	-4.6	1.9	1.9	-6.8	-6.8	3.5	3.5
Long. Q (SUS)	-42.1	42.1	29.2	-29.2	-30.9	30.9	22.6	-22.6
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.7	0.7	-0.7	-0.7	-0.7	-0.7	0.7	0.7
Shear Q (SUS)	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Pm (SUS)	60.0	62.3	60.0	62.3	60.0	62.3	60.0	62.3
Pm+Pl (SUS)	48.0	50.3	68.6	70.9	55.3	57.6	61.9	64.2

Pm+Pl+Q (Total)	39.5	77.9	86.6	53.3	8.8	115.0	107.2	21.0

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	62.26	137.90	Passed
Pm+Pl (SUS)	70.87	206.85	Passed
Pm+Pl+Q (TOTAL)	115.02	413.70	Passed

WRC 107/537 Stress Summations:

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

	Stress Intensity Values at							
Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Circ. Pl (SUS)	-16.9	-16.9	9.3	9.3	-8.0	-8.0	4.2	4.2
Circ. Q (SUS)	-16.5	16.5	9.8	-9.8	-77.8	77.8	52.0	-52.0
Long. Pm (SUS)	54.1	54.1	54.1	54.1	54.1	54.1	54.1	54.1
Long. Pl (SUS)	-8.3	-8.3	4.6	4.6	-19.6	-19.6	12.0	12.0
Long. Q (SUS)	-28.2	28.2	12.1	-12.1	-33.6	33.6	20.4	-20.4
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.7	0.7	-0.7	-0.7	-0.7	-0.7	0.7	0.7
Shear Q (SUS)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Pm (SUS)	108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Pm+Pl (SUS)	91.3	93.6	117.5	119.8	100.2	102.5	112.4	114.7
Pm+Pl+Q (Total)	74.9	110.3	127.3	110.0	22.5	180.4	164.5	63.0

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	110.48	137.90	Passed
Pm+Pl (SUS)	119.77	206.85	Passed
Pm+Pl+Q (TOTAL)	180.37	413.70	Passed

INPUT VALUES, Nozzle Description: LG2 From : 20

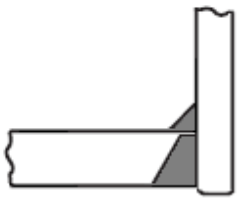
Pressure for Reinforcement Calculations	P	23.002	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1800.00	mm.
Design Length of Section	L	3299.9998	mm.
Shell Finished (Minimum) Thickness	t	22.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		250.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm^2
Allowable Stress At Ambient	Sna	137.90	N./mm^2
Diameter Basis (for tr calc only)		ID	
Layout Angle		180.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.5000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		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: LG2

ASME Code, Section VIII, Div. 1, 2017, 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)
= (23*903)/(137.9*1-0.6*23)
= 15.2153 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)
= (23*28.4)/(137.9*1-0.6*23)
= 0.4785 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.3963 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	122.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	61.0000	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	34.0000	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, 1)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	8.642	2.191	NA
Area in Shell	A1	2.468	7.357	NA
Area in Nozzle Wall	A2	8.923	8.979	NA

Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	12.390	17.336	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (56.8*15.22*1+2*13.6*15.22*1*(1-1))
= 8.642 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)
= 65.2 (1 * 19 - 1 * 15.22) - 2 * 13.6
(1 * 19 - 1 * 15.22) * (1 - 1)
= 2.468 cm^2

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 34)(13.6 - 0.479)1
= 8.923 cm^2

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 10² * 1 + (0)² * 1
= 1.000 cm^2

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

Wall Thickness for Internal/External pressures ta = 3.4785 mm.
Wall Thickness per UG16(b), tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 18.2153 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 18.2153 mm.
Wall Thickness, shell/head, external pressure trb2 = 3.7207 mm.
Wall Thickness tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45 tb3 = 7.8000 mm.

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[7.8, max(18.22, 4.5)]
= 7.8000 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(3.479, 7.8)
= 7.8000 mm.

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained :	14.9,	Allowable :	137.9 N./mm^2	Passed
Expansion :	0.0,	Allowable :	329.9 N./mm^2	Passed
Occasional :	1.9,	Allowable :	183.4 N./mm^2	Passed
Shear :	9.6,	Allowable :	96.5 N./mm^2	Passed

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :

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

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

Calculated Minimum Design Metal Temperature               -104 °C

Governing MDMT of all the sub-joints of this Junction  :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ANSI B16.5/47 flange per Matl. Specification       -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)           -48 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
`Design Pressure/Ambient Rating = 23.00/51.10 = 0.450`

Weld Size Calculations, Description: LG2

```
Intermediate Calc. for nozzle/shell Welds   Tmin     13.6000  mm.
```

Results Per UW-16.1:

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

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (8.642 - 2.468 + 2 * 13.6 * 1 *
    (1 * 19 - 15.22 ) )137.9 )
  = 99.34 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 8.923 + 0 + 1 - 0 * 1 ) * 137.9
  = 136.82 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 8.923 + 0 + 1 + ( 5.168 ) ) * 137.9
  = 208.08 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.923 + 0 + 1 + 0 + ( 5.168 ) ) * 137.9
  = 208.08 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.142/2.0 ) * 84 * 10 * 0.49 * 137.9
```

= 89. kN

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.142 * 35.2) * (16.6 - 3) * 0.7 * 137.9
= 145. kN

Tension, Shell Groove Weld [Tngw]:
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= (3.142/2.0) * 84 * (18.5 - 3) * 0.74 * 137.9
= 209. kN

Strength of Failure Paths:

PATH11 = (SONW + SNW) = (89.15 + 145.2) = 234.3 kN
PATH22 = (Sonw + Tpgw + Tngw + Sinw)
= (89.15 + 0 + 208.7 + 0) = 297.8 kN
PATH33 = (Sonw + Tngw + Sinw)
= (89.15 + 208.7 + 0) = 297.8 kN

Summary of Failure Path Calculations:
Path 1-1 = 234 kN , must exceed W = 99 kN or W1 = 136 kN
Path 2-2 = 297 kN , must exceed W = 99 kN or W2 = 208 kN
Path 3-3 = 297 kN , must exceed W = 99 kN or W3 = 208 kN

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 24.354 bars

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

Nozzle is O.K. for the External Pressure 1.100 bars

The Drop for this Nozzle is : 0.9806 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.9806 mm.

Input Echo, WRC107/537 Item 1, Description: LG2 :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1800.000	mm.
Vessel Thickness	Tv	22.000	mm.
Design Temperature		125.00	°C
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	137.90	N./mm^2
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	ID	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	50.800	mm.
Nozzle Thickness	Tn	16.600	mm.
Nozzle Material		SA-350 LF2	
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm^2
Design Internal Pressure	Dp	23.002	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	2.0	kN
Longitudinal Shear	(SUS)	Vl	2.0	kN
Circumferential Shear	(SUS)	Vc	2.0	kN
Circumferential Moment	(SUS)	Mc	400.0	N-m
Longitudinal Moment	(SUS)	Ml	400.0	N-m
Torsional Moment	(SUS)	Mt	500.0	N-m

Use Interactive Control		No
WRC107 Version	Version	March 1979
Include Pressure Stress Indices per Div. 2		No
Compute Pressure Stress per WRC-368		No
Local Loads applied at end of Nozzle/Attachment		No

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

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

```
= NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
= 84.0 + 2 * 1.65 * sqrt( 912.5 ( 22.0 - 3.0 ) )
= 518.517 mm.
```

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	2.0	kN
Circumferential Shear	VC	2.0	kN
Longitudinal Shear	VL	2.0	kN
Circumferential Moment	MC	400.0	N-m
Longitudinal Moment	ML	400.0	N-m
Torsional Moment	MT	500.0	N-m

Dimensionless Parameters used : Gamma = 48.03

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.040	4C	9.159	(A,B)
N(PHI) / (P/Rm)	0.040	3C	9.133	(C,D)
M(PHI) / (P)	0.040	2C1	0.159	(A,B)
M(PHI) / (P)	0.040	1C	0.201	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.040	3A	0.511	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.040	1A	0.104	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.040	3B	2.216	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.040	1B	0.060	(A,B,C,D)
N(x) / (P/Rm)	0.040	3C	9.133	(A,B)
N(x) / (P/Rm)	0.040	4C	9.159	(C,D)
M(x) / (P)	0.040	1C1	0.208	(A,B)
M(x) / (P)	0.040	2C	0.159	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.040	4A	0.692	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.040	2A	0.062	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.040	4B	0.536	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.040	2B	0.100	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1
Circ. Bend. P	-5.3	5.3	-5.3	5.3	-6.7	6.7	-6.7	6.7
Circ. Memb. MC	0.0	0.0	0.0	0.0	-0.3	-0.3	0.3	0.3
Circ. Memb. MC	0.0	0.0	0.0	0.0	-18.7	18.7	18.7	-18.7
Circ. Memb. ML	-1.4	-1.4	1.4	1.4	0.0	0.0	0.0	0.0
Circ. Bend. ML	-10.9	10.9	10.9	-10.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-18.6	13.7	6.0	-5.3	-26.8	24.0	11.3	-12.8
Long. Memb. P	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1
Long. Bend. P	-6.9	6.9	-6.9	6.9	-5.3	5.3	-5.3	5.3
Long. Memb. MC	0.0	0.0	0.0	0.0	-0.4	-0.4	0.4	0.4
Long. Bend. MC	0.0	0.0	0.0	0.0	-11.3	11.3	11.3	-11.3
Long. Memb. ML	-0.3	-0.3	0.3	0.3	0.0	0.0	0.0	0.0
Long. Bend. ML	-18.0	18.0	18.0	-18.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-26.3	23.6	10.4	-11.8	-18.1	15.1	5.4	-6.6
Shear VC	0.8	0.8	-0.8	-0.8	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.8	-0.8	0.8	0.8
Shear MT	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Tot. Shear	3.2	3.2	1.6	1.6	1.6	1.6	3.2	3.2
Str. Int.	27.5	24.5	10.9	12.2	27.1	24.3	12.7	14.1

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Circ. Pl (SUS)	-2.4	-2.4	0.3	0.3	-1.4	-1.4	-0.7	-0.7
Circ. Q (SUS)	-16.2	16.2	5.6	-5.6	-25.4	25.4	12.1	-12.1
Long. Pm (SUS)	54.1	54.1	54.1	54.1	54.1	54.1	54.1	54.1
Long. Pl (SUS)	-1.4	-1.4	-0.7	-0.7	-1.5	-1.5	-0.6	-0.6
Long. Q (SUS)	-25.0	25.0	11.1	-11.1	-16.6	16.6	6.0	-6.0
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.8	0.8	-0.8	-0.8	-0.8	-0.8	0.8	0.8
Shear Q (SUS)	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Pm (SUS)	108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Pm+Pl (SUS)	105.8	108.1	108.5	110.8	106.8	109.1	107.5	109.8
Pm+Pl+Q (Total)	89.7	124.4	114.2	105.2	81.4	134.6	119.7	97.9

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

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

Pm (SUS)	110.49	137.90	Passed
Pm+Pl (SUS)	110.83	206.85	Passed
Pm+Pl+Q (TOTAL)	134.57	413.70	Passed

INPUT VALUES, Nozzle Description: LT2 From : 20

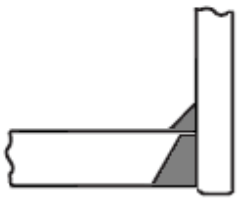
Pressure for Reinforcement Calculations	P	23.002	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1800.00	mm.
Design Length of Section	L	3299.9998	mm.
Shell Finished (Minimum) Thickness	t	22.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		250.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm^2
Allowable Stress At Ambient	Sna	137.90	N./mm^2
Diameter Basis (for tr calc only)		ID	
Layout Angle		270.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.5000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		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: LT2

ASME Code, Section VIII, Div. 1, 2017, 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)
= (23*903)/(137.9*1-0.6*23)
= 15.2153 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)
= (23*28.4)/(137.9*1-0.6*23)
= 0.4785 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.3963 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	122.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	61.0000	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	34.0000	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, 1)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	8.642	2.191	NA
Area in Shell	A1	2.468	7.357	NA
Area in Nozzle Wall	A2	8.923	8.979	NA

Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	12.390	17.336	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (56.8*15.22*1+2*13.6*15.22*1*(1-1))
= 8.642 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)
= 65.2 (1 * 19 - 1 * 15.22) - 2 * 13.6
(1 * 19 - 1 * 15.22) * (1 - 1)
= 2.468 cm^2

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 34)(13.6 - 0.479)1
= 8.923 cm^2

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 10² * 1 + (0)² * 1
= 1.000 cm^2

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

Wall Thickness for Internal/External pressures ta = 3.4785 mm.
Wall Thickness per UG16(b), tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 18.2153 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 18.2153 mm.
Wall Thickness, shell/head, external pressure trb2 = 3.7207 mm.
Wall Thickness tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45 tb3 = 7.8000 mm.

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[7.8, max(18.22, 4.5)]
= 7.8000 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(3.479, 7.8)
= 7.8000 mm.

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained :	14.9,	Allowable :	137.9 N./mm^2	Passed
Expansion :	0.0,	Allowable :	329.9 N./mm^2	Passed
Occasional :	1.9,	Allowable :	183.4 N./mm^2	Passed
Shear :	9.6,	Allowable :	96.5 N./mm^2	Passed

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :

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

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

Calculated Minimum Design Metal Temperature               -104 °C

Governing MDMT of all the sub-joints of this Junction  :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ANSI B16.5/47 flange per Matl. Specification       -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)           -48 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
`Design Pressure/Ambient Rating = 23.00/51.10 = 0.450`

Weld Size Calculations, Description: LT2

```
Intermediate Calc. for nozzle/shell Welds   Tmin     13.6000  mm.
```

Results Per UW-16.1:

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

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (8.642 - 2.468 + 2 * 13.6 * 1 *
    (1 * 19 - 15.22 ) )137.9 )
  = 99.34 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 8.923 + 0 + 1 - 0 * 1 ) * 137.9
  = 136.82 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 8.923 + 0 + 1 + ( 5.168 ) ) * 137.9
  = 208.08 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.923 + 0 + 1 + 0 + ( 5.168 ) ) * 137.9
  = 208.08 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.142/2.0 ) * 84 * 10 * 0.49 * 137.9
```

= 89. kN

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.142 * 35.2) * (16.6 - 3) * 0.7 * 137.9
= 145. kN

Tension, Shell Groove Weld [Tngw]:
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= (3.142/2.0) * 84 * (18.5 - 3) * 0.74 * 137.9
= 209. kN

Strength of Failure Paths:

PATH11 = (SONW + SNW) = (89.15 + 145.2) = 234.3 kN
PATH22 = (Sonw + Tpgw + Tngw + Sinw)
= (89.15 + 0 + 208.7 + 0) = 297.8 kN
PATH33 = (Sonw + Tngw + Sinw)
= (89.15 + 208.7 + 0) = 297.8 kN

Summary of Failure Path Calculations:
Path 1-1 = 234 kN , must exceed W = 99 kN or W1 = 136 kN
Path 2-2 = 297 kN , must exceed W = 99 kN or W2 = 208 kN
Path 3-3 = 297 kN , must exceed W = 99 kN or W3 = 208 kN

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 24.354 bars

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

Nozzle is O.K. for the External Pressure 1.100 bars

The Drop for this Nozzle is : 0.9806 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.9806 mm.

Input Echo, WRC107/537 Item 1, Description: LT2 :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1800.000	mm.
Vessel Thickness	Tv	22.000	mm.
Design Temperature		125.00	°C
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	137.90	N./mm^2
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	ID	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	50.800	mm.
Nozzle Thickness	Tn	16.600	mm.
Nozzle Material		SA-350 LF2	
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm^2
Design Internal Pressure	Dp	23.002	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	2.0	kN
Longitudinal Shear	(SUS)	Vl	2.0	kN
Circumferential Shear	(SUS)	Vc	2.0	kN
Circumferential Moment	(SUS)	Mc	400.0	N-m
Longitudinal Moment	(SUS)	Ml	400.0	N-m
Torsional Moment	(SUS)	Mt	500.0	N-m

Use Interactive Control		No
WRC107 Version	Version	March 1979
Include Pressure Stress Indices per Div. 2		No
Compute Pressure Stress per WRC-368		No
Local Loads applied at end of Nozzle/Attachment		No

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

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

```
= NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
= 84.0 + 2 * 1.65 * sqrt( 912.5 ( 22.0 - 3.0 ) )
= 518.517 mm.
```

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	2.0	kN
Circumferential Shear	VC	2.0	kN
Longitudinal Shear	VL	2.0	kN
Circumferential Moment	MC	400.0	N-m
Longitudinal Moment	ML	400.0	N-m
Torsional Moment	MT	500.0	N-m

Dimensionless Parameters used : Gamma = 48.03

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.040	4C	9.159	(A,B)
N(PHI) / (P/Rm)	0.040	3C	9.133	(C,D)
M(PHI) / (P)	0.040	2C1	0.159	(A,B)
M(PHI) / (P)	0.040	1C	0.201	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.040	3A	0.511	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.040	1A	0.104	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.040	3B	2.216	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.040	1B	0.060	(A,B,C,D)
N(x) / (P/Rm)	0.040	3C	9.133	(A,B)
N(x) / (P/Rm)	0.040	4C	9.159	(C,D)
M(x) / (P)	0.040	1C1	0.208	(A,B)
M(x) / (P)	0.040	2C	0.159	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.040	4A	0.692	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.040	2A	0.062	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.040	4B	0.536	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.040	2B	0.100	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1
Circ. Bend. P	-5.3	5.3	-5.3	5.3	-6.7	6.7	-6.7	6.7
Circ. Memb. MC	0.0	0.0	0.0	0.0	-0.3	-0.3	0.3	0.3
Circ. Memb. MC	0.0	0.0	0.0	0.0	-18.7	18.7	18.7	-18.7
Circ. Memb. ML	-1.4	-1.4	1.4	1.4	0.0	0.0	0.0	0.0
Circ. Bend. ML	-10.9	10.9	10.9	-10.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-18.6	13.7	6.0	-5.3	-26.8	24.0	11.3	-12.8
Long. Memb. P	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1
Long. Bend. P	-6.9	6.9	-6.9	6.9	-5.3	5.3	-5.3	5.3
Long. Memb. MC	0.0	0.0	0.0	0.0	-0.4	-0.4	0.4	0.4
Long. Bend. MC	0.0	0.0	0.0	0.0	-11.3	11.3	11.3	-11.3
Long. Memb. ML	-0.3	-0.3	0.3	0.3	0.0	0.0	0.0	0.0
Long. Bend. ML	-18.0	18.0	18.0	-18.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-26.3	23.6	10.4	-11.8	-18.1	15.1	5.4	-6.6
Shear VC	0.8	0.8	-0.8	-0.8	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.8	-0.8	0.8	0.8
Shear MT	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Tot. Shear	3.2	3.2	1.6	1.6	1.6	1.6	3.2	3.2
Str. Int.	27.5	24.5	10.9	12.2	27.1	24.3	12.7	14.1

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Circ. Pl (SUS)	-2.4	-2.4	0.3	0.3	-1.4	-1.4	-0.7	-0.7
Circ. Q (SUS)	-16.2	16.2	5.6	-5.6	-25.4	25.4	12.1	-12.1
Long. Pm (SUS)	54.1	54.1	54.1	54.1	54.1	54.1	54.1	54.1
Long. Pl (SUS)	-1.4	-1.4	-0.7	-0.7	-1.5	-1.5	-0.6	-0.6
Long. Q (SUS)	-25.0	25.0	11.1	-11.1	-16.6	16.6	6.0	-6.0
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.8	0.8	-0.8	-0.8	-0.8	-0.8	0.8	0.8
Shear Q (SUS)	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Pm (SUS)	108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Pm+Pl (SUS)	105.8	108.1	108.5	110.8	106.8	109.1	107.5	109.8
Pm+Pl+Q (Total)	89.7	124.4	114.2	105.2	81.4	134.6	119.7	97.9

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

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

Pm (SUS)	110.49	137.90	Passed
Pm+Pl (SUS)	110.83	206.85	Passed
Pm+Pl+Q (TOTAL)	134.57	413.70	Passed

INPUT VALUES, Nozzle Description: SV From : 20

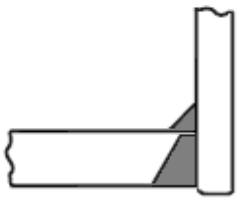
Pressure for Reinforcement Calculations	P	23.001	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1800.00	mm.
Design Length of Section	L	3299.9998	mm.
Shell Finished (Minimum) Thickness	t	22.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1550.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm^2
Allowable Stress At Ambient	Sna	137.90	N./mm^2
Diameter Basis (for tr calc only)		ID	
Layout Angle		0.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.5000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		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: SV

ASME Code, Section VIII, Div. 1, 2017, 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)
= (23*903)/(137.9*1-0.6*23)
= 15.2148 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)
= (23*28.4)/(137.9*1-0.6*23)
= 0.4785 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.3963 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	122.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	61.0000	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	34.0000	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, 1)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	8.642	2.191	NA
Area in Shell	A1	2.468	7.357	NA
Area in Nozzle Wall	A2	8.923	8.979	NA

Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	12.391	17.336	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (56.8*15.21*1+2*13.6*15.21*1*(1-1))
= 8.642 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)
= 65.2 (1 * 19 - 1 * 15.21) - 2 * 13.6
(1 * 19 - 1 * 15.21) * (1 - 1)
= 2.468 cm^2

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 34)(13.6 - 0.479)1
= 8.923 cm^2

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 10² * 1 + (0)² * 1
= 1.000 cm^2

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

Wall Thickness for Internal/External pressures ta = 3.4785 mm.
Wall Thickness per UG16(b), tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 18.2148 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 18.2148 mm.
Wall Thickness, shell/head, external pressure trb2 = 3.7207 mm.
Wall Thickness tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45 tb3 = 7.8000 mm.

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[7.8, max(18.21, 4.5)]
= 7.8000 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(3.479, 7.8)
= 7.8000 mm.

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained :	14.9,	Allowable :	137.9 N./mm^2	Passed
Expansion :	0.0,	Allowable :	329.9 N./mm^2	Passed
Occasional :	1.9,	Allowable :	183.4 N./mm^2	Passed
Shear :	9.6,	Allowable :	96.5 N./mm^2	Passed

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :

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

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

Calculated Minimum Design Metal Temperature               -104 °C

Governing MDMT of all the sub-joints of this Junction  :  -104 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ANSI B16.5/47 flange per Matl. Specification       -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)           -48 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
`Design Pressure/Ambient Rating = 23.00/51.10 = 0.450`

Weld Size Calculations, Description: SV

```
Intermediate Calc. for nozzle/shell Welds   Tmin     13.6000  mm.
```

Results Per UW-16.1:

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

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

Weld Load [W]:
```
= max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max( 0, (8.642 - 2.468 + 2 * 13.6 * 1 *
  (1 * 19 - 15.21 ) )137.9 )
= 99.33 kN
```

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

Weld Load [W1]:
```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 8.923 + 0 + 1 - 0 * 1 ) * 137.9
= 136.82 kN
```

Weld Load [W2]:
```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 8.923 + 0 + 1 + ( 5.168 ) ) * 137.9
= 208.08 kN
```

Weld Load [W3]:
```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 8.923 + 0 + 1 + 0 + ( 5.168 ) ) * 137.9
= 208.08 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.142/2.0 ) * 84 * 10 * 0.49 * 137.9
```

= 89. kN

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.142 * 35.2) * (16.6 - 3) * 0.7 * 137.9
= 145. kN

Tension, Shell Groove Weld [Tngw]:
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= (3.142/2.0) * 84 * (18.5 - 3) * 0.74 * 137.9
= 209. kN

Strength of Failure Paths:

PATH11 = (SONW + SNW) = (89.15 + 145.2) = 234.3 kN
PATH22 = (Sonw + Tpgw + Tngw + Sinw)
= (89.15 + 0 + 208.7 + 0) = 297.8 kN
PATH33 = (Sonw + Tngw + Sinw)
= (89.15 + 208.7 + 0) = 297.8 kN

Summary of Failure Path Calculations:
Path 1-1 = 234 kN , must exceed W = 99 kN or W1 = 136 kN
Path 2-2 = 297 kN , must exceed W = 99 kN or W2 = 208 kN
Path 3-3 = 297 kN , must exceed W = 99 kN or W3 = 208 kN

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 24.353 bars

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

Nozzle is O.K. for the External Pressure 1.100 bars

The Drop for this Nozzle is : 0.9806 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.9806 mm.

Input Echo, WRC107/537 Item 1, Description: SV :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1800.000	mm.
Vessel Thickness	Tv	22.000	mm.
Design Temperature		125.00	°C
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	137.90	N./mm^2
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	ID	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	50.800	mm.
Nozzle Thickness	Tn	16.600	mm.
Nozzle Material		SA-350 LF2	
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm^2
Design Internal Pressure	Dp	23.001	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	2.0	kN
Longitudinal Shear	(SUS)	Vl	2.0	kN
Circumferential Shear	(SUS)	Vc	2.0	kN
Circumferential Moment	(SUS)	Mc	400.0	N-m
Longitudinal Moment	(SUS)	Ml	400.0	N-m
Torsional Moment	(SUS)	Mt	500.0	N-m

Use Interactive Control		No
WRC107 Version	Version	March 1979
Include Pressure Stress Indices per Div. 2		No
Compute Pressure Stress per WRC-368		No
Local Loads applied at end of Nozzle/Attachment		No

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

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

```
= NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
= 84.0 + 2 * 1.65 * sqrt( 912.5 ( 22.0 - 3.0 ) )
= 518.517 mm.
```

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	2.0	kN
Circumferential Shear	VC	2.0	kN
Longitudinal Shear	VL	2.0	kN
Circumferential Moment	MC	400.0	N-m
Longitudinal Moment	ML	400.0	N-m
Torsional Moment	MT	500.0	N-m

Dimensionless Parameters used : Gamma = 48.03

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.040	4C	9.159	(A,B)
N(PHI) / (P/Rm)	0.040	3C	9.133	(C,D)
M(PHI) / (P)	0.040	2C1	0.159	(A,B)
M(PHI) / (P)	0.040	1C	0.201	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.040	3A	0.511	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.040	1A	0.104	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.040	3B	2.216	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.040	1B	0.060	(A,B,C,D)
N(x) / (P/Rm)	0.040	3C	9.133	(A,B)
N(x) / (P/Rm)	0.040	4C	9.159	(C,D)
M(x) / (P)	0.040	1C1	0.208	(A,B)
M(x) / (P)	0.040	2C	0.159	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.040	4A	0.692	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.040	2A	0.062	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.040	4B	0.536	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.040	2B	0.100	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1
Circ. Bend. P	-5.3	5.3	-5.3	5.3	-6.7	6.7	-6.7	6.7
Circ. Memb. MC	0.0	0.0	0.0	0.0	-0.3	-0.3	0.3	0.3
Circ. Memb. MC	0.0	0.0	0.0	0.0	-18.7	18.7	18.7	-18.7
Circ. Memb. ML	-1.4	-1.4	1.4	1.4	0.0	0.0	0.0	0.0
Circ. Bend. ML	-10.9	10.9	10.9	-10.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-18.6	13.7	6.0	-5.3	-26.8	24.0	11.3	-12.8
Long. Memb. P	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1
Long. Bend. P	-6.9	6.9	-6.9	6.9	-5.3	5.3	-5.3	5.3
Long. Memb. MC	0.0	0.0	0.0	0.0	-0.4	-0.4	0.4	0.4
Long. Bend. MC	0.0	0.0	0.0	0.0	-11.3	11.3	11.3	-11.3
Long. Memb. ML	-0.3	-0.3	0.3	0.3	0.0	0.0	0.0	0.0
Long. Bend. ML	-18.0	18.0	18.0	-18.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-26.3	23.6	10.4	-11.8	-18.1	15.1	5.4	-6.6
Shear VC	0.8	0.8	-0.8	-0.8	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.8	-0.8	0.8	0.8
Shear MT	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Tot. Shear	3.2	3.2	1.6	1.6	1.6	1.6	3.2	3.2
Str. Int.	27.5	24.5	10.9	12.2	27.1	24.3	12.7	14.1

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Circ. Pl (SUS)	-2.4	-2.4	0.3	0.3	-1.4	-1.4	-0.7	-0.7
Circ. Q (SUS)	-16.2	16.2	5.6	-5.6	-25.4	25.4	12.1	-12.1
Long. Pm (SUS)	54.1	54.1	54.1	54.1	54.1	54.1	54.1	54.1
Long. Pl (SUS)	-1.4	-1.4	-0.7	-0.7	-1.5	-1.5	-0.6	-0.6
Long. Q (SUS)	-25.0	25.0	11.1	-11.1	-16.6	16.6	6.0	-6.0
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.8	0.8	-0.8	-0.8	-0.8	-0.8	0.8	0.8
Shear Q (SUS)	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Pm (SUS)	108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Pm+Pl (SUS)	105.7	108.0	108.5	110.8	106.8	109.1	107.5	109.8
Pm+Pl+Q (Total)	89.7	124.4	114.2	105.2	81.4	134.6	119.7	97.9

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

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

Pm (SUS)	110.48	137.90	Passed
Pm+Pl (SUS)	110.83	206.85	Passed
Pm+Pl+Q (TOTAL)	134.57	413.70	Passed

INPUT VALUES, Nozzle Description: M2 From : 20

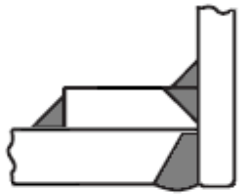
Pressure for Reinforcement Calculations	P	23.001	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1800.00	mm.
Design Length of Section	L	3299.9998	mm.
Shell Finished (Minimum) Thickness	t	22.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		2300.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type		Smls. & wld. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		6.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	22.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
Diameter of Pad along vessel surface	Dp	368.2750	mm.
Thickness of Pad	te	15.0000	mm.
Weld leg size between Pad and Shell	Wp	14.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	15.0000	mm.
Reinforcing Pad Width		100.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		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: M2

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation	6.625	in.
Actual Thickness Used in Calculation	0.378	in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (23*903)/(137.9*1-0.6*23)
= 15.2145 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)
= (23*84.14)/(117.9*1+0.4*23)
= 1.6287 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.5944 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	310.1452	mm.
Parallel to Vessel Wall, opening length	d	155.0726	mm.
Normal to Vessel Wall (Thickness Limit), pad side	Tlwp	31.5030	mm.

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

Weld Strength Reduction Factor [fr1]:
= min(1, Sn/Sv)
= min(1, 117.9/137.9)
= 0.855

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 117.9/137.9)
= 0.855

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(0.855, 1)
= 0.855

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	23.885	6.056	NA
Area in Shell	A1	5.798	17.283	NA
Area in Nozzle Wall	A2	2.679	3.236	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.855	0.855	NA
Area in Element	A5	21.281	21.281	NA
TOTAL AREA AVAILABLE	Atot	30.612	42.654	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Insufficient.
The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	265.2967	15.0000	mm.
Based on given Pad Diameter:	368.2750	10.2582	mm.
Based on the Estimated Diameter Limit:	308.5577	10.3742	mm.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (155.1*15.21*1+2*6.601*15.21*1*(1-0.855))
= 23.885 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)
= 155.1 (1 * 19 - 1 * 15.21) - 2 * 6.601
(1 * 19 - 1 * 15.21) * (1 - 0.855)
= 5.798 cm^2

Area Available in Nozzle Wall Projecting Outward [A2]:
= (2 * Tlwp) * (tn - trn) * fr2
= (2 * 31.5) * (6.601 - 1.629) * 0.855
= 2.679 cm^2

Area Available in Welds [A41 + A42 + A43]:
= Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
= 10² * 0.855 + (0)² * 0.855 + 0² * 1
= 0.855 cm^2

Area Available in Element [A5]:
= (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
= (310.1 - 168.3) * 15 * 1
= 21.281 cm^2

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

Wall Thickness for Internal/External pressures ta = 4.6287 mm.
Wall Thickness per UG16(b), tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 18.2145 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 18.2145 mm.
Wall Thickness, shell/head, external pressure trb2 = 3.7207 mm.
Wall Thickness tb2 = max(trb2, tr16b) = 4.5000 mm.

Wall Thickness per table UG-45 tb3 = 9.2200 mm.

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[9.22, max(18.21, 4.5)]
= 9.2200 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(4.629, 9.22)
= 9.2200 mm.

Available Nozzle Neck Thickness = 9.6012 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):

Sustained :	55.9,	Allowable :	117.9 N./mm^2	Passed
Expansion :	0.0,	Allowable :	238.8 N./mm^2	Passed
Occasional :	13.0,	Allowable :	156.8 N./mm^2	Passed
Shear :	24.1,	Allowable :	82.5 N./mm^2	Passed

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

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

Impact Test Temperature provided per Specification -46 °C

Calculated Minimum Design Metal Temperature -104 °C

Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :

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

Impact Test Temperature provided per Specification -46 °C

Calculated Minimum Design Metal Temperature -104 °C

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

Govrn. thk, tg = 9.601, tr = 1.629, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.247, Temp. Reduction = 78 °C

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

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

Govrn. thk, tg = 15, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.801, Temp. Reduction = 11 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

Min Metal Temp. w/o impact per UCS-66, Curve D -47 °C
Min Metal Temp. at Required thickness (UCS 66.1) -48 °C

Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :

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

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

Calculated Minimum Design Metal Temperature               -104 °C

Governing MDMT of the Nozzle                          :   -104 °C
Governing MDMT of the Reinforcement Pad               :    -48 °C
Governing MDMT of all the sub-joints of this Junction :    -48 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ANSI B16.5/47 flange per Matl. Specification       -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)           -48 °C
Flange MDMT with Temp reduction per UCS-66(i)(3)          -104 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
`Design Pressure/Ambient Rating = 23.00/51.10 = 0.450`

Note:
Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.

Weld Size Calculations, Description: M2

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.6012  mm.
Intermediate Calc. for pad/shell Welds   TminPad     15.0000  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.6208 = 0.7 * tmin.	7.0700 = 0.7 * Wo mm.
Pad Weld	7.5000 = 0.5*TminPad	9.8980 = 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, (23.88 - 5.798 + 2 * 6.601 * 0.855 *
    (1 * 19 - 15.21 ) )137.9 )
  = 255.29 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 2.679 + 21.28 + 0.855 - 0 * 0.855 ) * 137.9
  = 342.16 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 2.679 + 0 + 0.855 + ( 2.145 ) ) * 137.9
  = 78.30 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 2.679 + 0 + 0.855 + 21.28 + ( 2.145 ) ) * 137.9
  = 371.73 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.142/2.0 ) * 168.3 * 10 * 0.49 * 117.9
  = 153. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.142/2.0 ) * 368.3 * 14 * 0.49 * 137.9
  = 547. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.142 * 80.84 ) * ( 9.601 - 3 ) * 0.7 * 117.9
  = 138. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.142/2 ) * 168.3 * 15 * 0.74 * 137.9
  = 405. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.142/2.0 ) * 168.3 * ( 22 - 3 ) * 0.74 * 137.9
  = 512. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 547.2 + 138.3 ) = 685.5 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 152.7 + 404.6 + 512.5 + 0 ) = 1070 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 547.2 + 512.5 + 0 ) = 1060 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 685 kN , must exceed W = 255 kN  or W1 = 342 kN
 Path 2-2 = 1069 kN , must exceed W = 255 kN  or W2 = 78 kN
 Path 3-3 = 1059 kN , must exceed W = 255 kN  or W3 = 371 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case       24.353  bars
```

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

```
 Nozzle is O.K. for the External Pressure                1.100  bars
```

The Drop for this Nozzle is : 3.9414 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 225.9414 mm.

Input Echo, WRC107/537 Item 1, Description: M2 :

```
 Diameter Basis for Vessel                Vbasis      ID
 Cylindrical or Spherical Vessel          Cylsph      Cylindrical
 Internal Corrosion Allowance               Cas      3.0000  mm.
 Vessel Diameter                             Dv    1800.000  mm.
 Vessel Thickness                            Tv      22.000  mm.

 Design Temperature                                  125.00  °C
 Vessel Material                                  SA-516 70
 Vessel Cold S.I. Allowable                 Smc      137.90  N./mm^2
 Vessel Hot  S.I. Allowable                 Smh      137.90  N./mm^2

 Attachment Type                           Type      Round
```

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no: K.O. Drum (D-PK6101-3)
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for K.O. Drum (D-PK6101-3)
Nozzle Calcs.: M2 Nozl: 23 8:44pm Dec 24,2021

Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	168.275	mm.
Nozzle Thickness	Tn	9.601	mm.
Nozzle Material		SA-333 6	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm^2
Thickness of Reinforcing Pad	Tpad	15.000	mm.
Diameter of Reinforcing Pad	Dpad	368.275	mm.
Design Internal Pressure	Dp	23.001	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	6.0	kN
Longitudinal Shear	(SUS)	Vl	6.0	kN
Circumferential Shear	(SUS)	Vc	6.0	kN
Circumferential Moment	(SUS)	Mc	3800.0	N-m
Longitudinal Moment	(SUS)	Ml	3800.0	N-m
Torsional Moment	(SUS)	Mt	4700.0	N-m

Use Interactive Control		No
WRC107 Version	Version	March 1979
Include Pressure Stress Indices per Div. 2		No
Compute Pressure Stress per WRC-368		No
Local Loads applied at end of Nozzle/Attachment		No

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

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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 168.275 + 2 * 1.65 * sqrt( 912.5 ( 22.0 - 3.0 ) )
  = 602.792 mm.
```

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	6.0	kN
Circumferential Shear	VC	6.0	kN
Longitudinal Shear	VL	6.0	kN
Circumferential Moment	MC	3800.0	N-m
Longitudinal Moment	ML	3800.0	N-m
Torsional Moment	MT	4700.0	N-m

Dimensionless Parameters used : Gamma = 27.06

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.080	4C	5.021	(A,B)
N(PHI) / (P/Rm)	0.080	3C	4.672	(C,D)
M(PHI) / (P)	0.080	2C1	0.127	(A,B)
M(PHI) / (P)	0.080	1C	0.164	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.080	3A	0.544	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.080	1A	0.102	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.080	3B	1.930	(A,B,C,D)

M(PHI) / (ML/(Rm * Beta))	0.080	1B	0.053	(A,B,C,D)
N(x) / (P/Rm)	0.080	3C	4.672	(A,B)
N(x) / (P/Rm)	0.080	4C	5.021	(C,D)
M(x) / (P)	0.080	1C1	0.166	(A,B)
M(x) / (P)	0.080	2C	0.127	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.080	4A	0.711	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.080	2A	0.059	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.080	4B	0.526	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.080	2B	0.089	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-1.0	-1.0	-1.0	-1.0	-0.9	-0.9	-0.9	-0.9
Circ. Bend. P	-4.0	4.0	-4.0	4.0	-5.1	5.1	-5.1	5.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	-27.2	27.2	27.2	-27.2
Circ. Memb. ML	-3.2	-3.2	3.2	3.2	0.0	0.0	0.0	0.0
Circ. Bend. ML	-14.3	14.3	14.3	-14.3	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-22.4	14.1	12.5	-8.1	-34.2	30.6	22.1	-22.1
Long. Memb. P	-0.9	-0.9	-0.9	-0.9	-1.0	-1.0	-1.0	-1.0
Long. Bend. P	-5.2	5.2	-5.2	5.2	-4.0	4.0	-4.0	4.0
Long. Memb. MC	0.0	0.0	0.0	0.0	-1.2	-1.2	1.2	1.2
Long. Bend. MC	0.0	0.0	0.0	0.0	-15.8	15.8	15.8	-15.8
Long. Memb. ML	-0.9	-0.9	0.9	0.9	0.0	0.0	0.0	0.0
Long. Bend. ML	-23.8	23.8	23.8	-23.8	0.0	0.0	0.0	0.0
Tot. Long. Str.	-30.8	27.2	18.6	-18.7	-21.9	17.6	12.1	-11.7
Shear VC	0.7	0.7	-0.7	-0.7	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Shear MT	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Tot. Shear	3.8	3.8	2.4	2.4	2.4	2.4	3.8	3.8
Str. Int.	32.2	28.2	19.5	19.2	34.6	31.0	23.4	23.4

Dimensionless Parameters used : Gamma = 48.03

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.177	4C	6.899	(A,B)
N(PHI) / (P/Rm)	0.177	3C	4.682	(C,D)
M(PHI) / (P)	0.177	2C1	0.037	(A,B)
M(PHI) / (P)	0.177	1C	0.069	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.177	3A	1.950	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.177	1A	0.076	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.177	3B	5.000	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.177	1B	0.026	(A,B,C,D)
N(x) / (P/Rm)	0.177	3C	4.682	(A,B)
N(x) / (P/Rm)	0.177	4C	6.899	(C,D)
M(x) / (P)	0.177	1C1	0.072	(A,B)

M(x) / (P)	0.177	2C	0.037	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.177	4A	3.601	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.177	2A	0.037	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.177	4B	1.941	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.177	2B	0.037	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-2.4	-2.4	-2.4	-2.4	-1.6	-1.6	-1.6	-1.6
Circ. Bend. P	-3.7	3.7	-3.7	3.7	-6.9	6.9	-6.9	6.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	-2.7	-2.7	2.7	2.7
Circ. Memb. MC	0.0	0.0	0.0	0.0	-29.7	29.7	29.7	-29.7
Circ. Memb. ML	-6.8	-6.8	6.8	6.8	0.0	0.0	0.0	0.0
Circ. Bend. ML	-10.3	10.3	10.3	-10.3	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-23.2	4.8	11.0	-2.2	-40.9	32.4	23.8	-21.8
Long. Memb. P	-1.6	-1.6	-1.6	-1.6	-2.4	-2.4	-2.4	-2.4
Long. Bend. P	-7.1	7.1	-7.1	7.1	-3.7	3.7	-3.7	3.7
Long. Memb. MC	0.0	0.0	0.0	0.0	-4.9	-4.9	4.9	4.9
Long. Bend. MC	0.0	0.0	0.0	0.0	-14.4	14.4	14.4	-14.4
Long. Memb. ML	-2.6	-2.6	2.6	2.6	0.0	0.0	0.0	0.0
Long. Bend. ML	-14.7	14.7	14.7	-14.7	0.0	0.0	0.0	0.0
Tot. Long. Str.	-26.1	17.6	8.6	-6.5	-25.4	10.8	13.2	-8.2
Shear VC	0.5	0.5	-0.5	-0.5	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.5	-0.5	0.5	0.5
Shear MT	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Tot. Shear	1.7	1.7	0.6	0.6	0.6	0.6	1.7	1.7
Str. Int.	26.9	17.8	11.1	6.6	41.0	32.4	24.1	22.0

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	60.0	62.3	60.0	62.3	60.0	62.3	60.0	62.3
Circ. Pl (SUS)	-4.1	-4.1	2.2	2.2	-1.8	-1.8	0.0	0.0
Circ. Q (SUS)	-18.2	18.2	10.3	-10.3	-32.4	32.4	22.1	-22.1
Long. Pm (SUS)	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Long. Pl (SUS)	-1.8	-1.8	-0.0	-0.0	-2.1	-2.1	0.2	0.2
Long. Q (SUS)	-29.0	29.0	18.7	-18.7	-19.8	19.8	11.9	-11.9
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.7	0.7	-0.7	-0.7	-0.7	-0.7	0.7	0.7
Shear Q (SUS)	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Pm (SUS)	60.0	62.3	60.0	62.3	60.0	62.3	60.0	62.3

Pm+Pl (SUS)	55.8	58.1	62.2	64.5	58.2	60.5	60.0	62.3
Pm+Pl+Q (Total)	39.1	77.1	72.7	54.3	26.1	93.0	82.5	40.8

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	62.26	137.90	Passed
Pm+Pl (SUS)	64.50	206.85	Passed
Pm+Pl+Q (TOTAL)	92.96	413.70	Passed

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Circ. Pl (SUS)	-9.2	-9.2	4.4	4.4	-4.3	-4.3	1.0	1.0
Circ. Q (SUS)	-14.0	14.0	6.6	-6.6	-36.7	36.7	22.8	-22.8
Long. Pm (SUS)	54.1	54.1	54.1	54.1	54.1	54.1	54.1	54.1
Long. Pl (SUS)	-4.3	-4.3	1.0	1.0	-7.3	-7.3	2.5	2.5
Long. Q (SUS)	-21.8	21.8	7.6	-7.6	-18.1	18.1	10.7	-10.7
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.5	0.5	-0.5	-0.5	-0.5	-0.5	0.5	0.5
Shear Q (SUS)	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Pm (SUS)	108.2	110.5	108.2	110.5	108.2	110.5	108.2	110.5
Pm+Pl (SUS)	99.0	101.3	112.6	114.9	103.9	106.2	109.2	111.5
Pm+Pl+Q (Total)	85.0	115.4	119.2	108.3	67.3	142.9	132.1	88.8

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	110.48	137.90	Passed
Pm+Pl (SUS)	114.90	206.85	Passed
Pm+Pl+Q (TOTAL)	142.87	413.70	Passed

INPUT VALUES, Nozzle Description: T1 From : 20

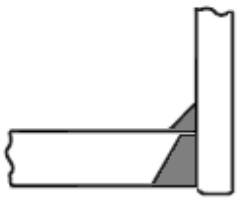
Pressure for Reinforcement Calculations	P	23.002	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1800.00	mm.
Design Length of Section	L	3299.9998	mm.
Shell Finished (Minimum) Thickness	t	22.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		750.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm^2
Allowable Stress At Ambient	Sna	137.90	N./mm^2
Diameter Basis (for tr calc only)		ID	
Layout Angle		270.00	deg
Diameter		1.5000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	15.9500	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.5000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		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: T1

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Inside Diameter Used in Calculation	1.500	in.
Actual Thickness Used in Calculation	0.628	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)
= (23*903)/(137.9*1-0.6*23)
= 15.2151 mm.

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]
= R(exp([P/(Sn*E)] - 1) per Appendix 1-2 (a)(1)
= 22.05(exp([23/(137.9*1]-1)
= 0.3709 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.3569 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	108.0000	mm.
Parallel to Vessel Wall	Rn+tn+t	54.0000	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	32.3750	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, 1)
= 1.000

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	6.710	1.701	NA
Area in Shell	A1	2.419	7.211	NA
Area in Nozzle Wall	A2	8.145	8.154	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	11.564	16.365	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)
= (44.1*15.22*1+2*12.95*15.22*1*(1-1))
= 6.710 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)
= 63.9 (1 * 19 - 1 * 15.22) - 2 * 12.95
(1 * 19 - 1 * 15.22) * (1 - 1)
= 2.419 cm^2

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 32.37)(12.95 - 0.371)1
= 8.145 cm^2

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 10² * 1 + (0)² * 1
= 1.000 cm^2

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
Wall Thickness for Internal/External pressures ta = 3.3709 mm.
Wall Thickness per UG16(b), tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 18.2151 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 18.2151 mm.
Wall Thickness, shell/head, external pressure trb2 = 3.7207 mm.
Wall Thickness tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45 tb3 = 7.5200 mm.

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[7.52, max(18.22, 4.5)]
= 7.5200 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(3.371, 7.52)
= 7.5200 mm.

Available Nozzle Neck Thickness = 15.9500 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :

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

Impact Test Temperature provided per Specification -46 °C

Calculated Minimum Design Metal Temperature -104 °C

Governing MDMT of all the sub-joints of this Junction : -104 °C

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

MDMT of ANSI B16.5/47 flange per Matl. Specification -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2) -48 °C

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
Design Pressure/Ambient Rating = 23.00/51.10 = 0.450

Weld Size Calculations, Description: T1

Intermediate Calc. for nozzle/shell Welds Tmin 12.9500 mm.

Results Per UW-16.1:

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

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

Weld Load [W]:
= max(0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max(0, (6.71 - 2.419 + 2 * 12.95 * 1 *
(1 * 19 - 15.22))137.9)
= 72.69 kN

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

Weld Load [W1]:
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= (8.145 + 0 + 1 - 0 * 1) * 137.9
= 126.10 kN

Weld Load [W2]:
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= (8.145 + 0 + 1 + (4.921)) * 137.9
= 193.95 kN

Weld Load [W3]:
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= (8.145 + 0 + 1 + 0 + (4.921)) * 137.9
= 193.95 kN

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
= (pi/2) * Dlo * Wo * 0.49 * Snw
= (3.142/2.0) * 70 * 10 * 0.49 * 137.9
= 74. kN

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.142 * 28.52) * (15.95 - 3) * 0.7 * 137.9
= 112. kN

Tension, Shell Groove Weld [Tngw]:
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= (3.142/2.0) * 70 * (18.5 - 3) * 0.74 * 137.9

= 174. kN

Strength of Failure Paths:

PATH11 = (SONW + SNW) = (74.29 + 112) = 186.3 kN
PATH22 = (Sonw + Tpgw + Tngw + Sinw)
= (74.29 + 0 + 173.9 + 0) = 248.2 kN
PATH33 = (Sonw + Tngw + Sinw)
= (74.29 + 173.9 + 0) = 248.2 kN

Summary of Failure Path Calculations:

Path 1-1 = 186 kN , must exceed W = 72 kN or W1 = 126 kN
Path 2-2 = 248 kN , must exceed W = 72 kN or W2 = 193 kN
Path 3-3 = 248 kN , must exceed W = 72 kN or W3 = 193 kN

Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case 24.354 bars

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

Nozzle is O.K. for the External Pressure 1.100 bars

The Drop for this Nozzle is : 0.6808 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.6808 mm.

INPUT VALUES, Nozzle Description: M1 From : 20

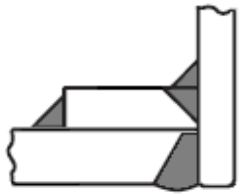
Pressure for Reinforcement Calculations	P	23.002	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1800.00	mm.
Design Length of Section	L	3299.9998	mm.
Shell Finished (Minimum) Thickness	t	22.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		750.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-516 70	
Material UNS Number		K02700	
Material Specification/Type		Plate	
Allowable Stress at Temperature	Sn	137.90	N./mm^2
Allowable Stress At Ambient	Sna	137.90	N./mm^2
Diameter Basis (for tr calc only)		OD	
Layout Angle		0.00	deg
Diameter		20.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	22.0000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	250.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	20.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	22.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Impact Tested]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
Diameter of Pad along vessel surface	Dp	808.0000	mm.
Thickness of Pad	te	22.0000	mm.
Weld leg size between Pad and Shell	Wp	14.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	22.0000	mm.
Reinforcing Pad Width		150.0000	mm.
This is a Manway or Access Opening.			
Class of attached Flange		300	
Grade of attached Flange		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

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation	20.000	in.
Actual Thickness Used in Calculation	0.866	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)
= (23*903)/(137.9*1-0.6*23)
= 15.2151 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)
= (23*254)/(137.9*1+0.4*23)
= 4.2088 mm.

Required Nozzle thickness under External Pressure per UG-28 : 1.2465 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	940.0001	mm.
Parallel to Vessel Wall, opening length	d	470.0000	mm.
Normal to Vessel Wall (Thickness Limit), pad side	Tlwp	47.5000	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, 1)

= 1.000

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	71.511	18.132	NA
Area in Shell	A1	17.789	53.036	NA
Area in Nozzle Wall	A2	14.052	16.866	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	5.960	5.960	NA
Area in Element	A5	49.500	49.500	NA
TOTAL AREA AVAILABLE	Atot	87.301	125.362	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Insufficient.
The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	712.3038	22.0000	mm.
Based on given Pad Diameter:	808.0001	14.9823	mm.
Based on Shell or Nozzle Thickness:	712.3038	22.0000	mm.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (470*15.22*1+2*19*15.22*1*(1-1))
= 71.511 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)
= 470 (1 * 19 - 1 * 15.22) - 2 * 19
(1 * 19 - 1 * 15.22) * (1 - 1)
= 17.789 cm^2

Area Available in Nozzle Wall Projecting Outward [A2]:
= (2 * Tlwp) * (tn - trn) * fr2
= (2 * 47.5) * (19 - 4.209) * 1
= 14.052 cm^2

Area Available in Welds [A41 + A42 + A43]:
= Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
= 20² * 1 + (0)² * 1 + 14² * 1
= 5.960 cm^2

Area Available in Element, also see UG-37(h) [A5]:
= (min(Dp,DL)-(Nozzle OD))(min(tp,Tlwp,te)) * fr4 * 0.75
= (808 - 508)22 * 1 * 0.75
= 49.500 cm^2

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :

Note: This Element/Detail was specified as being Impact Tested.

Nozzle Neck to Pad Weld for Reinf. pad (Impact tested) :

Note: This Element/Detail was specified as being Impact Tested.

Shell to Pad Weld at Pad OD for pad (Impact tested) :

Note: This Element/Detail was specified as being Impact Tested.

Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :

Note: This Element/Detail was specified as being Impact Tested.

```
Governing MDMT of the Nozzle                          :   -45 °C
Governing MDMT of the Reinforcement Pad               :   -45 °C
Governing MDMT of all the sub-joints of this Junction :   -45 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ANSI B16.5/47 flange per Matl. Specification      -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)          -48 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
`Design Pressure/Ambient Rating = 23.00/51.10 = 0.450`

Weld Size Calculations, Description: M1

```
Intermediate Calc. for nozzle/shell Welds   Tmin     19.0000  mm.
Intermediate Calc. for pad/shell Welds   TminPad     19.0000  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	14.1400 = 0.7 * Wo mm.
Pad Weld	9.5000 = 0.5*TminPad	9.8980 = 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, (71.51 - 17.79 + 2 * 19 * 1 *
  (1 * 19 - 15.22 ) )137.9 )
= 760.59 kN
```

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

Weld Load [W1]:

```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 14.05 + 49.5 + 5.96 - 0 * 1 ) * 137.9
= 958.48 kN
```

Weld Load [W2]:

```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 14.05 + 0 + 4 + ( 7.22 ) ) * 137.9
= 348.47 kN
```

Weld Load [W3]:

```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 14.05 + 0 + 5.96 + 49.5 + ( 7.22 ) ) * 137.9
= 1058.04 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
= (pi/2) * Dlo * Wo * 0.49 * Snw
= (3.142/2.0) * 508 * 20 * 0.49 * 137.9
= 1078. kN

Shear, Pad Element Weld [Spew]:
= (pi/2) * DP * WP * 0.49 * SEW
= (3.142/2.0) * 808 * 14 * 0.49 * 137.9
= 1201. kN

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.142 * 244.5) * (22 - 3) * 0.7 * 137.9
= 1409. kN

Tension, Pad Groove Weld [Tpgw]:
= (pi/2) * Dlo * Wgpn * 0.74 * Seg
= (3.142/2) * 508 * 22 * 0.74 * 137.9
= 1791. kN

Tension, Shell Groove Weld [Tngw]:
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= (3.142/2.0) * 508 * (22 - 3) * 0.74 * 137.9
= 1547. kN

Strength of Failure Paths:

PATH11 = (SPEW + SNW) = (1201 + 1409) = 2609 kN
PATH22 = (Sonw + Tpgw + Tngw + Sinw)
= (1078 + 1791 + 1547 + 0) = 4417 kN
PATH33 = (Spew + Tngw + Sinw)
= (1201 + 1547 + 0) = 2748 kN

Summary of Failure Path Calculations:
Path 1-1 = 2609 kN , must exceed W = 760 kN or W1 = 958 kN
Path 2-2 = 4416 kN , must exceed W = 760 kN or W2 = 348 kN
Path 3-3 = 2747 kN , must exceed W = 760 kN or W3 = 1058 kN

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 24.354 bars

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

Nozzle is O.K. for the External Pressure 1.100 bars

The Drop for this Nozzle is : 36.5858 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 308.5858 mm.

Percent Elongation Calculations:
% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 4.527 %

INPUT VALUES, Nozzle Description: V From : 30

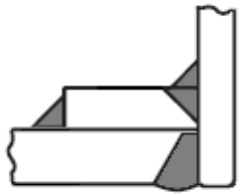
Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Elliptical Head	D	1800.00	mm.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	18.5000	mm.
Head Internal Corrosion Allowance	c	3.0000	mm.
Head External Corrosion Allowance	co	0.0000	mm.
Distance from Head Centerline	L1	0.0000	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type		Smls. & wld. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
Diameter Basis (for tr calc only)		OD	
Layout Angle		0.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.5000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
Diameter of Pad along vessel surface	Dp	190.0000	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	10.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		64.8375	mm.
Class of attached Flange		300	
Grade of attached Flange		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: V

ASME Code, Section VIII, Div. 1, 2017, UG-37 to UG-45

Actual Outside Diameter Used in Calculation	2.375	in.
Actual Thickness Used in Calculation	0.301	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)
= (23*0.897*1806)/(2 *137.9*1-0.2*23)
= 13.5353 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)
= (23*30.16)/(117.9*1+0.4*23)
= 0.5839 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.3261 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	102.0684	mm.
Parallel to Vessel Wall, opening length	d	51.0342	mm.
Normal to Vessel Wall (Thickness Limit), pad side	Tlwp	21.6135	mm.

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

Weld Strength Reduction Factor [fr1]:
= min(1, Sn/Sv)
= min(1, 117.9/137.9)
= 0.855

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 117.9/137.9)
= 0.855

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(0.855, 1)
= 0.855

Results of Nozzle Reinforcement Area Calculations: (cm^2)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.090	1.285	NA
Area in Shell	A1	0.976	5.264	NA
Area in Nozzle Wall	A2	1.501	1.596	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.547	0.547	NA
Area in Element	A5	4.174	4.174	NA
TOTAL AREA AVAILABLE	Atot	7.199	11.582	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Insufficient.
The area available with the given pad is Sufficient.

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	100.9798	10.0000	mm.
Based on given Pad Diameter:	190.0000	9.7392	mm.
Based on the Estimated Diameter Limit:	100.4809	10.1243	mm.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (51.03*13.54*1+2*4.645*13.54*1*(1-0.855))
= 7.090 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)
= 51.03 (1 * 15.5 - 1 * 13.54) - 2 * 4.645
(1 * 15.5 - 1 * 13.54) * (1 - 0.855)
= 0.976 cm^2

Area Available in Nozzle Wall Projecting Outward [A2]:
= (2 * Tlwp) * (tn - trn) * fr2
= (2 * 21.61) * (4.645 - 0.584) * 0.855
= 1.501 cm^2

Area Available in Welds [A41 + A42 + A43]:
= Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
= 8² * 0.855 + (0)² * 0.855 + 0² * 1
= 0.547 cm^2

Area Available in Element [A5]:
= (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
= (102.1 - 60.33) * 10 * 1
= 4.174 cm^2

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

Wall Thickness for Internal/External pressures ta = 3.5839 mm.
Wall Thickness per UG16(b), tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 18.0205 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 18.0205 mm.
Wall Thickness, shell/head, external pressure trb2 = 3.7172 mm.
Wall Thickness tb2 = max(trb2, tr16b) = 4.5000 mm.

Wall Thickness per table UG-45 tb3 = 6.4200 mm.

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[6.42, max(18.02, 4.5)]
= 6.4200 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(3.584, 6.42)
= 6.4200 mm.

Available Nozzle Neck Thickness = 7.6454 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

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

Impact Test Temperature provided per Specification -46 °C

Calculated Minimum Design Metal Temperature -104 °C

Nozzle Neck to Pad Weld for the Nozzle (Impact tested) :

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

Impact Test Temperature provided per Specification -46 °C

Calculated Minimum Design Metal Temperature -104 °C

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

Govrn. thk, tg = 7.645, tr = 0.584, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.126, Temp. Reduction = 78 °C

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

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

Govrn. thk, tg = 10, c = 3 mm., E* = 1
Thickness Ratio = tr * (E*)/(tg - c) = 0.873, Temp. Reduction = 7 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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

Nozzle-Shell/Head Weld for the Nozzle (Impact tested) :

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

Impact Test Temperature provided per Specification -46 °C

Calculated Minimum Design Metal Temperature -104 °C

Governing MDMT of the Nozzle : -104 °C
Governing MDMT of the Reinforcement Pad : -48 °C
Governing MDMT of all the sub-joints of this Junction : -48 °C

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ANSI B16.5/47 flange per Matl. Specification       -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)           -48 °C
Flange MDMT with Temp reduction per UCS-66(i)(3)          -104 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
```
Design Pressure/Ambient Rating = 23.00/51.10 = 0.450
```

Note:
Using the min value from (i)(2) and (i)(3) above as the computed nozzle flange MDMT.

Weld Size Calculations, Description: V

```
Intermediate Calc. for nozzle/shell Welds   Tmin      4.6454  mm.
Intermediate Calc. for pad/shell Welds   TminPad     10.0000  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	3.2518 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.
Pad Weld	5.0000 = 0.5*TminPad	7.0700 = 0.7 * Wp mm.

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

Weld Load [W]:
```
= max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max( 0, (7.09 - 0.976 + 2 * 4.645 * 0.855 *
  (1 * 15.5 - 13.54 ) )137.9 )
= 86.45 kN
```

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

Weld Load [W1]:
```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 1.501 + 4.174 + 0.547 - 0 * 0.855 ) * 137.9
= 85.80 kN
```

Weld Load [W2]:
```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 1.501 + 0 + 0.547 + ( 1.231 ) ) * 137.9
= 45.22 kN
```

Weld Load [W3]:
```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 1.501 + 0 + 0.547 + 4.174 + ( 1.231 ) ) * 137.9
= 102.78 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.142/2.0 ) * 60.33 * 8 * 0.49 * 117.9
= 44. kN
```

Shear, Pad Element Weld [Spew]:
```
= (pi/2) * DP * WP * 0.49 * SEW
= ( 3.142/2.0 ) * 190 * 10 * 0.49 * 137.9
= 202. kN
```

Shear, Nozzle Wall [Snw]:
```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
```

```
  = (3.142 * 27.84 ) * ( 7.645 - 3 ) * 0.7 * 117.9
  = 34. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.142/2 ) * 60.33 * 10 * 0.74 * 137.9
  = 97. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.142/2.0 ) * 60.33 * ( 18.5 - 3 ) * 0.74 * 137.9
  = 150. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 201.6 + 33.53 ) = 235.2 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 43.79 + 96.69 + 149.9 + 0 ) = 290.3 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 201.6 + 149.9 + 0 ) = 351.5 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 235 kN , must exceed W = 86 kN  or W1 = 85 kN
 Path 2-2 = 290 kN , must exceed W = 86 kN  or W2 = 45 kN
 Path 3-3 = 351 kN , must exceed W = 86 kN  or W3 = 102 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case       23.178  bars

 Nozzle is O.K. for the External Pressure                1.100  bars
```

The Drop for this Nozzle is : 0.2783 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 218.7783 mm.

Nozzle Schedule:

Description	Nominal or Actual Size	Schd or FVC Type	Flg Type	Nozzle O/Dia in	Wall Thk mm.	Reinforcing Pad Diameter mm.	Reinforcing Pad Thk mm.	Cut Length mm.	Flg Class
T1	1.500 in	Actual	LWN	2.756	15.950	...	...	222.68	300
D	2.000 in	160	WNF	2.375	8.738	190.00	10.00	218.78	300
LG1	2.000 in	Actual	LWN	3.307	16.600	...	...	233.54	300
LT2	2.000 in	Actual	LWN	3.307	16.600	...	...	233.54	300
LG2	2.000 in	Actual	LWN	3.307	16.600	...	...	222.98	300
LT2	2.000 in	Actual	LWN	3.307	16.600	...	...	222.98	300
SV	2.000 in	Actual	LWN	3.307	16.600	...	...	222.98	300
V	2.000 in	160	WNF	2.375	8.738	190.00	10.00	218.78	300
M2	6.000 in	80	WNF	6.625	10.973	368.27	15.00	225.94	300
A2	8.000 in	80	WNF	8.625	12.700	419.07	15.00	228.69	300
A1	10.000 in	80	WNF	10.750	15.088	473.05	15.00	232.42	300
B	12.000 in	80	WNF	12.750	17.450	563.85	15.00	236.69	300
M1	20.000 in	Actual	LWN	20.000	22.000	808.00	22.00	308.59	300

General Notes for the above table:

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

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

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

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

Description	Material	Shl Grve Weld	Noz Shl/Pad Weld	Pad OD Weld	Pad Grve Weld	Inside Weld
T1	SA-350 LF2	18.500	10.000	...	...	...
D	SA-333 6	18.500	8.000	10.000	10.000	...
LG1	SA-350 LF2	18.500	10.000	...	...	...
LT2	SA-350 LF2	18.500	10.000	...	...	...
LG2	SA-350 LF2	18.500	10.000	...	...	...
LT2	SA-350 LF2	18.500	10.000	...	...	...

SV	SA-350 LF2	18.500	10.000	...	...	...
V	SA-333 6	18.500	8.000	10.000	10.000	...
M2	SA-333 6	22.000	10.000	14.000	15.000	...
A2	SA-333 6	22.000	10.000	14.000	15.000	...
A1	SA-333 6	22.000	10.000	14.000	15.000	...
B	SA-333 6	22.000	10.000	14.000	15.000	...
M1	SA-516 70	22.000	20.000	14.000	22.000	...

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
T1	700.000	270.0	200.00	0.00	SHELL
D	...	0.0	200.00	0.00	HEAD 001
LG1	...	180.0	200.00	0.00	HEAD 001
LT2	...	270.0	200.00	0.00	HEAD 001
LG2	200.000	180.0	200.00	0.00	SHELL
LT2	200.000	270.0	200.00	0.00	SHELL
SV	1500.000	0.0	200.00	0.00	SHELL
V	...	0.0	200.00	0.00	HEAD 002
M2	2250.000	90.0	200.00	0.00	SHELL
A2	1100.000	45.0	200.00	0.00	SHELL
A1	500.000	90.0	200.00	0.00	SHELL
B	2250.000	270.0	200.00	0.00	SHELL
M1	700.000	0.0	250.00	0.00	SHELL

Note: The Description of Nozzle: LT2 is DUPLICATED

Note: For best performance, please do not duplicate nozzle descriptions.

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
HEAD 001	[10]	!	-45			0.977	18.500	1.00	No
HEAD 001	[7]	!	-45			0.807	22.000	1.00	No
SHELL	[8]	!	-45			0.808	22.000	0.85	No
HEAD 002	[10]	!	-45			0.976	18.500	1.00	No
HEAD 002	[7]	!	-45			0.807	22.000	1.00	No
D	[1]	D	-48	-48	-29	0.873	10.000	1.00	No
Nozzle Flg	[4]	!	-18	-96					
LG1	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg	[5]	!	-18	-48					
LT2	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg	[5]	!	-18	-48					
A1	[1]	D	-47	-48	-29	0.801	15.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
A2	[1]	D	-47	-48	-29	0.801	15.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
B	[1]	!	-46	-46		0.801	15.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
LG2	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg	[5]	!	-46	-48					
LT2	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg	[5]	!	-46	-48					
SV	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg	[5]	!	-46	-48					
M2	[1]	D	-47	-48	-29	0.801	15.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
T1	[1]	!	-46	-104		0.029	15.950	1.00	No
Nozzle Flg	[5]	!	-46	-48					
M1	[1]	!	-45	-45		0.801	22.000	1.00	No
Nozzle Flg	[5]	!	-46	-48					
V	[1]	D	-48	-48	-29	0.873	10.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
Warmest MDMT:			-18	-45					

Required Minimum Design Metal Temperature -45 °C
Warmest Computed Minimum Design Metal Temperature -45 °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)

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.

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no: K.O. Drum (D-PK6101-3)
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for K.O. Drum (D-PK6101-3)
Vessel Design Summary: Step: 35 8:44pm Dec 24,2021

ASME Code, Section VIII Division 1, 2017

Diameter Spec : 1800.000 mm. ID		
Vessel Design Length, Tangent to Tangent	3000.00	mm.
Distance of Bottom Tangent above Grade	123000.00	mm.
Specified Datum Line Distance	50.00	mm.
Shell Material	SA-516 70 [Impact Tested]	
Nozzle Material	SA-333 6 [Impact Tested]	
Nozzle Material	SA-350 LF2 [Impact Tested]	
Nozzle Material	SA-516 70 [Impact Tested]	
Re-Pad Material	SA-516 70 [Normalized]	
Internal Design Temperature	125	°C
Internal Design Pressure	23.000	bars
External Design Temperature	125	°C
External Design Pressure	1.034	bars
Maximum Allowable Working Pressure	23.176	bars
External Max. Allowable Working Pressure	8.440	bars
Hydrostatic Test Pressure	29.900	bars
Required Minimum Design Metal Temperature	-45	°C
Warmest Computed Minimum Design Metal Temperature	-45	°C
Wind Design Code	ASCE-2010	
Earthquake Design Code	ASCE 7-2010	

Element Pressures and MAWP (bars):

Element Description	Design Pres. + Stat. head	External Pressure	M.A.W.P	Corrosion Allowance	Str. Flange Governing
HEAD 001	23.002	1.100	23.731	3.0000	No
SHELL	23.002	1.100	24.352	3.0000	N/A
HEAD 002	23.000	1.100	23.733	3.0000	No

Liquid Level: 3900.00 mm. Dens.: 0.000 kg./cm^3 Sp. Gr.: 0.006

Element Types and Properties:

Element Type	"To" Elev mm.	Length mm.	Element Thk mm.	R e q d T h k Int.	Ext.	Joint Eff Long	Circ
Ellipse	0.0	50.0	22.0	18.0	7.9	1.00	0.85
Cylinder	2900.0	2900.0	22.0	20.9	10.7	0.85	0.85
Ellipse	2950.0	50.0	22.0	18.0	7.9	1.00	0.85

Element thicknesses are shown as Nominal if specified, otherwise are Minimum

Loads for Foundation/Support Design:

Total Wind Shear on top of all Legs	7.	kN
Total Earthquake Shear on top of all Legs	14.	kN
Total Wind Moment at top of all Legs	8379.	N-m
Total Earthquake Moment at top of all Legs	23281.	N-m
Max. Wind Shear on one Leg (top & bottom)	2.	kN
Max. Earthq. Shear on one Leg (top & bottom)	3.	kN
Max. Wind Moment at base of one Leg	3275.	N-m

Max. Earthquake Moment at base of one Leg	6126.	N-m
Max. Vertical Load (Wt. + Wind) on one Leg	19.	kN
Max. Vertical Load (Wt. + Eq.) on one Leg	27.	kN

Note:
Wind and Earthquake moments include the effects of user defined forces and moments if any exist in the job and were specified to act (compute loads and stresses) during these cases. Also included are moment effects due to eccentric weights if any are present in the input.

Weights:

Fabricated - Bare W/O Removable Internals	5723.4	kg.
Shop Test - Fabricated + Water (Full)	14880.3	kg.
Shipping - Fab. + Rem. Intls.+ Shipping App.	5723.4	kg.
Erected - Fab. + Rem. Intls.+ Insul. (etc)	6065.8	kg.
Empty - Fab. + Intls. + Details + Wghts.	6065.8	kg.
Operating - Empty + Operating Liquid (No CA)	6118.9	kg.
Field Test - Empty Weight + Water (Full)	14709.0	kg.