PPI / NARGAN	DEHDASHT PETROCHEMICAL INDUSTRY COMPANY DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT	PGPIC
	DOCUMENT TITLE: Mechanical Calculation for Oil Cooler	POI: IFA
Contract No.: DPIC/98-12	DOCUMENT NUMBER: DPIC9812-000-VD-1002-ME-CLN-0091	Rev. No.: D1

DOCUMENT TITLE:

Mechanical Calculation for Oil Cooler

(E-PK6101-1A/B)

PURCHASER'S COMMENT/APPROVAL STATUS		Purchaser: NARGAN
1	AP: Approved (Released for Manufacturing)	Requisition No.: DPIC98-12-001-000-ME-MR-4150-0001-D1
X	AN: Approved With Minor Comments (Fabrication may Proceed)	
3	NF: Approved With Comments (Fabrication not Proceed)	Item No. (Tag No.): E-PK6101-1A/B
4	RJ: Rejected	
5	NR: Not be Returned	Vendor Doc. No.: DPIC9812-000-VD-1002-ME-CLN-0091-D1
Date: 06.03.2022	Signature: A.AB	

REV	DATE ISSUE	PREPARED	CHECKED	APPROVED
D1	06.Feb.2022	A.VOSOUGH	DR.A.NEJATI	DR.A.NEJATI
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 Oil Cooler	**POI: IFA**
Contract No.: DPIC/98-12	**DOCUMENT NUMBER: DPIC9812-000-VD-1002-ME-CLN-0091**	**Rev. No.: D1**

Page	Rev-D0	Rev-D1	Rev-D2	Rev-D3	Rev-D4
1	x	x			
2	x	x			
3	x	x			
4	x	x			
5	x	x			
6	x	x			
7	x	x			
8	x	x			
9	x	x			
10	x	x			
11	x	x			
12	x	x			
13	x	x			
14	x	x			
15	x	x			
16	x	x			
17	x	x			
18	x	x			
19	x	x			
20	x	x			
21	x	x			
22	x	x			
23	x	x			
24	x	x			
25	x	x			
26	x	x			
27	x	x			
28	x	x			
29	x	x			
30	x	x			
31	x	x			
32	x	x			
33	x	x			
34	x	x			
35	x	x			

Page	Rev-D0	Rev-D1	Rev-D2	Rev-D3	Rev-D4
36	x	x			
37	x	x			
38	x	x			
39	x	x			
40	x	x			
41	x	x			
42	x	x			
43	x	x			
44	x	x			
45	x	x			
46	x	x			
47	x	x			
48	x	x			
49	x	x			
50	x	x			
51	x	x			
52	x	x			
53	x	x			
54	x	x			
55	x	x			
56	x	x			
57	x	x			
58	x	x			
59	x	x			
60	x	x			
61	x	x			
62	x	x			
63	x	x			
64	x	x			
65	x	x			
66	x	x			
67	x	x			
68	x	x			
69	x	x			
70	x	x			

PPI / NARGAN	**DEHDASHT PETROCHEMICAL INDUSTRY COMPANY** **DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT**	PGPIC
	DOCUMENT TITLE: Mechanical Calculation for Oil Cooler	**POI: IFA**
Contract No.: DPIC/98-12	**DOCUMENT NUMBER: DPIC9812-000-VD-1002-ME-CLN-0091**	**Rev. No.: D1**

Page	Rev-D0	Rev-D1	Rev-D2	Rev-D3	Rev-D4
71	x	x			
72	x	x			
73	x	x			
74	x	x			
75	x	x			
76	x	x			
77	x	x			
78	x	x			
79	x	x			
80	x	x			
81	x	x			
82	x	x			
83	x	x			
84	x	x			
85	x	x			
86	x	x			
87	x	x			
88	x	x			
89	x	x			
90	x	x			
91	x	x			
92	x	x			
93	x	x			
94	x	x			
95	x	x			
96	x	x			
97	x	x			
98	x	x			
99	x	x			
100	x	x			
101	x	x			
102	x	x			
103	x	x			
104	x	x			
105	x	x			

Page	Rev-D0	Rev-D1	Rev-D2	Rev-D3	Rev-D4
106	x	x			
107	x	x			
108	x	x			
109	x	x			
110	x	x			
111	x	x			
112	x	x			
113	x	x			
114	x	x			
115	x	x			
116	x	x			
117	x	x			
118	x	x			
119	x	x			
120	x	x			
121	x	x			
122	x	x			
123	x	x			
124	x	x			
125	x	x			
126	x	x			
127	x	x			
128	x	x			
129	x	x			
130	x	x			
131	x	x			
132	x	x			
133	x	x			
134	x	x			
135	x	x			
136	x	x			
137	x	x			
138	x	x			
139	x	x			
140	x	x			

PPI / NARGAN	**DEHDASHT PETROCHEMICAL INDUSTRY COMPANY** **DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT**	PGPIC
	DOCUMENT TITLE: Mechanical Calculation for Oil Cooler	**POI: IFA**
Contract No.: DPIC/98-12	**DOCUMENT NUMBER: DPIC9812-000-VD-1002-ME-CLN-0091**	**Rev. No.: D1**

Page	Rev-D0	Rev-D1	Rev-D2	Rev-D3	Rev-D4
141	x	x			
142	x	x			
143	x	x			
144	x	x			
145	x	x			
146	x	x			
147	x	x			
148	x	x			
149	x				
150	x				
151	x				
152	x				
153	x				
154	x				
155	x				
156	x				
157	x				
158	x				
159	x				
160	x				
161	x				
162	x				
163	x				
164					
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:E-PK6101-1 AB OIL COOLER

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 : Feb 7,2022 0:02am

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:E-PK6101-1 AB OIL COOLER

Exchanger Design Pressures and Temperatures

Shell Side Design Pressure	25	bars
Channel Side Design Pressure	25	bars
Shell Side Design Temperature	120.0	°C
Channel Side Design Temperature	190.0	°C
Type of Hydrotest	UG-99(b) Note [36]	
Hydrotest Position	Horizontal	
Projection of Nozzle from Vessel Top	0	mm.
Projection of Nozzle from Vessel Bottom	0	mm.
Type of Construction	Welded	
Special Service	None	
Degree of Radiography	RT-3	
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	Yes	
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]	200	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	20.0	
Using User defined Wind Press. Vs Elev.	N	
Height of Hill or Escarpment H or Hh	0	mm.

Distance Upwind of Crest	Lh	0	mm.
Distance from Crest to the Vessel	x	0	mm.
Type of Terrain (Hill, Escarpment)		Flat	
Damping Factor (Beta) for Wind (Ope)		0.0100	
Damping Factor (Beta) for Wind (Empty)		0.0000	
Damping Factor (Beta) for Wind (Filled)		0.0000	
Seismic Design Code		ASCE 7-2010	
Seismic Load Reduction Scale Factor		0.700	
Importance Factor		1.250	
Table Value Fa		1.000	
Table Value Fv		1.300	
Short Period Acceleration value Ss		0.900	
Long Period Acceleration Value Sl		0.537	
Moment Reduction Factor Tau		1.000	
Force Modification Factor R		3.000	
Site Class		C	
Component Elevation Ratio	z/h	0.000	
Amplification Factor	Ap	0.000	
Force Factor		0.000	
Consider Vertical Acceleration		Yes	
Minimum Acceleration Multiplier		0.000	
User Value of Sds (used if > 0)		0.624	
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 1	
Distance "FROM" to "TO"	50	mm.
Inside Diameter	381	mm.
Element Thickness	11.113	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	14	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	25	bars
Design Temperature Internal Pressure	190	°C
Design External Pressure	1.1	bars
Design Temperature External Pressure	190	°C
Effective Diameter Multiplier	1.2	

Material Name	SA-516 70 [Normalized]	
Allowable Stress, Ambient	137.9	N./mm^2
Allowable Stress, Operating	137.9	N./mm^2
Allowable Stress, Hydrotest	235.81	N./mm^2
Material Density	0.00775	kg./cm^3
P Number Thickness	30.988	mm.
Yield Stress, Operating	226.06	N./mm^2
UCS-66 Chart Curve Designation	D	
External Pressure Chart Name	CS-2	
UNS Number	K02700	
Product Form	Plate	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	0.85	
Elliptical Head Factor	2.0	
Weld is pre-Heated	No	
Element From Node	10	
Detail Type	Liquid	
Detail ID	1	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	381	mm.
Liquid Density	0.0009996	kg./cm^3

Element From Node	20	
Element To Node	30	
Element Type	Cylinder	
Description	CHANNEL 01	
Distance "FROM" to "TO"	321	mm.
Inside Diameter	381	mm.
Element Thickness	11.113	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	12.7	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	25	bars
Design Temperature Internal Pressure	190	°C
Design External Pressure	1.1	bars
Design Temperature External Pressure	190	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-106 B	
Allowable Stress, Ambient	117.9	N./mm^2
Allowable Stress, Operating	117.9	N./mm^2
Allowable Stress, Hydrotest	217.19	N./mm^2
Material Density	0.00775	kg./cm^3
P Number Thickness	31.75	mm.
Yield Stress, Operating	208.13	N./mm^2
UCS-66 Chart Curve Designation	B	
External Pressure Chart Name	CS-2	
UNS Number	K03006	
Product Form	Smls. pipe	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Weld is pre-Heated	No	
Element From Node	20	
Detail Type	Liquid	
Detail ID	2	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	381	mm.
Liquid Density	0.0009996	kg./cm^3
Element From Node	20	

Detail Type	Nozzle	
Detail ID	T2	
Dist. from "FROM" Node / Offset dist	160	mm.
Nozzle Diameter	3	in.
Nozzle Schedule	160	
Nozzle Class	300	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.1895	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	

Element From Node	20	
Detail Type	Nozzle	
Detail ID	T1	
Dist. from "FROM" Node / Offset dist	160	mm.
Nozzle Diameter	3	in.
Nozzle Schedule	160	
Nozzle Class	300	
Layout Angle	180.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.1968	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	

Element From Node	30	
Element To Node	40	
Element Type	Flange	
Description	BODY FLANGE 01	
Distance "FROM" to "TO"	74	mm.
Flange Inside Diameter	381	mm.
Element Thickness	48	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	79	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	25	bars
Design Temperature Internal Pressure	190	°C
Design External Pressure	1.1	bars
Design Temperature External Pressure	190	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-266 2	
Allowable Stress, Ambient	137.9	N./mm^2
Allowable Stress, Operating	137.9	N./mm^2
Allowable Stress, Hydrotest	223.4	N./mm^2
Material Density	0.00775	kg./cm^3
P Number Thickness	30.988	mm.
Yield Stress, Operating	214.2	N./mm^2
UCS-66 Chart Curve Designation	C	
External Pressure Chart Name	CS-2	
UNS Number	K03506	
Product Form	Forgings	
Perform Flange Stress Calculation (Y/N)	Y	
Weight of ANSI B16.5/B16.47 Flange	0	kN
Class of ANSI B16.5/B16.47 Flange		
Grade of ANSI B16.5/B16.47 Flange		
Weld is pre-Heated	No	

Element From Node	30	
Detail Type	Liquid	
Detail ID	3	
Dist. from "FROM" Node / Offset dist	0	mm.

Height/Length of Liquid	381	mm.
Liquid Density	0.0009996	kg./cm^3

Element From Node	40	
Element To Node	50	
Element Type	Cylinder	
Description	SHELL	
Distance "FROM" to "TO"	2908	mm.
Inside Diameter	381	mm.
Element Thickness	11.113	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	12.7	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	25	bars
Design Temperature Internal Pressure	120	°C
Design External Pressure	1.1	bars
Design Temperature External Pressure	120	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-106 B	
Allowable Stress, Ambient	117.9	N./mm^2
Allowable Stress, Operating	117.9	N./mm^2
Allowable Stress, Hydrotest	217.19	N./mm^2
Material Density	0.00775	kg./cm^3
P Number Thickness	31.75	mm.
Yield Stress, Operating	217.36	N./mm^2
UCS-66 Chart Curve Designation	B	
External Pressure Chart Name	CS-2	
UNS Number	K03006	
Product Form	Smls. pipe	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Weld is pre-Heated	No	

Element From Node	40	
Detail Type	Saddle	
Detail ID	Fixed Saddle	
Dist. from "FROM" Node / Offset dist	464	mm.
Width of Saddle	140	mm.
Height of Saddle at Bottom	500	mm.
Saddle Contact Angle	120.0	
Height of Composite Ring Stiffener	0	mm.
Width of Wear Plate	200	mm.
Thickness of Wear Plate	10	mm.
Contact Angle, Wear Plate (degrees)	132.0	

Element From Node	40	
Detail Type	Saddle	
Detail ID	Sliding Saddle	
Dist. from "FROM" Node / Offset dist	2444	mm.
Width of Saddle	140	mm.
Height of Saddle at Bottom	500	mm.
Saddle Contact Angle	120.0	
Height of Composite Ring Stiffener	0	mm.
Width of Wear Plate	200	mm.
Thickness of Wear Plate	10	mm.
Contact Angle, Wear Plate (degrees)	132.0	

Element From Node	40	
Detail Type	Liquid	
Detail ID	4	
Dist. from "FROM" Node / Offset dist	0	mm.

Height/Length of Liquid	381	mm.
Liquid Density	0.0008747	kg./cm^3
Element From Node	40	
Detail Type	Nozzle	
Detail ID	S2	
Dist. from "FROM" Node / Offset dist	164	mm.
Nozzle Diameter	3	in.
Nozzle Schedule	160	
Nozzle Class	300	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.1968	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	
Element From Node	40	
Detail Type	Nozzle	
Detail ID	S1	
Dist. from "FROM" Node / Offset dist	2698	mm.
Nozzle Diameter	3	in.
Nozzle Schedule	160	
Nozzle Class	300	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.1968	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	
Element From Node	40	
Detail Type	Nozzle	
Detail ID	S3	
Dist. from "FROM" Node / Offset dist	164	mm.
Nozzle Diameter	2	in.
Nozzle Schedule	160	
Nozzle Class	300	
Layout Angle	180.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.1175	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	
Element From Node	40	
Detail Type	Weight	
Detail ID	WEIGHT BAFFLE	
Dist. from "FROM" Node / Offset dist	1456	mm.
Miscellaneous Weight	0.4903	kN
Offset from Element Centerline	0	mm.

Element From Node	50	
Element To Node	60	
Element Type	Flange	
Description	BODY FLANGE 002	
Distance "FROM" to "TO"	74	mm.
Flange Inside Diameter	381	mm.
Element Thickness	48	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	79	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	25	bars
Design Temperature Internal Pressure	190	°C

Design External Pressure	1.1	bars
Design Temperature External Pressure	190	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-266 2	
Allowable Stress, Ambient	137.9	N./mm^2
Allowable Stress, Operating	137.9	N./mm^2
Allowable Stress, Hydrotest	223.4	N./mm^2
Material Density	0.00775	kg./cm^3
P Number Thickness	30.988	mm.
Yield Stress, Operating	214.2	N./mm^2
UCS-66 Chart Curve Designation	C	
External Pressure Chart Name	CS-2	
UNS Number	K03506	
Product Form	Forgings	
Perform Flange Stress Calculation (Y/N)	Y	
Weight of ANSI B16.5/B16.47 Flange	0	kN
Class of ANSI B16.5/B16.47 Flange		
Grade of ANSI B16.5/B16.47 Flange		
Weld is pre-Heated	No	
Element From Node	50	
Detail Type	Liquid	
Detail ID	5	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	381	mm.
Liquid Density	0.0009996	kg./cm^3

Element From Node	60	
Element To Node	70	
Element Type	Cylinder	
Description	CHANNEL 002	
Distance "FROM" to "TO"	321	mm.
Inside Diameter	381	mm.
Element Thickness	11.113	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	12.7	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	25	bars
Design Temperature Internal Pressure	190	°C
Design External Pressure	1.1	bars
Design Temperature External Pressure	190	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-106 B	
Allowable Stress, Ambient	117.9	N./mm^2
Allowable Stress, Operating	117.9	N./mm^2
Allowable Stress, Hydrotest	217.19	N./mm^2
Material Density	0.00775	kg./cm^3
P Number Thickness	31.75	mm.
Yield Stress, Operating	208.13	N./mm^2
UCS-66 Chart Curve Designation	B	
External Pressure Chart Name	CS-2	
UNS Number	K03006	
Product Form	Smls. pipe	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Weld is pre-Heated	No	
Element From Node	60	
Detail Type	Liquid	
Detail ID	5	
Dist. from "FROM" Node / Offset dist	0	mm.

Height/Length of Liquid	381	mm.
Liquid Density	0.0009996	kg./cm^3
Element From Node	60	
Detail Type	Nozzle	
Detail ID	T4	
Dist. from "FROM" Node / Offset dist	160	mm.
Nozzle Diameter	0.75	in.
Nozzle Schedule	None	
Nozzle Class	300	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.04839	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	[Normalized]
Element From Node	60	
Detail Type	Nozzle	
Detail ID	T3	
Dist. from "FROM" Node / Offset dist	160	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	300	
Layout Angle	180.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.05845	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-105	[Normalized]

Element From Node	70	
Element To Node	80	
Element Type	Elliptical	
Description	HEAD 002	
Distance "FROM" to "TO"	50	mm.
Inside Diameter	381	mm.
Element Thickness	11.113	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	14	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	25	bars
Design Temperature Internal Pressure	190	°C
Design External Pressure	1.1	bars
Design Temperature External Pressure	190	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	[Normalized]
Allowable Stress, Ambient	137.9	N./mm^2
Allowable Stress, Operating	137.9	N./mm^2
Allowable Stress, Hydrotest	235.81	N./mm^2
Material Density	0.00775	kg./cm^3
P Number Thickness	30.988	mm.
Yield Stress, Operating	226.06	N./mm^2
UCS-66 Chart Curve Designation	D	
External Pressure Chart Name	CS-2	
UNS Number	K02700	
Product Form	Plate	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Elliptical Head Factor	2.0	
Weld is pre-Heated	No	
Element From Node	70	

Detail Type	Liquid	
Detail ID	6	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	381	mm.
Liquid Density	0.0009996	kg./cm^3

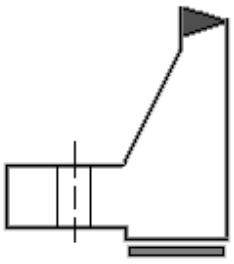
XY Coordinate Calculations:

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
HEAD 1		50	...	50	...
CHANNEL 01		371	...	321	...
BODY FLANGE 01		445	...	74	...
SHELL		3406.17	...	2908	...
BODY FLANGE 002		3486.35	...	74	...
CHANNEL 002		3854.35	...	321	...
HEAD 002		3904.35	...	50	...

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

BODY FLANGE 01

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	25.04	bars
Design Temperature		190	°C
Internal Corrosion Allowance	ci	3.0000	mm.
External Corrosion Allowance	ce	0.0000	mm.
Use Corrosion Allowance in Thickness Calcs.		Yes	
Flange Inside Diameter	B	381.000	mm.
Flange Outside Diameter	A	515.000	mm.
Flange Thickness	t	48.0000	mm.
Thickness of Hub at Small End	go	11.1125	mm.
Thickness of Hub at Large End	g1	17.0000	mm.
Length of Hub	h	26.0000	mm.
Flange Material		SA-266 2	
Flange Material UNS number		K03506	
Flange Allowable Stress At Temperature	Sfo	137.90	N./mm^2
Flange Allowable Stress At Ambient	Sfa	137.90	N./mm^2
Bolt Material		SA-193 B7	
Bolt Allowable Stress At Temperature	Sb	172.38	N./mm^2
Bolt Allowable Stress At Ambient	Sa	172.38	N./mm^2
Diameter of Bolt Circle	C	473.000	mm.
Nominal Bolt Diameter	a	19.0500	mm.
Type of Threads		UNC Thread Series	
Number of Bolts		28	
Flange Face Outside Diameter	Fod	447.000	mm.
Flange Face Inside Diameter	Fid	381.000	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	444.000	mm.
Gasket Inside Diameter	Gi	404.000	mm.
Gasket Factor	m	3.7800	
Gasket Design Seating Stress	y	62.05	N./mm^2
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	3.0000	mm.
Length of Partition Gasket	lp	1078.0000	mm.
Width of Partition Gasket	tp	6.0000	mm.
Partition Gasket Factor	mPart	3.7500	
Partition Gasket Design Seating Stress	yPart	62.05	N./mm^2



ASME Code, Section VIII Division 1, 2017

Hub Small End Required Thickness due to Internal Pressure:
= (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
= (25.04*(381.0/2+3.0))/(137.9*1.0-0.6*25.04)+Ca
= 6.5521 mm.

Hub Small End Hub MAWP:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (137.9 * 1.0 * 8.1125)/(193.5 + 0.6 * 8.1125)
= 56.393 bars

Corroded Flange Thickness,	tc = T-ci	45.000	mm.
Corroded Flange ID,	Bcor = B+2*Fcor	387.000	mm.
Corroded Large Hub,	g1Cor = g1-ci	14.000	mm.
Corroded Small Hub,	g0Cor = go-ci	8.113	mm.
Code R Dimension,	R = ((C-Bcor)/2)-g1cor	29.000	mm.
Gasket Contact Width,	N = (Go - Gi) / 2	20.000	mm.
Basic Gasket Width,	bo = N / 2	10.000	mm.
Effective Gasket Width,	b = Cb sqrt(bo)	7.969	mm.
Gasket Reaction Diameter,	G = Go - 2 * b	428.063	mm.

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
= 0.785 * G² * Peq
= 0.785 * 428.0626² * 25.037
= 360.314 kN
Contact Load on Gasket Surfaces [Hp]:
= 2 * b * Pi * G * m * P + 2 * lp * bPart * mPart * P
= 2 * 7.9687 * 3.1416 * 428.0626 * 3.78 * 25.04
+ 2.0 * 1078.0 * 3.0 * 3.75 * 25.0373
= 263.561 kN
Hydrostatic End Load at Flange ID [Hd]:
= Pi * Bcor² * P / 4
= 3.1416 * 387.0² *25.0373/4
= 294.502 kN
Pressure Force on Flange Face [Ht]:
= H - Hd
= 360 - 295
= 65.812 kN
Operating Bolt Load [Wm1]:
= max(H + Hp + H'p, 0)
= max(360 + 264 + 0, 0)
= 623.875 kN
Gasket Seating Bolt Load [Wm2]:
= y * b * Pi * G + yPart * bPart * lp
= 62.05*7.9687*3.141*428.063+62.05*3.0*1078.0
= 865.581 kN
Required Bolt Area [Am]:
= Maximum of Wm1/Sb, Wm2/Sa
= Maximum of 624/172, 866/172
= 50.219 cm^2

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
= 2a + 6t/(m + 0.5)
= 2 * 19.05 + 6 * 45.0/(3.78 + 0.5)
= 101.184 mm.

Actual Circumferential Bolt Spacing [Bs]:
= C * sin(pi / n)
= 473.0 * sin(3.142/28)

= 52.959 mm.

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
= max(sqrt(Bs/(2a + t)), 1)
= max(sqrt(52.959/(2 * 19.05 + 45.0)), 1)
= 1.0000

Bolting Information for UNC Thread Series (Non Mandatory):

	Minimum	Actual	Maximum
Bolt Area, cm^2	50.219	54.555	
Radial Distance between Hub and Bolts:	28.575	29.000	
Radial Distance between Bolts and the Ed	20.637	21.000	
Circumferential Spacing between the Bolt	44.450	52.959	101.184

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
= Ab * Sa/(y * Pi * (Go + Gi))
= 54.555 * 172.38/(62.05 * 3.14 * (444.0 + 404.0))
= 5.689 mm.

Flange Design Bolt Load, Gasket Seating [W]:
= Sa * (Am + Ab) / 2
= 172.38 * (50.2192 + 54.5547)/2
= 902.94 kN
Gasket Load for the Operating Condition [HG]:
= Wm1 - H
= 624 - 360
= 263.56 kN

Moment Arm Calculations:
Distance to Gasket Load Reaction [hg]:
= (C - G) / 2
= (473.0 - 428.0626)/2
= 22.4687 mm.
Distance to Face Pressure Reaction [ht]:
= (R + g1 + hg) / 2
= (29.0 + 14.0 + 22.4687)/2
= 32.7343 mm.
Distance to End Pressure Reaction [hd]:
= R + (g1 / 2)
= 29.0 + (14.0/2.0)
= 36.0000 mm.

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

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	295.	36.0000	1.0000	10606.
Face Pressure, Mt	66.	32.7343	1.0000	2155.
Gasket Load, Mg	264.	22.4687	1.0000	5924.
Gasket Seating, Matm	903.	22.4687	1.0000	20296.

Total Moment for Operation, Mop 18686. N-m
Total Moment for Gasket seating, Matm 20296. N-m

Effective Hub Length, ho = sqrt(Bcor*goCor) 56.032 mm.
Hub Ratio, h/h0 = HL / H0 0.464
Thickness Ratio, g1/g0 = (g1Cor/goCor) 1.726

Flange Factors for Integral Flange:

```
 Factor F                                                  0.842
 Factor V                                                  0.275
 Factor f                                                  1.000
 Factors from Figure 2-7.1                    K =          1.331
                     T =      1.784           U =          7.636
                     Y =      6.948           Z =          3.594
                     d = 0.10241E+06 mm.³      e =        0.0150 mm.^-1
 Stress Factors                          ALPHA =          1.676
                  BETA =      1.902      GAMMA =          0.940
                 DELTA =      0.890      Lamda =          1.829
```

Longitudinal Hub Stress, Operating [SHo]:
= (f * Mop / Bcor) / (L * g1²)
= (1.0*18686/387.0)/(1.8294*14.0²)
= 134.61 N./mm^2
Longitudinal Hub Stress, Seating [SHa]:
= (f * Matm / Bcor) / (L * g1²)
= (1.0*20296/387.0)/(1.8294*14.0²)
= 146.21 N./mm^2

Radial Flange Stress, Operating [SRo]:
= (Beta * Mop / Bcor) / (L * t²)
= (1.9019*18686/387.0)/(1.8294*45.0²)
= 24.78 N./mm^2
Radial Flange Stress, Seating [SRa]:
= (Beta * Matm/Bcor) / (L * t²)
= (1.9019*20296/387.0)/(1.8294*45.0²)
= 26.92 N./mm^2

Tangential Flange Stress, Operating [STo]:
= (Y * Mo / (t² * Bcor)) - Z * SRo
= (6.9484*18686/(45.0²*387.0))-3.5944*25
= 76.55 N./mm^2
Tangential Flange Stress, Seating [STa]:
= (y * Matm / (t² * Bcor)) - Z * SRa
= (6.9484*20296/(45.0²*387.0))-3.5944*27
= 83.15 N./mm^2

Average Flange Stress, Operating [SAo]:
= (SHo + max(SRo, STo)) / 2
= (135+max(25,77))/2
= 105.58 N./mm^2
Average Flange Stress, Seating [SAa]:
= (SHa + max(SRa, STa)) / 2
= (146+max(27,83))/2
= 114.68 N./mm^2

Bolt Stress, Operating [BSo]:
= Wm1 / Ab
= 624/54.5547
= 114.37 N./mm^2
Bolt Stress, Seating [BSa]:
= (Wm2 / Ab)
= (866/54.5547)
= 158.68 N./mm^2

Flange Stress Analysis Results: N./mm^2

	Operating		Gasket Seating	
	Actual	Allowed	Actual	Allowed
Longitudinal Hub	135.	207.	146.	207.

Radial Flange	25.	138.	27.	138.
Tangential Flange	77.	138.	83.	138.
Maximum Average	106.	138.	115.	138.
Bolting	114.	172.	159.	172.

Minimum Required Flange Thickness	41.427	mm.
Estimated M.A.W.P. (Operating)	32.700	bars
Estimated Finished Weight of Flange at given Thk.	38.6	kg.
Estimated Unfinished Weight of Forging at given Thk	54.1	kg.

Flange Rigidity Based on Required Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
= 52.14 * Ma / Bsc * Cnv_fac * V / (Lambda * Eamb * go^2 * ho * Ki)
= 52.14 * 20296.2/1.0 * 999.68 * 0.275/(1.437 * 202713 *
8.113^2 * 56.032 * 0.3)
= 0.902 (should be <= 1)

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:
= 52.14 * Mo / Bsc * Cnv_fac * V / (Lambda * Eop * goc^2 * ho * Ki)
= 52.14 * 18685.8/1.0 * 999.68 * 0.275/(1.437 * 193088
* 8.113^2 * 56.032 * 0.3)
= 0.872 (should be <= 1)

Flange Rigidity Based on Given Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
= 52.14 * Ma / Bsc * Cnv_fac * V / (Lambda * Eamb * go^2 * ho * Ki)
= 52.14 * 20296.2/1.0 * 999.68 * 0.275/(1.829 * 202713 *
8.113^2 * 56.032 * 0.3)
= 0.709 (should be <= 1)

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:
= 52.14 * Mo / Bsc * Cnv_fac * V / (Lambda * Eop * goc^2 * ho * Ki)
= 52.14 * 18685.8/1.0 * 999.68 * 0.275/(1.829 * 193088
* 8.113^2 * 56.032 * 0.3)
= 0.685 (should be <= 1)

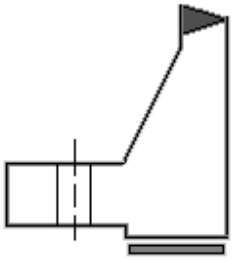
Minimum Design Metal Temperature Results:
Thickness Ratio = 0.766, Temperature Reduction per Fig. UCS 66.1 = 13 °C

Min Metal Temp. w/o impact per UCS-66, Curve C	-41 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-48 °C

Flange Input Data Values **Description: New Flange :**

BODY FLANGE 002

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	25.04	bars
Design Temperature		190	°C
Internal Corrosion Allowance	ci	3.0000	mm.
External Corrosion Allowance	ce	0.0000	mm.
Use Corrosion Allowance in Thickness Calcs.		Yes	
Flange Inside Diameter	B	381.000	mm.
Flange Outside Diameter	A	515.000	mm.
Flange Thickness	t	48.0000	mm.
Thickness of Hub at Small End	go	11.1125	mm.
Thickness of Hub at Large End	g1	17.0000	mm.
Length of Hub	h	26.0000	mm.
Flange Material		SA-266 2	
Flange Material UNS number		K03506	
Flange Allowable Stress At Temperature	Sfo	137.90	N./mm^2
Flange Allowable Stress At Ambient	Sfa	137.90	N./mm^2
Bolt Material		SA-193 B7	
Bolt Allowable Stress At Temperature	Sb	172.38	N./mm^2
Bolt Allowable Stress At Ambient	Sa	172.38	N./mm^2
Diameter of Bolt Circle	C	473.000	mm.
Nominal Bolt Diameter	a	19.0500	mm.
Type of Threads		UNC Thread Series	
Number of Bolts		28	
Flange Face Outside Diameter	Fod	447.000	mm.
Flange Face Inside Diameter	Fid	381.000	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	444.000	mm.
Gasket Inside Diameter	Gi	404.000	mm.
Gasket Factor	m	3.7800	
Gasket Design Seating Stress	y	62.05	N./mm^2
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	3.0000	mm.
Length of Partition Gasket	lp	1078.0000	mm.
Width of Partition Gasket	tp	6.0000	mm.
Partition Gasket Factor	mPart	3.7500	
Partition Gasket Design Seating Stress	yPart	62.05	N./mm^2



ASME Code, Section VIII Division 1, 2017

Hub Small End Required Thickness due to Internal Pressure:
= (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
= (25.04*(381.0/2+3.0))/(137.9*1.0-0.6*25.04)+Ca
= 6.5521 mm.

Hub Small End Hub MAWP:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (137.9 * 1.0 * 8.1125)/(193.5 + 0.6 * 8.1125)
= 56.393 bars

Corroded Flange Thickness,	tc = T-ci	45.000	mm.
Corroded Flange ID,	Bcor = B+2*Fcor	387.000	mm.
Corroded Large Hub,	g1Cor = g1-ci	14.000	mm.
Corroded Small Hub,	g0Cor = go-ci	8.113	mm.
Code R Dimension,	R = ((C-Bcor)/2)-g1cor	29.000	mm.
Gasket Contact Width,	N = (Go - Gi) / 2	20.000	mm.
Basic Gasket Width,	bo = N / 2	10.000	mm.
Effective Gasket Width,	b = Cb sqrt(bo)	7.969	mm.
Gasket Reaction Diameter,	G = Go - 2 * b	428.063	mm.

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
= 0.785 * G² * Peq
= 0.785 * 428.0626² * 25.037
= 360.314 kN
Contact Load on Gasket Surfaces [Hp]:
= 2 * b * Pi * G * m * P + 2 * lp * bPart * mPart * P
= 2 * 7.9687 * 3.1416 * 428.0626 * 3.78 * 25.04
+ 2.0 * 1078.0 * 3.0 * 3.75 * 25.0373
= 263.561 kN
Hydrostatic End Load at Flange ID [Hd]:
= Pi * Bcor² * P / 4
= 3.1416 * 387.0² *25.0373/4
= 294.502 kN
Pressure Force on Flange Face [Ht]:
= H - Hd
= 360 - 295
= 65.812 kN
Operating Bolt Load [Wm1]:
= max(H + Hp + H'p, 0)
= max(360 + 264 + 0, 0)
= 623.875 kN
Gasket Seating Bolt Load [Wm2]:
= y * b * Pi * G + yPart * bPart * lp
= 62.05*7.9687*3.141*428.063+62.05*3.0*1078.0
= 865.581 kN
Required Bolt Area [Am]:
= Maximum of Wm1/Sb, Wm2/Sa
= Maximum of 624/172, 866/172
= 50.219 cm^2

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
= 2a + 6t/(m + 0.5)
= 2 * 19.05 + 6 * 45.0/(3.78 + 0.5)
= 101.184 mm.

Actual Circumferential Bolt Spacing [Bs]:
= C * sin(pi / n)
= 473.0 * sin(3.142/28)

= 52.959 mm.

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
= max(sqrt(Bs/(2a + t)), 1)
= max(sqrt(52.959/(2 * 19.05 + 45.0)), 1)
= 1.0000

Bolting Information for UNC Thread Series (Non Mandatory):

	Minimum	Actual	Maximum
Bolt Area, cm^2	50.219	54.555	
Radial Distance between Hub and Bolts:	28.575	29.000	
Radial Distance between Bolts and the Ed	20.637	21.000	
Circumferential Spacing between the Bolt	44.450	52.959	101.184

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
= Ab * Sa/(y * Pi * (Go + Gi))
= 54.555 * 172.38/(62.05 * 3.14 * (444.0 + 404.0))
= 5.689 mm.

Flange Design Bolt Load, Gasket Seating [W]:
= Sa * (Am + Ab) / 2
= 172.38 * (50.2192 + 54.5547)/2
= 902.94 kN
Gasket Load for the Operating Condition [HG]:
= Wm1 - H
= 624 - 360
= 263.56 kN

Moment Arm Calculations:
Distance to Gasket Load Reaction [hg]:
= (C - G) / 2
= (473.0 - 428.0626)/2
= 22.4687 mm.
Distance to Face Pressure Reaction [ht]:
= (R + g1 + hg) / 2
= (29.0 + 14.0 + 22.4687)/2
= 32.7343 mm.
Distance to End Pressure Reaction [hd]:
= R + (g1 / 2)
= 29.0 + (14.0/2.0)
= 36.0000 mm.

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

Loading	Force	Distance	Bolt Corr	Moment
End Pressure, Md	295.	36.0000	1.0000	10606.
Face Pressure, Mt	66.	32.7343	1.0000	2155.
Gasket Load, Mg	264.	22.4687	1.0000	5924.
Gasket Seating, Matm	903.	22.4687	1.0000	20296.

Total Moment for Operation,	Mop	18686. N-m
Total Moment for Gasket seating,	Matm	20296. N-m

Effective Hub Length,	ho = sqrt(Bcor*goCor)	56.032	mm.
Hub Ratio,	h/h0 = HL / H0	0.464	
Thickness Ratio,	g1/g0 = (g1Cor/goCor)	1.726	

Flange Factors for Integral Flange:

```
 Factor F                                                  0.842
 Factor V                                                  0.275
 Factor f                                                  1.000
 Factors from Figure 2-7.1                    K =          1.331
                     T =      1.784           U =          7.636
                     Y =      6.948           Z =          3.594
                     d = 0.10241E+06 mm.³      e =        0.0150 mm.^-1
 Stress Factors                          ALPHA =          1.676
                 BETA =      1.902       GAMMA =          0.940
                DELTA =      0.890       Lamda =          1.829
```

Longitudinal Hub Stress, Operating [SHo]:
= (f * Mop / Bcor) / (L * g1²)
= (1.0*18686/387.0)/(1.8294*14.0²)
= 134.61 N./mm^2
Longitudinal Hub Stress, Seating [SHa]:
= (f * Matm / Bcor) / (L * g1²)
= (1.0*20296/387.0)/(1.8294*14.0²)
= 146.21 N./mm^2

Radial Flange Stress, Operating [SRo]:
= (Beta * Mop / Bcor) / (L * t²)
= (1.9019*18686/387.0)/(1.8294*45.0²)
= 24.78 N./mm^2
Radial Flange Stress, Seating [SRa]:
= (Beta * Matm/Bcor) / (L * t²)
= (1.9019*20296/387.0)/(1.8294*45.0²)
= 26.92 N./mm^2

Tangential Flange Stress, Operating [STo]:
= (Y * Mo / (t² * Bcor)) - Z * SRo
= (6.9484*18686/(45.0²*387.0))-3.5944*25
= 76.55 N./mm^2
Tangential Flange Stress, Seating [STa]:
= (y * Matm / (t² * Bcor)) - Z * SRa
= (6.9484*20296/(45.0²*387.0))-3.5944*27
= 83.15 N./mm^2

Average Flange Stress, Operating [SAo]:
= (SHo + max(SRo, STo)) / 2
= (135+max(25,77))/2
= 105.58 N./mm^2
Average Flange Stress, Seating [SAa]:
= (SHa + max(SRa, STa)) / 2
= (146+max(27,83))/2
= 114.68 N./mm^2

Bolt Stress, Operating [BSo]:
= Wm1 / Ab
= 624/54.5547
= 114.37 N./mm^2
Bolt Stress, Seating [BSa]:
= (Wm2 / Ab)
= (866/54.5547)
= 158.68 N./mm^2

Flange Stress Analysis Results: N./mm^2

	Operating		Gasket Seating	
	Actual	Allowed	Actual	Allowed
Longitudinal Hub	135.	207.	146.	207.

Radial Flange	25.	138.	27.	138.
Tangential Flange	77.	138.	83.	138.
Maximum Average	106.	138.	115.	138.
Bolting	114.	172.	159.	172.

Minimum Required Flange Thickness	41.427	mm.
Estimated M.A.W.P. (Operating)	32.700	bars
Estimated Finished Weight of Flange at given Thk.	38.6	kg.
Estimated Unfinished Weight of Forging at given Thk	54.1	kg.

Flange Rigidity Based on Required Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
= 52.14 * Ma / Bsc * Cnv_fac * V / (Lambda * Eamb * go^2 * ho * Ki)
= 52.14 * 20296.2/1.0 * 999.68 * 0.275/(1.437 * 202713 *
8.113^2 * 56.032 * 0.3)
= 0.902 (should be <= 1)

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:
= 52.14 * Mo / Bsc * Cnv_fac * V / (Lambda * Eop * goc^2 * ho * Ki)
= 52.14 * 18685.8/1.0 * 999.68 * 0.275/(1.437 * 193088
* 8.113^2 * 56.032 * 0.3)
= 0.872 (should be <= 1)

Flange Rigidity Based on Given Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
= 52.14 * Ma / Bsc * Cnv_fac * V / (Lambda * Eamb * go^2 * ho * Ki)
= 52.14 * 20296.2/1.0 * 999.68 * 0.275/(1.829 * 202713 *
8.113^2 * 56.032 * 0.3)
= 0.709 (should be <= 1)

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:
= 52.14 * Mo / Bsc * Cnv_fac * V / (Lambda * Eop * goc^2 * ho * Ki)
= 52.14 * 18685.8/1.0 * 999.68 * 0.275/(1.829 * 193088
* 8.113^2 * 56.032 * 0.3)
= 0.685 (should be <= 1)

Minimum Design Metal Temperature Results:
Thickness Ratio = 0.766, Temperature Reduction per Fig. UCS 66.1 = 13 °C

Min Metal Temp. w/o impact per UCS-66, Curve C	-41 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-48 °C

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 1		25.038	14	3	381	137.9
CHANNEL 01		25.038	12.7	3	381	117.9
BODY FLANGE 01		25.037	79	3	381	137.9
SHELL		25.033	12.7	3	381	117.9
BODY FLANGE 002		25.037	79	3	381	137.9
CHANNEL 002		25.038	12.7	3	381	117.9
HEAD 002		25.038	14	3	381	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 1		25	No Calc	No Calc	11.1125	6.44875
CHANNEL 01		25	No Calc	No Calc	11.1125	7.16235
BODY FLANGE 01		25	No Calc	No Calc	48	41.4274
SHELL		25	No Calc	No Calc	11.1125	7.16156
BODY FLANGE 002		25	No Calc	No Calc	48	41.4274
CHANNEL 002		25	No Calc	No Calc	11.1125	7.16235
HEAD 002		25	No Calc	No Calc	11.1125	6.44875

Summary of Heat Exchanger Maximum Allowable Working Pressures :

Note:
For Exchanger designs, the following values include MAWPs that consider the tubesheet, tubes, tube/tubesheet joint etc. These values were determined by iteration. Review the tubesheet analysis report for more information.

```
Shell Side MAWP     =     45.967 bars
Shell Side MAPnc    =     51.100 bars
Channel Side  MAWP  =     27.070 bars
Channel Side  MAPnc =     37.739 bars
```

Note:
PV Elite could not compute the MAWP of one of the Flanges.
Please check the reported MAWP by entering it as the design pressure and performing an extra analysis.

Internal Pressure Calculation Results :

ASME Code, Section VIII Division 1, 2017

Elliptical Head From 10 To 20 SA-516 70 , UCS-66 Crv. D at 190 °C

HEAD 1

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
= (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)

= (25.038*387.0*0.98)/(2*137.9*1.0-0.2*25.038)
= 3.4487 + 3.0000 = 6.4487 mm.

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(Kcor*D+0.2*t))/(2*E*t)
= (25.038*(0.98*387.0+0.2*8.1125))/(2*1.0*8.1125)
= 58.767 N./mm^2

Straight Flange Required Thickness:
= (P*R)/(S*E-0.6*P) + c per UG-27 (c)(1)
= (25.038*193.5)/(137.9*1.0-0.6*25.038)+3.0
= 6.552 mm.

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.038 bars
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (137.9 * 1.0 * 11.0)/(193.5 + 0.6 * 11.0)
= 75.803 - 0.038 = 75.765 bars

Factor K, corroded condition [Kcor]:
= (2 + (Inside Diameter/(2 * Inside Head Depth))^2)/6
= (2 + (387.0/(2 * 98.25))^2)/6
= 0.979799

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 14.630 %
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 11.113, tr = 3.449, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.425, Temp. Reduction = 45 °C

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

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 14.0, tr = 3.552, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.323, 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

Cylindrical Shell From 20 To 30 SA-106 B , UCS-66 Crv. B at 190 °C

CHANNEL 01

Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
= (25.038*193.5)/(117.9*1.0-0.6*25.038)
= 4.1623 + 3.0000 = 7.1623 mm.

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(R+0.6*t))/(E*t)
= (25.038*(193.5+0.6*8.1125))/(1.0*8.1125)
= 61.226 N./mm^2

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 11.113, tr = 4.162, c = 3.0 mm., E* = 1.0

Thickness Ratio = tr * (E*)/(tg - c) = 0.513, Temp. Reduction = 31 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -26 °C
Min Metal Temp. at Required thickness (UCS 66.1)        -48 °C
Min Metal Temp. w/o impact per UG-20(f)                 -29 °C
```

Cylindrical Shell From 40 To 50 SA-106 B , UCS-66 Crv. B at 120 °C

SHELL

Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
= (25.033*193.5)/(117.9*1.0-0.6*25.033)
= 4.1616 + 3.0000 = 7.1616 mm.

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(R+0.6*t))/(E*t)
= (25.033*(193.5+0.6*8.1125))/(1.0*8.1125)
= 61.214 N./mm^2

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 11.113, tr = 4.162, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.513, Temp. Reduction = 31 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -26 °C
Min Metal Temp. at Required thickness (UCS 66.1)        -48 °C
Min Metal Temp. w/o impact per UG-20(f)                 -29 °C
```

Cylindrical Shell From 60 To 70 SA-106 B , UCS-66 Crv. B at 190 °C

CHANNEL 002

Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
= (25.038*193.5)/(117.9*1.0-0.6*25.038)
= 4.1623 + 3.0000 = 7.1623 mm.

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(R+0.6*t))/(E*t)
= (25.038*(193.5+0.6*8.1125))/(1.0*8.1125)
= 61.226 N./mm^2

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 11.113, tr = 4.162, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.513, Temp. Reduction = 31 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -26 °C
Min Metal Temp. at Required thickness (UCS 66.1)        -48 °C
Min Metal Temp. w/o impact per UG-20(f)                 -29 °C
```

Elliptical Head From 70 To 80 SA-516 70 , UCS-66 Crv. D at 190 °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)
= (25.038*387.0*0.98)/(2*137.9*1.0-0.2*25.038)
= 3.4487 + 3.0000 = 6.4487 mm.

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(Kcor*D+0.2*t))/(2*E*t)
= (25.038*(0.98*387.0+0.2*8.1125))/(2*1.0*8.1125)
= 58.767 N./mm^2

Straight Flange Required Thickness:
= (P*R)/(S*E-0.6*P) + c per UG-27 (c)(1)
= (25.038*193.5)/(137.9*1.0-0.6*25.038)+3.0
= 6.552 mm.

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.038 bars
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (137.9 * 1.0 * 11.0)/(193.5 + 0.6 * 11.0)
= 75.803 - 0.038 = 75.765 bars

Factor K, corroded condition [Kcor]:
= (2 + (Inside Diameter/(2 * Inside Head Depth))^2)/6
= (2 + (387.0/(2 * 98.25))^2)/6
= 0.979799

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 14.630 %
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 11.113, tr = 3.449, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.425, Temp. Reduction = 45 °C

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

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 14.0, tr = 3.552, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.323, 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

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

Hydrostatic Test Pressure Results:

Exchanger Shell Side Hydrostatic Test Pressures:

Pressure per UG99b	= 1.30 * M.A.W.P. * Sa/S	59.757	bars
Pressure per UG99b[36]	= 1.30 * Design Pres * Sa/S	32.500	bars
Pressure per UG99c	= 1.30 * M.A.P. - Head(Hyd)	66.430	bars
Pressure per UG100	= 1.10 * M.A.W.P. * Sa/S	50.564	bars
Pressure per PED	= max(1.43*DP, 1.25*DP*ratio)	35.625	bars
Pressure per App 27-4	= 1.30 * M.A.W.P. * Sa/S	59.757	bars

Exchanger Channel Side Hydrostatic Test Pressures:

```
Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S          35.191  bars
Pressure per UG99b[36] = 1.30 * Design Pres * Sa/S        32.500  bars
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)       49.023  bars
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S          29.777  bars
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)     35.625  bars
Pressure per App 27-4  = 1.30 * M.A.W.P. * Sa/S          35.191  bars
```

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

```
  = Test Factor * Design Pressure * Stress Ratio
  = 1.3 * 25.0 * 1.0
  = 32.500 bars
```

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

```
  = Test Factor * Design Pressure * Stress Ratio
  = 1.3 * 25.0 * 1.0
  = 32.500 bars
```

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

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

Stresses on Elements due to Test Pressure (N./mm^2 & bars):

From To	Stress	Allowable	Ratio	Pressure
HEAD 1	76.4	235.8	0.324	32.54
CHANNEL 01	79.6	217.2	0.366	32.54
SHELL	79.6	217.2	0.366	32.54
CHANNEL 002	79.6	217.2	0.366	32.54
HEAD 002	76.4	235.8	0.324	32.54

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

Description	Pad/Nozzle	Ambient	Operating	Ratio
T2	Nozzle	117.90	117.90	1.000
T2	Pad	137.90	137.90	1.000
T1	Nozzle	117.90	117.90	1.000
T1	Pad	137.90	137.90	1.000
S2	Nozzle	117.90	117.90	1.000
S2	Pad	137.90	137.90	1.000
S1	Nozzle	117.90	117.90	1.000
S1	Pad	137.90	137.90	1.000
S3	Nozzle	137.90	137.90	1.000
T4	Nozzle	137.90	137.90	1.000
T3	Nozzle	137.90	137.90	1.000
Minimum				1.000

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

Description	Ambient	Operating	Ratio
HEAD 1	137.90	137.90	1.000
CHANNEL 01	117.90	117.90	1.000
BODY FLANGE 01	137.90	137.90	1.000
SHELL	117.90	117.90	1.000

BODY FLANGE 002	137.90	137.90	1.000
CHANNEL 002	117.90	117.90	1.000
HEAD 002	137.90	137.90	1.000
Minimum			1.000

Stress ratios for Exchanger Materials (N./mm^2):

Description	Ambient	Operating	Ratio
Tube Material	92.39	92.39	1.000
Tubesheet Material	137.90	137.90	1.000
Minimum			1.000

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

Description	Ambient	Operating	Ratio
T2	20.18	217.19	0.093
T1	20.18	217.19	0.093
S2	20.18	217.19	0.093
S1	20.18	217.19	0.093
S3	8.75	223.40	0.039
T4	5.56	223.40	0.025
T3	6.47	223.40	0.029

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	403.225	8.1125	0.0027943	100.758
20	30	402.75	403.225	8.1125	0.0038853	105.978
30	40	No Calc	...	45	No Calc	No Calc
40	50	2908	403.225	8.1125	0.00050303	50.292
50	60	No Calc	...	45	No Calc	No Calc
60	70	402.75	403.225	8.1125	0.0038853	105.978
70	80	No Calc	403.225	8.1125	0.0027943	100.758

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	11.1125	4.5	1.1	22.5225
20	30	11.1125	4.34351	1.1	28.4274
30	40	48	41.4274	1.1	No Calc
40	50	11.1125	6.07728	1.1	13.4903
50	60	48	41.4274	1.1	No Calc
60	70	11.1125	4.34351	1.1	28.4274
70	80	11.1125	4.5	1.1	22.5225
Minimum					13.490

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	402.75	26273.1	No Calc	No Calc
30	40	No Calc	No Calc	No Calc	No Calc
40	50	2908	111055	No Calc	No Calc
50	60	No Calc	No Calc	No Calc	No Calc
60	70	402.75	26273.1	No Calc	No Calc
70	80	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 190 °C

HEAD 1

Elastic Modulus from Chart: CS-2 at 190 °C : 0.195E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	D/t	Factor A	B
8.113	403.23	49.70	0.0027943	100.76

```
 EMAP = B/(K0*D/t) = 100.7576/( 0.9 *49.7042 ) = 22.5225 bars
```

Results for Required Thickness (Tca):

```
     Tca          OD          D/t     Factor A           B
   1.091      403.23       369.68    0.0003757       36.60
 EMAP = B/(K0*D/t) = 36.6038/( 0.9 *369.677 ) = 1.1001 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*387.0*0.98)/(2*137.9*1.0-0.2*1.837)
  = 0.2526 + 3.0000 = 3.2526 mm.
```

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

```
  = ((2*S*E*t)/(Kcor*D+0.2*t))/1.67 per Appendix 1-4 (c)
  = ((2*137.9*1.0*8.1125)/(0.98*387.0+0.2*8.1125))/1.67
  = 35.181 bars
```

Maximum Allowable External Pressure [MAEP]:

```
  = min( MAEP, MAWP )
  = min( 22.52, 35.1807 )
  = 22.523 bars
```

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

Cylindrical Shell From 20 to 30 Ext. Chart: CS-2 at 190 °C

CHANNEL 01

Elastic Modulus from Chart: CS-2 at 190 °C : 0.195E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

```
     Tca          OD          SLEN        D/t        L/D    Factor A         B
   8.113      403.23       402.75      49.70     0.9988   0.0038853    105.98
 EMAP = (4*B)/(3*(D/t)) = (4*105.978)/(3*49.7042) = 28.4274 bars
```

Results for Required Thickness (Tca):

```
     Tca          OD          SLEN        D/t        L/D    Factor A         B
   1.344      403.23       402.75     300.13     0.9988   0.0002542     24.76
 EMAP = (4*B)/(3*(D/t)) = (4*24.7636)/(3*300.1288) = 1.1001 bars
```

Results for Maximum Stiffened Length (Slen):

```
     Tca          OD          SLEN        D/t        L/D    Factor A         B
   8.113      403.23     26273.08      49.70    50.0000   0.0004463     43.48
 EMAP = (4*B)/(3*(D/t)) = (4*43.4818)/(3*49.7042) = 11.6635 bars
```

Cylindrical Shell **From 40 to 50 Ext. Chart: CS-2 at 120 °C**

SHELL

Elastic Modulus from Chart: CS-2 at 120 °C : 0.200E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

```
     Tca          OD          SLEN        D/t        L/D    Factor A         B
   8.113      403.23      2908.00      49.70     7.2119   0.0005030     50.29
 EMAP = (4*B)/(3*(D/t)) = (4*50.292)/(3*49.7042) = 13.4903 bars
```

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.077	403.23	2908.00	131.03	7.2119	0.0001081	10.81

EMAP = (4*B)/(3*(D/t)) = (4*10.8112)/(3*131.0331) = 1.1 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
8.113	403.23	111054.98	49.70	50.0000	0.0004463	44.62

EMAP = (4*B)/(3*(D/t)) = (4*44.6199)/(3*49.7042) = 11.9688 bars

Cylindrical Shell From 60 to 70 Ext. Chart: CS-2 at 190 °C

CHANNEL 002

Elastic Modulus from Chart: CS-2 at 190 °C : 0.195E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
8.113	403.23	402.75	49.70	0.9988	0.0038853	105.98

EMAP = (4*B)/(3*(D/t)) = (4*105.978)/(3*49.7042) = 28.4274 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
1.344	403.23	402.75	300.13	0.9988	0.0002542	24.76

EMAP = (4*B)/(3*(D/t)) = (4*24.7636)/(3*300.1288) = 1.1001 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
8.113	403.23	26273.08	49.70	50.0000	0.0004463	43.48

EMAP = (4*B)/(3*(D/t)) = (4*43.4818)/(3*49.7042) = 11.6635 bars

Elliptical Head From 70 to 80 Ext. Chart: CS-2 at 190 °C

HEAD 002

Elastic Modulus from Chart: CS-2 at 190 °C : 0.195E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	D/t	Factor A	B
8.113	403.23	49.70	0.0027943	100.76

EMAP = B/(K0*D/t) = 100.7576/(0.9 *49.7042) = 22.5225 bars

Results for Required Thickness (Tca):

Tca	OD	D/t	Factor A	B
1.091	403.23	369.68	0.0003757	36.60

EMAP = B/(K0*D/t) = 36.6038/(0.9 *369.677) = 1.1001 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*387.0*0.98)/(2*137.9*1.0-0.2*1.837)
= 0.2526 + 3.0000 = 3.2526 mm.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
= ((2*S*E*t)/(Kcor*D+0.2*t))/1.67 per Appendix 1-4 (c)
= ((2*137.9*1.0*8.1125)/(0.98*387.0+0.2*8.1125))/1.67

= 35.181 bars

Maximum Allowable External Pressure [MAEP]:
= min(MAEP, MAWP)
= min(22.52, 35.1807)
= 22.523 bars

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

Element and Detail Weights:

From	To	Element Metal Wgt. kg.	Element ID Volume Cm3	Corroded Metal Wgt. kg.	Corroded ID Volume Cm3	Extra due Misc % kg.
10	20	26.995	12942.4	21.2103	13470.9	1.34975
20	30	39.08	36603.5	30.0759	37765.5	1.954
30	40	61.2532	12259.1	58.3079	12353.2	3.06266
40	50	354.033	193985	272.463	204511	17.7016
50	60	61.2532	12259.1	58.3079	12353.2	3.06266
60	70	39.08	36603.5	30.0759	37765.5	1.954
70	80	26.995	12942.4	21.2103	13470.9	1.34975
Total		608	317594.72	491	331690.12	30

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

Weight of Details:

From	Type	Weight of Detail kg.	X Offset, Dtl. Cent. mm.	Y Offset, Dtl. Cent. mm.	Description
10	Liqd	12.9345	-31.75	...	1
20	Liqd	36.5812	160.5	...	2
20	Nozl	20.2925	160	234.95	T2
20	Nozl	21.078	160	234.95	T1
30	Liqd	12.2516	37	...	3
40	Sadl	32.8035	464	334.694	Fixed Saddle
40	Sadl	32.8035	2444	334.694	Sliding Saddle
40	Liqd	169.633	1454	...	4
40	Nozl	21.078	164	234.95	S2
40	Nozl	21.078	2698	234.95	S1
40	Nozl	12.585	164	215.9	S3
40	Wght	50	1456	...	WEIGHT BAFFLE
50	Liqd	12.2516	37	...	5
60	Liqd	36.5812	160.5	...	5
60	Nozl	5.18177	160	200.025	T4
60	Nozl	6.25877	160	203.2	T3
70	Liqd	12.9345	81.75	...	6
30	FTsh	61.5779	103.5	...	TUBE SHEET
30	Tube	454.709	1580	...	
30	RTsh	61.5779	3056.5	...	

Total Weight of Each Detail Type

Total Weight of Saddles	65.6
Total Weight of Liquid	293.2
Total Weight of Nozzles	107.6
Total Weight of Weights	50.0
Total Weight of Exchanger Components	577.9
Total Weight of Liquid in Tubes	86.0
Sum of the Detail Weights	1180.2 kg.

Weight Summation: kg.

Fabricated	Shop Test	Shipping	Erected	Empty	Operating

639.1	1440.1	639.1	1440.1	639.1	1440.1
65.6	317.4	65.6	...	65.6	293.2
107.6	...	107.6	...	...	...
...	86.0	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	107.6	86.0
577.9	...	577.9	...	...	...
50.0	...	50.0	...	...	...
...	...	...	...	577.9	...
...	...	...	...	50.0	...
1440.1	1843.6	1440.1	1440.1	1440.1	1819.3

Miscellaneous Weight Percent: 5.0 %

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

Weight Summary

Fabricated Wt.	- Bare Weight W/O Removable Internals	1440.1 kg.
Shop Test Wt.	- Fabricated Weight + Water (Full)	1843.6 kg.
Shipping Wt.	- Fab. Wt + Rem. Intls.+ Shipping App.	1440.1 kg.
Erected Wt.	- Fab. Wt + Rem. Intls.+ Insul. (etc)	1440.1 kg.
Ope. Wt. no Liq	- Fab. Wt + Intls. + Details + Wghts.	1440.1 kg.
Operating Wt.	- Empty Wt + Operating Liq. Uncorroded	1819.3 kg.
Oper. Wt. + CA	- Corr Wt. + Operating Liquid	1696.5 kg.
Field Test Wt.	- Empty Weight + Water (Full)	1734.8 kg.

Exchanger Tube Data

Volume of Exchanger tubes	:	86082.2 Cm3
Weight of Ope Liq in tubes	:	86.0 kg.
Weight of Water in tubes	:	86.0 kg.

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

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

Outside Surface Areas of Elements:

From	To	Surface Area cm^2
10	20	2455.76
20	30	4098.35
30	40	2560.12
40	50	37127.7
50	60	2560.12
60	70	4098.35
70	80	2455.76
Total		55356.133 cm^2

Nozzle Flange MAWP Results:

Nozzle Description	Flange Rating Ope. bars	Flange Rating Ambient bars	Design Temp °C	Class	Grade/ Group	Equiv. Press	Max Pressure PVP	Max Pressure 50%	Max Pressure DNV bars
T2	44.1	51.1	190	300	GR 1.1	...	...	...	...
T1	44.1	51.1	190	300	GR 1.1	...	...	...	...
S2	46.0	51.1	120	300	GR 1.1	...	...	...	...
S1	46.0	51.1	120	300	GR 1.1	...	...	...	...
S3	46.0	51.1	120	300	GR 1.1	...	...	...	...
T4	44.1	51.1	190	300	GR 1.1	...	...	...	...
T3	44.1	51.1	190	300	GR 1.1	...	...	...	...

Shellside Flange Rating

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

Channelside Flange Rating

Lowest Flange Pressure Rating was (Ope)[TubeSide]: 44.060 bars
Lowest Flange Pressure Rating was (Amb)[TubeSide]: 51.100 bars

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)

Input Values:

Wind Design Code		ASCE-7 2010	
Wind Load Reduction Scale Factor		0.600	
Basic Wind Speed	[V]	200	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		20.0	
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*0.143*0.837)/(1+1.7*3.4*0.143)))
= min(0.85, 0.856)
= 0.850

Natural Frequency of Vessel (Operating)		33.000 Hz
Natural Frequency of Vessel (Empty)		33.000 Hz
Natural Frequency of Vessel (Test)		33.000 Hz
Force Coefficient	[Cf]	0.618
Structure Height to Diameter ratio		10.299

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
= 500.0 + 123000. = 123500. mm.
= 405.184 ft. Imperial Units

Velocity Pressure coefficient evaluated at height z [Kz]:

Because z (405.184 ft.) > 15 ft.
= 2.01 * (z / Zg) $^{2 / Alpha}$
= 2.01 * (405.184/900.0)$^{2/9.5}$
= 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* 0.0* 0.0)²
= 1.0

Velocity Pressure evaluated at height z, Imperial Units [qz]:
= max(16, 0.00256 * Kz * Kzt * Kd * V(mph)²)
= max(16, 0.00256 * 1.699 * 1.0 * 0.95 * 124.278²)
= 63.8 psf [311.617] Kgs/m^2

Force on the first element [F]:
= qz * G * Cf * WindArea
= 63.823 * 0.85 * 0.618 * 0.623
= 20.9 lbs. [0.1] kN

Element	Hgt (z) mm.	K1	K2	K3	Kz	Kzt	qz Kgs/m^2
HEAD 1	*******	0.000	0.000	0.000	1.699	1.000	311.617
CHANNEL 01	*******	0.000	0.000	0.000	1.699	1.000	311.617
BODY FLANGE 01	*******	0.000	0.000	0.000	1.699	1.000	311.617
SHELL	*******	0.000	0.000	0.000	1.699	1.000	311.617
BODY FLANGE 002	*******	0.000	0.000	0.000	1.699	1.000	311.617
CHANNEL 002	*******	0.000	0.000	0.000	1.699	1.000	311.617
HEAD 002	*******	0.000	0.000	0.000	1.699	1.000	311.617

Wind Loads on Masses/Equipment/Piping

ID	Wind Area cm^2	Elevation mm.	Pressure Kgs/m^2	Force kN
WEIGHT BAFFLE	0.00	124456.01	311.62	0.00

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	123500	483.87	578.777	311.617	0.055772
20	30	123500	483.87	1553.22	311.617	0.14967
30	40	123500	457.2	338.328	311.617	0.032602
40	50	123500	483.87	14070.9	311.617	1.3559
50	60	123500	457.2	338.328	311.617	0.032602
60	70	123500	483.87	1553.22	311.617	0.14967
70	80	123500	483.87	578.777	311.617	0.055772

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

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

Earthquake Load Calculation:

Input Values:

Seismic Design Code		ASCE 7-2010
Seismic Load Reduction Scale Factor		0.700
Importance Factor		1.250
Table Value Fa		1.000
Table Value Fv		1.300
Short Period Acceleration value Ss		0.900
Long Period Acceleration Value Sl		0.537
Moment Reduction Factor Tau		1.000
Force Modification Factor R		3.000
Site Class		C
Component Elevation Ratio	z/h	0.000
Amplification Factor	Ap	0.000
Force Factor		0.000
Consider Vertical Acceleration		Yes
Minimum Acceleration Multiplier		0.000
User Value of Sds (used if > 0)		0.624

Seismic Analysis Results:

```
Sms = Fa * Ss = 1.0 * 0.9 = 0.9
Sm1 = Fv * S1 = 1.3 * 0.537 = 0.698
Sds = 2/3 * Sms = 2/3 * 0.9 = 0.6

Sds = Max( 0.8*Sds, SdsUser )
    = Max( 0.48, 0.624 )
    = 0.624

Sd1 = 2/3 * Sm1 = 2/3 * 0.698 = 0.465

Sd1 = Max( 0.8*Sd1, Sd1User )
    = Max( 0.372, 0.39 )
    = 0.390
```

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

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

$= 0.020 * (2.2654^{0.75})$

$= 0.037$ seconds

The Coefficient Cu from Table 12.8-1 is : 1.400

Fundamental Period (1/Frequency) [T]:

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

$= 0.030$

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

= Minimum Value of (1.4 * 0.037, 0.03) per 12.8.2

= 0.030

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

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

$= 0.3 * Sds * W * I$

$= 0.3 * 0.624 * 17 * 1.25$

$= 3.893$ kN

Vertical load per 12.4-4, [YEq]:

$= 0.2 * Sds * W$

= 0.2 * 0.624 * 17 = 2.08 kN

Final Base Shear, V = 2.72 kN
Final Vertical Load, YEq = 1.45 kN

Earthquake Load Calculation:

From	To	Earthquake Height mm.	Earthquake Weight kN	Element Ope Load kN
10	20	190.5	1.84838	0.30276
20	30	190.5	1.84838	0.30276
30	40	190.5	1.84838	0.30276
40	Sadl	190.5	1.84838	0.30276
Sadl	50	190.5	1.84838	0.30276
40	50	190.5	1.84838	0.30276
50	60	190.5	1.84838	0.30276
60	70	190.5	1.84838	0.30276
70	80	190.5	1.84838	0.30276

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

Shop/Field Installation Options :

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

Center of Gravity of Saddles	1952.175 mm.
Center of Gravity of Liquid	1950.211 mm.
Center of Gravity of Nozzles	1307.288 mm.
Center of Gravity of Added Weights (Operating)	1954.175 mm.
Center of Gravity of Added Weights (Empty)	1954.175 mm.
Center of Gravity of Tubesheet(s)	1951.000 mm.
Center of Gravity of Tubes	1951.000 mm.
Center of Gravity of Bare Shell New and Cold	1947.445 mm.
Center of Gravity of Bare Shell Corroded	1946.601 mm.
Vessel CG in the Operating Condition	1908.854 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition	1901.513 mm.
Vessel CG in the Test Condition	1912.232 mm.

Rigging Analysis Results:

Total Effective Length of Vessel for this analysis		3798.00 mm.
Total vessel weight (No Liquid)	Twt	14.12 kN
Impact weight multiplication factor	Imp	1.50
Design lifting weight, DWT = Imp * Twt		21.18 kN
Elevation of the Tailing Lug (bottom)		1070.00 mm.
Elevation of the Lifting Lug (top)		2870.00 mm.
Design Reaction force at the tailing lug		11.40 kN
Design Reaction force at the lifting lug		9.79 kN
CG Distance from Tailing Lug		831.51 mm.
CG Distance from the Nearer Lifting Lug		831.51 mm.

Critical Values:

	Max Stress N./mm^2	Elevation mm.	Allowables N./mm^2	
Bending	5.48	1026.60	117.90	(UG-23)
Shear	0.77	1026.60	82.53	(0.7*S)

Forces and Moments at selected elevations (not all analysis points shown):

Distance mm.	Bending Moment N-m	Bending Stress N./mm^2	Shear Force kN	Shear Stress N./mm^2
0.00	0.0	0.0	4.1	0.3
114.20	522.0	0.4	4.9	0.4
400.60	1867.6	1.4	7.7	0.6
2189.80	4891.7	3.7	0.2	0.0
3412.20	1123.1	0.9	3.1	0.2
3748.00	179.7	0.1	0.3	0.0

Unity Check (Actual Stress / Allowable Stress):

Maximum Unity Check is 0.0465 at elevation 1026.6001 mm. - Must be <=1

Note: The rigging analysis is performed using a uniformly distributed load.

--- Plot data successfully generated ...----

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

Horizontal Vessel Stress Calculations : Operating Case

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

Minimum Wear Plate Width to be considered in analysis [b1]:
= min(b + 1.56*sqrt(Rm * t), 2a)
= min(140.0 + 1.56*sqrt(197.5563 * 8.1125), 2 * 500.0)
= 202.4521 mm.

Input and Calculated Values:

Vessel Mean Radius	Rm	197.56	mm.
Stiffened Vessel Length per 4.15.6	L	2908.00	mm.
Distance from Saddle to Vessel tangent	a	500.00	mm.
Saddle Width	b	140.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Shell Allowable Stress used in Calculation		117.90	N./mm^2
Head Allowable Stress used in Calculation		137.90	N./mm^2
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Operating Case		15.06	kN

Horizontal Vessel Analysis Results:	Actual N./mm^2	Allowable N./mm^2
Long. Stress at Top of Midspan	26.92	117.90
Long. Stress at Bottom of Midspan	34.00	117.90
Long. Stress at Top of Saddles	41.72	117.90
Long. Stress at Bottom of Saddles	24.22	117.90
Tangential Shear in Shell	7.22	94.32
Circ. Stress at Horn of Saddle	20.43	147.38
Circ. Compressive Stress in Shell	0.70	117.90

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:
= Ftr * (Ft/Num of Saddles + Z Force Load) * B / E
= 3.0 * (1.8/2 + 0) * 500.0/342.1775
= 4.0 kN

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
= max(Fl, Friction Load, Sum of X Forces) * B / Ls
= max(0.28, 0.0, 0) * 500.0/1980.0005
= 0.1 kN

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:
= max(Fl, Friction Force, Sum of X Forces) * B / Ls
= max(2.72, 0.0, 0) * 500.0/1980.0005
= 0.7 kN

Saddle Reaction Force due to Earthquake Ft [Fst]:

```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0 * ( 3/2 + 0 ) * 500.0/342.1775
  = 6.0 kN
```

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

```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 9 + Max( 0.1, 4, 0.7, 6 )
  = 15.1 kN
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	15.38	kN
Transverse Shear Load Saddle	1.36	kN
Longitudinal Shear Load Saddle	2.72	kN

Formulas and Substitutions for Horizontal Vessel Analysis:

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

The Computed K values from Table 4.15.1:

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

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

Moment per Equation 4.15.3 [M1]:

```
  = -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -15*500.0[1-(1-500.0/2908.0+(197.556²-0.0²)/
    (2*500.0*2908.0))/(1+(4*0.0)/(3*2908.0))]
  = -1194.1 N-m
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 15*2908/4(1+2(198²-0²)/(2908²))/(1+(4*0)/
    (3*2908))-4*500/2908
  = 3520.9 N-m
```

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

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 25.016 * 197.556/(2*8.113) - 3520.9/(pi*197.6²*8.113)
  = 26.92 N./mm^2
```

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

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 25.016 * 197.556/(2 * 8.113) + 3520.9/(pi * 197.6² * 8.113 )
  = 34.00 N./mm^2
```

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

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 25.016*197.556/(2*8.113)--1194.1/(0.1066*pi*197.6²*8.113)
  = 41.72 N./mm^2
```

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

```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 25.016*197.556/(2*8.113)+-1194.1/(0.1923*pi*197.6²*8.113)
  = 24.22 N./mm^2
```

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

```
  = Q(L-2a)/(L+(4*h2/3))
  = 15( 2908.0 - 2 * 500.0)/(2908.0 + ( 4 * 0.0/3))
  = 9.9 kN
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
```
= K2 * T / ( Rm * t )
= 1.1707 * 9.88/( 197.5563 * 8.1125 )
= 7.22 N./mm^2
```

Decay Length (4.15.22) [x1,x2]:
```
= 0.78 * sqrt( Rm * t )
= 0.78 * sqrt( 197.556 * 8.113 )
= 31.226 mm.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
= -K5 * Q * k / ( t * ( b + X1 + X2 ) )
= - 0.7603 * 15 * 0.1/( 8.113 * ( 140.0 + 31.23 + 31.23 ) )
= -0.70 N./mm^2
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.24) [sigma7]:
```
= -Q/(4*t*(b+X1+X2)) - 3*K7*Q/(2*t²)
= -15/(4*8.113*(140.0+31.226+31.226)) -
   3* 0.0529*15/(2*8.113²)
= -20.43 N./mm^2
```

Effective reinforcing plate width (4.15.1) [B1]:
```
= min( b + 1.56 * sqrt( Rm * t ), 2a  )
= min( 140.0 + 1.56 * sqrt( 197.556 * 8.113 ), 2 * 500.0 )
= 202.45 mm.
```

Free Un-Restrained Thermal Expansion between the Saddles [Exp]:
```
= Alpha * Ls * ( Design Temperature - Ambient Temperature )
= 0.000012 * 1980.0 * ( 120.0 - 21.1 )
= 2.395 mm.
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	370.0000	mm.
Baseplate Thickness	Bpthk	12.0000	mm.
Baseplate Width	Bpwid	150.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	2	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Side	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	262.	8.	4.	21.	8615.	4.66
Wearplate	200.	10.	13.	20.	26225.	36.1
Web	10.	276.	156.	28.	432011.	0.851E+04
BasePlate	150.	12.	300.	18.	540900.	0.163E+05
Totals	...	...	...	87.	1007751.	0.248E+05

Value C1 = Sumof(Ay)/Sumof(A)	=	116.	mm.
Value I = Sumof(Io) - C1*Sumof(Ay)	=	0.131E+05	cm**4
Value As = Sumof(A) - Ashell	=	65.6	cm^2

K1 = (1+cos(beta)-0.5*sin(beta)²)/(pi-beta+sin(beta)*cos(beta)) = 0.2035

Fh = K1 * Q = 0.2035 * 15.059 = 3.0649 kN

Tension Stress, St = (Fh/As)	=	0.4670	N./mm^2
Allowed Stress, Sa = 0.6 * Yield Str	=	124.1100	N./mm^2

Saddle Splitting Dimension [d]:

```
  = B - R * sin( theta )/ theta
  = 500.0 - 193.5 * sin( 1.0472 )/1.0472
  = 339.977 mm.

 Bending Moment, M  = Fh * d          =       1042.4070  N-m

 Bending Stress, Sb = ( M * C1 / I  ) =          0.9214  N./mm^2
 Allowed Stress, Sa = 2/3 * Yield Str =        137.9000  N./mm^2
```

Minimum Thickness of Baseplate per Moss:

```
  = ( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))½
  = ( 3(15 + 0.3)150.0/( 2 * 370.0 * 137.9 ))½
  = 8.236 mm.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 371.7198/( 2 - 1 )
  = 371.720 mm.
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 371.7198 * 150.0/2
  = 278.790 cm^2
```

Axial Load [P]:

```
  = Ap * Bp
  = 278.8 * 0.03
  = 7.565 kN
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 13.0 + 18.586
  = 31.586 cm^2
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 7.6/31.586
  = 2.395 N./mm^2
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	10.0	130.0	75.0	13.0	97500.0	183.
Web	185.9	10.0	5.0	18.6	9293.0	1.55
Values	...	...	...	31.6	106793.0	185.

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * rl / 2
  = 2.7/( 2 * 370.0 ) * 371.72 * 381.6/2
  = 261.267 N-m
```

Compressive Allowable, KL/R < Cc (9.0671 < 138.1347) per AISC E2-1 [Sca]:

```
  = (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 9.07 )²/(2 * 138.13² )) * 207/
    ( 5/3+3*(9.07)/(8* 138.13)-( 9.07³)/(8*138.13³)
  = 122.043 N./mm^2
```

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

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

= 2.4/122.04 + (261.27 * 106.19/5594590)/137.9
= 0.056

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	172.38	N./mm^2
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	85.0	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	2.1705	cm^2
Saddle Load QO (Weight)	QO	9.4	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.7	kN
Maximum Transverse Force	Ft	1.4	kN
Maximum Longitudinal Force	Fl	3.5	kN
Saddle Bolted to Steel Foundation		Yes	

Bolt Area Calculation per Dennis R. Moss

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

Bolt Area due to Shear Load [Bltarears]:
= Fl / (Stba * Nbolts)
= 3.47/(172.38 * 2.0)
= 0.1007 cm^2

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
= B * Ft + Sum of X Moments
= 500.0 * 1.36 + 0.0
= 681.50 N-m

Eccentricity (e):
= Rmom / QO
= 681.5/9.41
= 72.41 mm. > Bplen/6 --> Uplift in Transverse direction

f = Bplen / 2 - Edgedis
= 370.0/2 - 84.99
= 100.01 mm.

K1 = 3 (e - 0.5 * Bplen)
= 3 (72.41 - 0.5*370.0)
= -337.78 mm.

K2 = 6 * n1 * At / Bpwid * (f + e)
= 6 * 1.0 * 2.17/150.0 * (100.01 + 72.41)
= 1496.94 mm.²

K3 = -K2 * (0.5 * Bplen + f)
= -1496.94 * (0.5 * 370.0 + 100.01)
= -426644.71 mm.³

Iteratively Solving for the Effective Bearing Length:
$Y^3 + K1 * Y^2 + K2 * Y + K3 = 0$
$Y^3 + -337.78 * Y^2 + 1496.94 * Y + -426644.69 = 0$

```
Y  = 337.10 mm.

Num = (Bplen / 2 - Y / 3 - e)
    = (370.0/2 - 337.1/3 - 72.41)
    = 0.23

Denom = (Bplen / 2 - Y / 3 + f)
      = (370.0/2 - 337.1/3 + 100.01)
      = 172.65
```

Total Bolt Tension Force [Tforce]:
```
= - QO * Num / Denom
= - 9.41 * 0.23/172.65
= -0.01 kN
```

Bolt Area Required due to Transverse Load [Bltareart]:
```
= Tforce / (Stba * Nbt)
= -0.01/( 172.38 * 1.0 )
= -0.0007 cm^2
```

Required Area of a Single Bolt [Bltarear]:
```
= max[Bltarearl, Bltarears, Bltareart]
= max[0.0, 0.1007, -0.0007]
= 0.1007 cm^2
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)
```
= 2(QO + Tforce) / (Y * Bpwid)
= 2(9.41 + -0.01)/(337.1 * 150.0)
= 3.72 bars
```

Distance from Baseplate Edge to the Web [ADIST]:
```
= (Bplen - Weblngth) / 2
= (370.0 - 319.2)/2
= 25.4000 mm.
```

Overturning Moment due To Bolt Tension [Mt]:
```
= Tforce * Adist
= -0.01 * 25.4
= -0.32 N-m
```

Equivalent Bearing Pressure (f1):
```
= fc * (Y - Adist) / Y
= 3.72 * (337.1 - 25.4)/337.1
= 3.44 bars
```

Overturning Moment due to Bearing Pressure [Mc]:
```
= (Adist² * Bpwid / 6) * (f1 + 2 * fc)
= (25.4² * 150.0/6) * (3.44 + 2 * 3.72)
= 17.54 N-m
```

Baseplate Required Thickness [Treq]:
```
= (6 * max(Mt,Mc) / (Bpwid * Sba))½
= (6 *max(-0.32,17.54/(150.0 * 162.38))½
= 2.0782 mm.
```

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

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

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

```
= min( b + 1.56*sqrt( Rm * t ), 2a )
= min( 140.0 + 1.56*sqrt( 197.5563 * 8.1125 ), 2 * 500.0 )
= 202.4521 mm.
```

Input and Calculated Values:

Vessel Mean Radius	Rm	197.56	mm.
Stiffened Vessel Length per 4.15.6	L	2908.00	mm.
Distance from Saddle to Vessel tangent	a	500.00	mm.
Saddle Width	b	140.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Shell Allowable Stress used in Calculation		117.90	N./mm^2
Head Allowable Stress used in Calculation		137.90	N./mm^2
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Operating Case		14.33	kN

Horizontal Vessel Analysis Results:	Actual N./mm^2	Allowable N./mm^2
Long. Stress at Top of Midspan	27.09	117.90
Long. Stress at Bottom of Midspan	33.83	117.90
Long. Stress at Top of Saddles	41.17	117.90
Long. Stress at Bottom of Saddles	24.52	117.90
Tangential Shear in Shell	6.87	94.32
Circ. Stress at Horn of Saddle	19.45	147.38
Circ. Compressive Stress in Shell	0.66	117.90

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:

```
= Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
= 3.0 * ( 1.8/2 + 0 ) * 500.0/342.1775
= 4.0 kN
```

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

```
= max( Fl, Friction Load, Sum of X Forces) * B / Ls
= max( 0.28, 3.47, 0 ) * 500.0/1980.0005
= 0.9 kN
```

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

```
= max( Fl, Friction Force, Sum of X Forces ) * B / Ls
= max( 2.72, 3.47, 0 ) * 500.0/1980.0005
= 0.9 kN
```

Saddle Reaction Force due to Earthquake Ft [Fst]:

```
= Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
= 3.0 * ( 3/2 + 0 ) * 500.0/342.1775
= 6.0 kN
```

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

```
= Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
```

= 8 + Max(0.9, 4, 0.9, 6)
= 14.3 kN

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	14.65	kN
Transverse Shear Load Saddle	1.36	kN
Longitudinal Shear Load Saddle	3.47	kN

Formulas and Substitutions for Horizontal Vessel Analysis:

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

The Computed K values from Table 4.15.1:

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

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

Moment per Equation 4.15.3 [M1]:
= -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
= -14*500.0[1-(1-500.0/2908.0+(197.556²-0.0²)/
(2*500.0*2908.0))/(1+(4*0.0)/(3*2908.0))]
= -1136.3 N-m

Moment per Equation 4.15.4 [M2]:
= Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/(3L))-4a/L
= 14*2908/4(1+2(198²-0²)/(2908²))/(1+(4*0)/
(3*2908))-4*500/2908
= 3350.7 N-m

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
= P * Rm/(2t) - M2/(pi*Rm²t)
= 25.016 * 197.556/(2*8.113) - 3350.7/(pi*197.6²*8.113)
= 27.09 N./mm^2

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 25.016 * 197.556/(2 * 8.113) + 3350.7/(pi * 197.6² * 8.113)
= 33.83 N./mm^2

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 25.016*197.556/(2*8.113)--1136.3/(0.1066*pi*197.6²*8.113)
= 41.17 N./mm^2

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
= P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
= 25.016*197.556/(2*8.113)+-1136.3/(0.1923*pi*197.6²*8.113)
= 24.52 N./mm^2

Maximum Shear Force in the Saddle (4.15.5) [T]:
= Q(L-2a)/(L+(4*h2/3))
= 14(2908.0 - 2 * 500.0)/(2908.0 + (4 * 0.0/3))
= 9.4 kN

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
= K2 * T / (Rm * t)
= 1.1707 * 9.4/(197.5563 * 8.1125)
= 6.87 N./mm^2

Decay Length (4.15.22) [x1,x2]:

```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 197.556 * 8.113 )
  = 31.226 mm.
```

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

```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 14 * 0.1/( 8.113 * ( 140.0 + 31.23 + 31.23 ) )
  = -0.66 N./mm^2
```

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

```
  = -Q/(4*t*(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -14/(4*8.113*(140.0+31.226+31.226)) -
     3* 0.0529*14/(2*8.113²)
  = -19.45 N./mm^2
```

Effective reinforcing plate width (4.15.1) [B1]:

```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 140.0 + 1.56 * sqrt( 197.556 * 8.113 ), 2 * 500.0 )
  = 202.45 mm.
```

Results for Vessel Ribs, Web and Base

Baseplate Length	Bplen	370.0000	mm.
Baseplate Thickness	Bpthk	12.0000	mm.
Baseplate Width	Bpwid	150.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	2	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Side	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	262.	8.	4.	21.	8615.	4.66
Wearplate	200.	10.	13.	20.	26225.	36.1
Web	10.	276.	156.	28.	432011.	0.851E+04
BasePlate	150.	12.	300.	18.	540900.	0.163E+05
Totals	...	...	...	87.	1007751.	0.248E+05

```
Value  C1 = Sumof(Ay)/Sumof(A)              =     116.      mm.
Value   I = Sumof(Io) - C1*Sumof(Ay)        =    0.131E+05  cm**4
Value  As = Sumof(A) - Ashell               =     65.6      cm^2

K1 = (1+cos(beta)-0.5*sin(beta)² )/(pi-beta+sin(beta)*cos(beta)) = 0.2035

Fh = K1 * Q = 0.2035 * 14.331 = 2.9167 kN

Tension Stress, St = ( Fh/As )       =          0.4444  N./mm^2
Allowed Stress, Sa = 0.6 * Yield Str =        124.1100  N./mm^2
```

Saddle Splitting Dimension [d]:

```
  = B - R * sin( theta )/ theta
  = 500.0 - 193.5 * sin( 1.0472 )/1.0472
  = 339.977 mm.

Bending Moment, M  = Fh * d          =        992.0181  N-m

Bending Stress, Sb = ( M * C1 / I  ) =          0.8768  N./mm^2
Allowed Stress, Sa = 2/3 * Yield Str =        137.9000  N./mm^2
```

Minimum Thickness of Baseplate per Moss:

```
  = ( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))½
  = ( 3(14 + 0.3)150.0/( 2 * 370.0 * 137.9 ))½
  = 8.039 mm.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:
```
  = Web Length / ( Nribs - 1 )
  = 371.7198/( 2 - 1 )
  = 371.720 mm.
```

Baseplate Pressure Area [Ap]:
```
  = e * Bpwid / 2
  = 371.7198 * 150.0/2
  = 278.790 cm^2
```

Axial Load [P]:
```
  = Ap * Bp
  = 278.8 * 0.03
  = 7.199 kN
```

Area of the Rib and Web [Ar]:
```
  = Rib Area + Web Area
  = 13.0 + 18.586
  = 31.586 cm^2
```

Compressive Stress [Sc]:
```
  = P/Ar
  = 7.2/31.586
  = 2.279 N./mm^2
```

Check of Outside Ribs:
Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	10.0	130.0	75.0	13.0	97500.0	183.
Web	185.9	10.0	5.0	18.6	9293.0	1.55
Values	...	...	...	31.6	106793.0	185.

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * rl / 2
  = 3.5/( 2 * 370.0 ) * 371.72 * 381.6/2
  = 332.917 N-m
```

Compressive Allowable, KL/R < Cc (9.0671 < 138.1347) per AISC E2-1 [Sca]:
```
  = (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 9.07 )²/(2 * 138.13² )) * 207/
    ( 5/3+3*(9.07)/(8* 138.13)-( 9.07³)/(8*138.13³)
  = 122.043 N./mm^2
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * Distance Side/I )/Sba
  = 2.28/122.04 + ( 332.92 * 106.19/5594590 )/137.9
  = 0.064
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	172.38	N./mm^2
Bolt Corrosion Allowance	Bca	0.0	mm.

Distance from Bolts to Edge	Edgedis	85.0	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	2.1705	cm^2
Saddle Load QO (Weight)	QO	8.7	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.9	kN
Maximum Transverse Force	Ft	1.4	kN
Maximum Longitudinal Force	Fl	3.5	kN
Saddle Bolted to Steel Foundation		Yes	

Bolt Area Calculation per Dennis R. Moss

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

Bolt Area due to Shear Load [Bltarears]:
= Fl / (Stba * Nbolts)
= 3.47/(172.38 * 2.0)
= 0.1007 cm^2

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
= B * Ft + Sum of X Moments
= 500.0 * 1.36 + 0.0
= 681.50 N-m

Eccentricity (e):
= Rmom / QO
= 681.5/8.68
= 78.48 mm. > Bplen/6 --> Uplift in Transverse direction

f = Bplen / 2 - Edgedis
= 370.0/2 - 84.99
= 100.01 mm.

K1 = 3 (e - 0.5 * Bplen)
= 3 (78.48 - 0.5*370.0)
= -319.57 mm.

K2 = 6 * n1 * At / Bpwid * (f + e)
= 6 * 1.0 * 2.17/150.0 * (100.01 + 78.48)
= 1549.66 mm.²

K3 = -K2 * (0.5 * Bplen + f)
= -1549.66 * (0.5 * 370.0 + 100.01)
= -441669.93 mm.³

Iteratively Solving for the Effective Bearing Length:
Y³ + K1 * Y² + K2 * Y + K3 = 0
Y³ + -319.57 * Y² + 1549.66 * Y + -441669.91 = 0
Y = 319.05 mm.

Num = (Bplen / 2 - Y / 3 - e)
= (370.0/2 - 319.05/3 - 78.48)
= 0.17

Denom = (Bplen / 2 - Y / 3 + f)
= (370.0/2 - 319.05/3 + 100.01)
= 178.66

Total Bolt Tension Force [Tforce]:
= - QO * Num / Denom
= - 8.68 * 0.17/178.66
= -0.01 kN

Bolt Area Required due to Transverse Load [Bltareart]:
= Tforce / (Stba * Nbt)
= -0.01/(172.38 * 1.0)
= -0.0005 cm^2

Required Area of a Single Bolt [Bltarear]:
= max[Bltarearl, Bltarears, Bltareart]
= max[0.0, 0.1007, -0.0005]
= 0.1007 cm^2

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)
= 2(QO + Tforce) / (Y * Bpwid)
= 2(8.68 + -0.01)/(319.05 * 150.0)
= 3.62 bars

Distance from Baseplate Edge to the Web [ADIST]:
= (Bplen - Weblngth) / 2
= (370.0 - 319.2)/2
= 25.4000 mm.

Overturning Moment due To Bolt Tension [Mt]:
= Tforce * Adist
= -0.01 * 25.4
= -0.21 N-m

Equivalent Bearing Pressure (f1):
= fc * (Y - Adist) / Y
= 3.62 * (319.05 - 25.4)/319.05
= 3.34 bars

Overturning Moment due to Bearing Pressure [Mc]:
= (Adist² * Bpwid / 6) * (f1 + 2 * fc)
= (25.4² * 150.0/6) * (3.34 + 2 * 3.62)
= 17.08 N-m

Baseplate Required Thickness [Treq]:
= (6 * max(Mt,Mc) / (Bpwid * Sba))½
= (6 *max(-0.21,17.08/(150.0 * 162.38))½
= 2.0507 mm.

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

Horizontal Vessel Stress Calculations : Test Case

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

Minimum Wear Plate Width to be considered in analysis [b1]:
= min(b + 1.56*sqrt(Rm * t), 2a)
= min(140.0 + 1.56*sqrt(197.5563 * 8.1125), 2 * 500.0)
= 202.4521 mm.

Input and Calculated Values:

Vessel Mean Radius	Rm	197.56	mm.
Stiffened Vessel Length per 4.15.6	L	2908.00	mm.
Distance from Saddle to Vessel tangent	a	500.00	mm.
Saddle Width	b	140.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Shell Allowable Stress used in Calculation		217.19	N./mm^2
Head Allowable Stress used in Calculation		217.19	N./mm^2
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Test Case, no Ext. Forces		9.89	kN

Horizontal Vessel Analysis Results:	Actual N./mm^2	Allowable N./mm^2
Long. Stress at Top of Midspan	37.28	217.19
Long. Stress at Bottom of Midspan	41.92	217.19
Long. Stress at Top of Saddles	46.99	217.19
Long. Stress at Bottom of Saddles	35.50	217.19
Tangential Shear in Shell	4.74	173.75
Circ. Stress at Horn of Saddle	13.41	325.79
Circ. Compressive Stress in Shell	0.46	217.19

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:
= Ftr * (Ft/Num of Saddles + Z Force Load) * B / E
= 3.0 * (0.4/2 + 0) * 500.0/342.1775
= 0.8 kN

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
= max(Fl, Friction Load, Sum of X Forces) * B / Ls
= max(0.06, 0.0, 0) * 500.0/1980.0005
= 0.0 kN

Load Combination Results for Q + Wind or Seismic [Q]:
= Saddle Load + Max(Fwl, Fwt, Fsl, Fst)
= 9 + Max(0.0, 0.8, 0, 0)
= 9.9 kN

Summary of Loads at the base of this Saddle:

```
Vertical Load (including saddle weight)              10.21  kN
Transverse Shear Load Saddle                          0.18  kN
Longitudinal Shear Load Saddle                        0.06  kN
```

Hydrostatic Test Pressure at center of Vessel: 32.519 bars

Formulas and Substitutions for Horizontal Vessel Analysis:

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

The Computed K values from Table 4.15.1:

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

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

Moment per Equation 4.15.3 [M1]:

```
= -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
= -10*500.0[1-(1-500.0/2908.0+(197.556²-0.0²)/
  (2*500.0*2908.0))/(1+(4*0.0)/(3*2908.0))]
= -783.8 N-m
```

Moment per Equation 4.15.4 [M2]:

```
= Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
= 10*2908/4(1+2(198²-0²)/(2908²))/(1+(4*0)/
  (3*2908))-4*500/2908
= 2311.2 N-m
```

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

```
= P * Rm/(2t) - M2/(pi*Rm²t)
= 32.519 * 197.556/(2*8.113) - 2311.2/(pi*197.6²*8.113)
= 37.28 N./mm^2
```

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

```
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 32.519 * 197.556/(2 * 8.113) + 2311.2/(pi * 197.6² * 8.113 )
= 41.92 N./mm^2
```

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

```
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 32.519*197.556/(2*8.113)--783.8/(0.1066*pi*197.6²*8.113)
= 46.99 N./mm^2
```

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

```
= P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
= 32.519*197.556/(2*8.113)+-783.8/(0.1923*pi*197.6²*8.113)
= 35.50 N./mm^2
```

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

```
= Q(L-2a)/(L+(4*h2/3))
= 10( 2908.0 - 2 * 500.0)/(2908.0 + ( 4 * 0.0/3))
= 6.5 kN
```

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

```
= K2 * T / ( Rm * t )
= 1.1707 * 6.49/( 197.5563 * 8.1125 )
= 4.74 N./mm^2
```

Decay Length (4.15.22) [x1,x2]:

```
= 0.78 * sqrt( Rm * t )
= 0.78 * sqrt( 197.556 * 8.113 )
```

= 31.226 mm.

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
= -K5 * Q * k / (t * (b + X1 + X2))
= - 0.7603 * 10 * 0.1/(8.113 * (140.0 + 31.23 + 31.23))
= -0.46 N./mm^2

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.24) [sigma7]:
= -Q/(4*t*(b+X1+X2)) - 3*K7*Q/(2*t²)
= -10/(4*8.113*(140.0+31.226+31.226)) -
3* 0.0529*10/(2*8.113²)
= -13.41 N./mm^2

Effective reinforcing plate width (4.15.1) [B1]:
= min(b + 1.56 * sqrt(Rm * t), 2a)
= min(140.0 + 1.56 * sqrt(197.556 * 8.113), 2 * 500.0)
= 202.45 mm.

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	370.0000	mm.
Baseplate Thickness	Bpthk	12.0000	mm.
Baseplate Width	Bpwid	150.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	2	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Side	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	262.	8.	4.	21.	8615.	4.66
Wearplate	200.	10.	13.	20.	26225.	36.1
Web	10.	276.	156.	28.	432011.	0.851E+04
BasePlate	150.	12.	300.	18.	540900.	0.163E+05
Totals	...	...	...	87.	1007751.	0.248E+05

Value C1 = Sumof(Ay)/Sumof(A) = 116. mm.
Value I = Sumof(Io) - C1*Sumof(Ay) = 0.131E+05 cm**4
Value As = Sumof(A) - Ashell = 65.6 cm^2

K1 = (1+cos(beta)-0.5*sin(beta)²)/(pi-beta+sin(beta)*cos(beta)) = 0.2035

Fh = K1 * Q = 0.2035 * 9.885 = 2.0118 kN

Tension Stress, St = (Fh/As) = 0.3065 N./mm^2
Allowed Stress, Sa = 0.6 * Yield Str = 124.1100 N./mm^2

Saddle Splitting Dimension [d]:
= B - R * sin(theta)/ theta
= 500.0 - 193.5 * sin(1.0472)/1.0472
= 339.977 mm.

Bending Moment, M = Fh * d = 684.2582 N-m

Bending Stress, Sb = (M * C1 / I) = 0.6048 N./mm^2
Allowed Stress, Sa = 2/3 * Yield Str = 137.9000 N./mm^2

Minimum Thickness of Baseplate per Moss:
= (3(Q + Saddle_Wt)BasePlateWidth / (2 * BasePlateLength * AllStress))½
= (3(10 + 0.3)150.0/(2 * 370.0 * 137.9))½
= 6.709 mm.

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:
= Web Length / (Nribs - 1)
= 371.7198/(2 - 1)
= 371.720 mm.

Baseplate Pressure Area [Ap]:
= e * Bpwid / 2
= 371.7198 * 150.0/2
= 278.790 cm^2

Axial Load [P]:
= Ap * Bp
= 278.8 * 0.02
= 4.966 kN

Area of the Rib and Web [Ar]:
= Rib Area + Web Area
= 13.0 + 18.586
= 31.586 cm^2

Compressive Stress [Sc]:
= P/Ar
= 5.0/31.586
= 1.572 N./mm^2

Check of Outside Ribs:
Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	10.0	130.0	75.0	13.0	97500.0	183.
Web	185.9	10.0	5.0	18.6	9293.0	1.55
Values	...	...	...	31.6	106793.0	185.

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * rl / 2
= 0.1/(2 * 370.0) * 371.72 * 381.6/2
= 5.388 N-m

Compressive Allowable, KL/R < Cc (9.0671 < 138.1347) per AISC E2-1 [Sca]:
= (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= (1-(9.07)²/(2 * 138.13²)) * 207/
(5/3+3*(9.07)/(8* 138.13)-(9.07³)/(8*138.13³)
= 122.043 N./mm^2

AISC Unity Check of Outside Ribs (must be <= 1)
= Sc/Sca + (Rm * Distance Side/I)/Sba
= 1.57/122.04 + (5.39 * 106.19/5594590)/137.9
= 0.014

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	172.38	N./mm^2
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	85.0	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	

BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	2.1705	cm^2
Saddle Load QO (Weight)	QO	9.4	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.0	kN
Maximum Transverse Force	Ft	0.2	kN
Maximum Longitudinal Force	Fl	0.1	kN
Saddle Bolted to Steel Foundation		Yes	

Bolt Area Calculation per Dennis R. Moss

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

Bolt Area due to Shear Load [Bltearears]:
= Fl / (Stba * Nbolts)
= 0.06/(172.38 * 2.0)
= 0.0016 cm^2

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
= B * Ft + Sum of X Moments
= 500.0 * 0.18 + 0.0
= 91.64 N-m

Eccentricity (e):
= Rmom / QO
= 91.64/9.4
= 9.74 mm. < Bplen/6 --> No Uplift in Transverse direction

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

Required Area of a Single Bolt [Bltarear]:
= max[Bltearearl, Bltearears, Bltareart]
= max[0.0, 0.0016, 0.0]
= 0.0016 cm^2

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

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

Minimum Wear Plate Width to be considered in analysis [b1]:
= min(b + 1.56*sqrt(Rm * t), 2a)
= min(140.0 + 1.56*sqrt(197.5563 * 8.1125), 2 * 500.0)
= 202.4521 mm.

Input and Calculated Values:

Vessel Mean Radius	Rm	197.56	mm.
Stiffened Vessel Length per 4.15.6	L	2908.00	mm.
Distance from Saddle to Vessel tangent	a	500.00	mm.
Saddle Width	b	140.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Shell Allowable Stress used in Calculation		217.19	N./mm^2
Head Allowable Stress used in Calculation		217.19	N./mm^2

```
Circumferential Efficiency in Plane of Saddle          1.00
Circumferential Efficiency at Mid-Span                 1.00

Saddle Force Q, Test Case, no Ext. Forces              9.16  kN
```

Horizontal Vessel Analysis Results:	Actual N./mm^2	Allowable N./mm^2
Long. Stress at Top of Midspan	37.45	217.19
Long. Stress at Bottom of Midspan	41.75	217.19
Long. Stress at Top of Saddles	46.44	217.19
Long. Stress at Bottom of Saddles	35.80	217.19
Tangential Shear in Shell	4.39	173.75
Circ. Stress at Horn of Saddle	12.42	325.79
Circ. Compressive Stress in Shell	0.42	217.19

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:

```
= Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
= 3.0 * ( 0.4/2 + 0 ) * 500.0/342.1775
= 0.8 kN
```

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

```
= max( Fl, Friction Load, Sum of X Forces) * B / Ls
= max( 0.06, 0.0, 0 ) * 500.0/1980.0005
= 0.0 kN
```

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

```
= Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
= 8 + Max( 0.0, 0.8, 0, 0 )
= 9.2 kN
```

Summary of Loads at the base of this Saddle:

```
Vertical Load (including saddle weight)                9.48  kN
Transverse Shear Load Saddle                           0.18  kN
Longitudinal Shear Load Saddle                         0.06  kN
```

Hydrostatic Test Pressure at center of Vessel: 32.519 bars

Formulas and Substitutions for Horizontal Vessel Analysis:

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

The Computed K values from Table 4.15.1:

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

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

Moment per Equation 4.15.3 [M1]:

```
= -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
= -9*500.0[1-(1-500.0/2908.0+(197.556²-0.0²)/
  (2*500.0*2908.0))/(1+(4*0.0)/(3*2908.0))]
= -726.0 N-m
```

Moment per Equation 4.15.4 [M2]:

```
= Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
= 9*2908/4(1+2(198²-0²)/(2908²))/(1+(4*0)/
```

(3*2908))-4*500/2908
= 2140.7 N-m

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
= P * Rm/(2t) - M2/(pi*Rm²t)
= 32.519 * 197.556/(2*8.113) - 2140.7/(pi*197.6²*8.113)
= 37.45 N./mm^2

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 32.519 * 197.556/(2 * 8.113) + 2140.7/(pi * 197.6² * 8.113)
= 41.75 N./mm^2

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 32.519*197.556/(2*8.113)--726.0/(0.1066*pi*197.6²*8.113)
= 46.44 N./mm^2

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
= P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
= 32.519*197.556/(2*8.113)+-726.0/(0.1923*pi*197.6²*8.113)
= 35.80 N./mm^2

Maximum Shear Force in the Saddle (4.15.5) [T]:
= Q(L-2a)/(L+(4*h2/3))
= 9(2908.0 - 2 * 500.0)/(2908.0 + (4 * 0.0/3))
= 6.0 kN

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
= K2 * T / (Rm * t)
= 1.1707 * 6.01/(197.5563 * 8.1125)
= 4.39 N./mm^2

Decay Length (4.15.22) [x1,x2]:
= 0.78 * sqrt(Rm * t)
= 0.78 * sqrt(197.556 * 8.113)
= 31.226 mm.

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
= -K5 * Q * k / (t * (b + X1 + X2))
= - 0.7603 * 9 * 0.1/(8.113 * (140.0 + 31.23 + 31.23))
= -0.42 N./mm^2

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.24) [sigma7]:
= -Q/(4*t*(b+X1+X2)) - 3*K7*Q/(2*t²)
= -9/(4*8.113*(140.0+31.226+31.226)) -
3* 0.0529*9/(2*8.113²)
= -12.42 N./mm^2

Effective reinforcing plate width (4.15.1) [B1]:
= min(b + 1.56 * sqrt(Rm * t), 2a)
= min(140.0 + 1.56 * sqrt(197.556 * 8.113), 2 * 500.0)
= 202.45 mm.

Results for Vessel Ribs, Web and Base

Baseplate Length	Bplen	370.0000	mm.
Baseplate Thickness	Bpthk	12.0000	mm.
Baseplate Width	Bpwid	150.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	2	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.

Web Location Webloc Side

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	262.	8.	4.	21.	8615.	4.66
Wearplate	200.	10.	13.	20.	26225.	36.1
Web	10.	276.	156.	28.	432011.	0.851E+04
BasePlate	150.	12.	300.	18.	540900.	0.163E+05
Totals	...	...	...	87.	1007751.	0.248E+05

Value C1 = Sumof(Ay)/Sumof(A) = 116. mm.
Value I = Sumof(Io) - C1*Sumof(Ay) = 0.131E+05 cm**4
Value As = Sumof(A) - Ashell = 65.6 cm^2

K1 = (1+cos(beta)-0.5*sin(beta)²)/(pi-beta+sin(beta)*cos(beta)) = 0.2035

Fh = K1 * Q = 0.2035 * 9.156 = 1.8634 kN

Tension Stress, St = (Fh/As) = 0.2839 N./mm^2
Allowed Stress, Sa = 0.6 * Yield Str = 124.1100 N./mm^2

Saddle Splitting Dimension [d]:
= B - R * sin(theta)/ theta
= 500.0 - 193.5 * sin(1.0472)/1.0472
= 339.977 mm.

Bending Moment, M = Fh * d = 633.7698 N-m

Bending Stress, Sb = (M * C1 / I) = 0.5602 N./mm^2
Allowed Stress, Sa = 2/3 * Yield Str = 137.9000 N./mm^2

Minimum Thickness of Baseplate per Moss:
= (3(Q + Saddle_Wt)BasePlateWidth / (2 * BasePlateLength * AllStress))½
= (3(9 + 0.3)150.0/(2 * 370.0 * 137.9))½
= 6.465 mm.

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:
= Web Length / (Nribs - 1)
= 371.7198/(2 - 1)
= 371.720 mm.

Baseplate Pressure Area [Ap]:
= e * Bpwid / 2
= 371.7198 * 150.0/2
= 278.790 cm^2

Axial Load [P]:
= Ap * Bp
= 278.8 * 0.02
= 4.599 kN

Area of the Rib and Web [Ar]:
= Rib Area + Web Area
= 13.0 + 18.586
= 31.586 cm^2

Compressive Stress [Sc]:
= P/Ar

= 4.6/31.586
= 1.456 N./mm^2

Check of Outside Ribs:
Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	10.0	130.0	75.0	13.0	97500.0	183.
Web	185.9	10.0	5.0	18.6	9293.0	1.55
Values	...	...	...	31.6	106793.0	185.

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * rl / 2
= 0.1/(2 * 370.0) * 371.72 * 381.6/2
= 5.388 N-m

Compressive Allowable, KL/R < Cc (9.0671 < 138.1347) per AISC E2-1 [Sca]:
= (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= (1-(9.07)²/(2 * 138.13²)) * 207/
(5/3+3*(9.07)/(8* 138.13)-(9.07³)/(8*138.13³)
= 122.043 N./mm^2

AISC Unity Check of Outside Ribs (must be <= 1)
= Sc/Sca + (Rm * Distance Side/I)/Sba
= 1.46/122.04 + (5.39 * 106.19/5594590)/137.9
= 0.013

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	172.38	N./mm^2
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	85.0	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	2.1705	cm^2
Saddle Load QO (Weight)	QO	8.7	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.0	kN
Maximum Transverse Force	Ft	0.2	kN
Maximum Longitudinal Force	Fl	0.1	kN
Saddle Bolted to Steel Foundation		Yes	

Bolt Area Calculation per Dennis R. Moss

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

Bolt Area due to Shear Load [Bltarears]:
= Fl / (Stba * Nbolts)
= 0.06/(172.38 * 2.0)
= 0.0016 cm^2

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
= B * Ft + Sum of X Moments
= 500.0 * 0.18 + 0.0
= 91.64 N-m

Eccentricity (e):
= Rmom / QO
= 91.64/8.67
= 10.56 mm. < Bplen/6 --> No Uplift in Transverse direction

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

Required Area of a Single Bolt [Bltarear]:
= max[Bltarearl, Bltarears, Bltareart]
= max[0.0, 0.0016, 0.0]
= 0.0016 cm^2

Nozzle Calculation Summary:

Description	MAWP bars	Ext	MAPNC bars	UG-45	[tr] mm.	Weld Path	Areas or Stresses
T2	...	OK	...	OK	7.16	OK	Passed
T1	...	OK	...	OK	7.16	OK	Passed
S2	...	OK	...	OK	7.16	OK	Passed
S1	...	OK	...	OK	7.16	OK	Passed
S3	...	OK	...	OK	7.16	OK	Passed
T4	...	OK	...	OK	6.22	OK	Passed
T3	...	OK	...	OK	6.42	OK	Passed

MAWP Summary:

Minimum MAWP Nozzles : 0.000 Nozzle : T3

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

Check the Spatial Relationship between the Nozzles

From Node	Nozzle Description	X Coordinate mm.	Layout Angle deg	Dia. Limit mm.
20	T2	210.000	0.000	150.862
20	T1	210.000	180.000	150.862
40	S2	662.175	0.000	150.862
40	S1	3196.175	0.000	150.862
40	S3	662.175	180.000	113.600
60	T4	3693.350	0.000	63.875
60	T3	3693.350	180.000	70.225

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: T2 From : 20

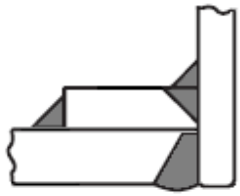
Pressure for Reinforcement Calculations	P	25.000	bars
Temperature for Internal Pressure	Temp	190	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	190	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	117.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	381.00	mm.
Design Length of Section	L	402.7500	mm.
Shell Finished (Minimum) Thickness	t	11.1125	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		210.00	mm.
User Entered Minimum Design Metal Temperature		-10.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	N./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		3.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.3344	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
Diameter of Pad along vessel surface	Dp	188.9000	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	8.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		50.0000	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: T2

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

Actual Outside Diameter Used in Calculation	3.500	in.
Actual Thickness Used in Calculation	0.383	in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (25.0*193.5)/(118*1.0-0.6*25.0)
= 4.1560 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)
= (25.0*44.45)/(118*1.0+0.4*25.0)
= 0.9346 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.4135 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	150.8618	mm.
Parallel to Vessel Wall, opening length	d	75.4309	mm.
Normal to Vessel Wall (Thickness Limit), pad side	Tlwp	20.2812	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, 117.9/117.9)
= 1.000

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 117.9/117.9)
= 1.000

Weld Strength Reduction Factor [fr4]:
= min(1, Sp/Sv)
= min(1, 137.9/117.9)
= 1.000

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

= min(1.0, 1.0)
= 1.000

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	3.135	0.507	NA
Area in Shell	A1	2.984	5.106	NA
Area in Nozzle Wall	A2	2.353	2.564	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	6.196	6.196	NA
TOTAL AREA AVAILABLE	Atot	12.173	14.506	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.
The area available with the given pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (75.4309*4.156*1.0+2*6.7345*4.156*1.0*(1-1.0))
= 3.135 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)
= 75.431(1.0 * 8.1125 - 1.0 * 4.156) - 2 * 6.735
(1.0 * 8.1125 - 1.0 * 4.156) * (1 - 1.0)
= 2.984 cm^2

Area Available in Nozzle Wall Projecting Outward [A2]:
= (2 * Tlwp) * (tn - trn) * fr2
= (2 * 20.28) * (6.73 - 0.93) * 1.0
= 2.353 cm^2

Area Available in Welds [A41 + A42 + A43]:
= Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
= 8.0² * 1.0 + (0.0)² * 1.0 + 0.0² * 1.0
= 0.640 cm^2

Area Available in Element [A5]:
= (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
= (150.8618 - 88.9) * 10.0 * 1.0
= 6.196 cm^2

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

Wall Thickness for Internal/External pressures ta = 3.9346 mm.
Wall Thickness per UG16(b), tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 7.1560 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 7.1560 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(7.156, 4.5)]
= 7.1560 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(3.9346, 7.156)
= 7.1560 mm.

Available Nozzle Neck Thickness = 9.7345 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	:	55.1,	Allowable :	117.9 N./mm^2	Passed
Expansion	:	0.0,	Allowable :	239.7 N./mm^2	Passed
Occasional	:	6.4,	Allowable :	156.8 N./mm^2	Passed
Shear	:	27.3,	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, Curve: B

Govrn. thk, tg = 9.735, tr = 0.935, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

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

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

Govrn. thk, tg = 9.735, tr = 0.935, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

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

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

Govrn. thk, tg = 9.735, tr = 0.935, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

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

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

Govrn. thk, tg = 10.0, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.512, Temp. Reduction = 31 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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

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

Govrn. thk, tg = 9.735, tr = 0.935, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

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

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:

```
 Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -29 °C
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -48 °C
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-c)      -104 °C
```

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

```
 Design Pressure/Ambient Rating = 25.00/51.10 = 0.489
```

Note:
Using the min value from (b)(1)(-b) and (b)(1)(-c) above as the computed nozzle flange MDMT.

Weld Size Calculations, Description: T2

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      6.7345  mm.
 Intermediate Calc. for pad/shell Welds   TminPad      9.7000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
 Nozzle Weld          4.7142 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
 Pad Weld             4.8500 = 0.5*TminPad  5.6560 = 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, (3.1349 - 2.9844 + 2 * 6.7345 * 1.0 *
    (1.0 * 8.1125 - 4.156 ) )118)
  = 8.06 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 2.3526 + 6.1962 + 0.64 - 0.0 * 1.0 ) * 118
  = 108.33 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 2.3526 + 0.0 + 0.64 + ( 1.0927 ) ) * 118
  = 48.16 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 2.3526 + 0.0 + 0.64 + 6.1962 + ( 1.0927 ) ) * 118
  = 121.21 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 88.9 * 8.0 * 0.49 * 118
  = 65. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 188.9 * 8.0 * 0.49 * 118
  = 137. kN
```

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.1416 * 41.0827) * (9.7345 - 3.0) * 0.7 * 118
= 72. kN

Tension, Pad Groove Weld [Tpgw]:
= (pi/2) * Dlo * Wgpn * 0.74 * Seg
= (3.1416/2) * 88.9 * 10.0 * 0.74 * 138
= 142. kN

Tension, Shell Groove Weld [Tngw]:
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= (3.1416/2.0) * 88.9 * (8.3344 - 3.0) * 0.74 * 118
= 65. kN

Strength of Failure Paths:

PATH11 = (SPEW + SNW) = (137 + 72) = 209 kN
PATH22 = (Sonw + Tpgw + Tngw + Sinw)
= (65 + 142 + 65 + 0) = 272 kN
PATH33 = (Spew + Tngw + Sinw)
= (137 + 65 + 0) = 202 kN

Summary of Failure Path Calculations:

Path 1-1 = 208 kN , must exceed W = 8 kN or W1 = 108 kN
Path 2-2 = 272 kN , must exceed W = 8 kN or W2 = 48 kN
Path 3-3 = 202 kN , must exceed W = 8 kN or W3 = 121 kN

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

The Drop for this Nozzle is : 5.2584 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 216.3709 mm.

Input Echo, WRC107/537 Item 1, Description: T2 :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	381.000	mm.
Vessel Thickness	Tv	11.113	mm.
Design Temperature		190.00	°C
Vessel Material		SA-106 B	
Vessel Cold S.I. Allowable	Smc	117.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	117.90	N./mm^2
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	88.900	mm.
Nozzle Thickness	Tn	9.735	mm.
Nozzle Material		SA-106 B	
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	10.000	mm.
Diameter of Reinforcing Pad	Dpad	188.900	mm.
Design Internal Pressure	Dp	25.000	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	3.2	kN
Longitudinal Shear	(SUS)	Vl	3.2	kN
Circumferential Shear	(SUS)	Vc	3.2	kN
Circumferential Moment	(SUS)	Mc	1100.0	N-m
Longitudinal Moment	(SUS)	Ml	1100.0	N-m
Torsional Moment	(SUS)	Mt	1300.0	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 ) )
= 88.9 + 2 * 1.65 * sqrt( 197.556 ( 11.113 - 3.0 ) )
= 221.010 mm.
```

WRC 107 Stress Calculation for SUStained loads:

Radial Load		P	3.2	kN
Circumferential Shear		VC	3.2	kN
Longitudinal Shear		VL	3.2	kN
Circumferential Moment		MC	1100.0	N-m
Longitudinal Moment		ML	1100.0	N-m
Torsional Moment		MT	1300.0	N-m

Dimensionless Parameters used : Gamma = 11.18

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.192	4C	1.931	(A,B)
N(PHI) / (P/Rm)	0.192	3C	1.667	(C,D)
M(PHI) / (P)	0.192	2C1	0.083	(A,B)
M(PHI) / (P)	0.192	1C	0.111	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.192	3A	0.339	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.192	1A	0.096	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.192	3B	1.207	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.192	1B	0.046	(A,B,C,D)
N(x) / (P/Rm)	0.192	3C	1.667	(A,B)
N(x) / (P/Rm)	0.192	4C	1.931	(C,D)
M(x) / (P)	0.192	1C1	0.113	(A,B)
M(x) / (P)	0.192	2C	0.081	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.192	4A	0.535	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.192	2A	0.055	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.192	4B	0.342	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.192	2B	0.074	(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	-1.5	-1.5	-1.5	-1.5
Circ. Bend. P	-4.8	4.8	-4.8	4.8	-6.5	6.5	-6.5	6.5
Circ. Memb. MC	0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Circ. Memb. MC	0.0	0.0	0.0	0.0	-49.7	49.7	49.7	-49.7
Circ. Memb. ML	-9.3	-9.3	9.3	9.3	0.0	0.0	0.0	0.0
Circ. Bend. ML	-23.9	23.9	23.9	-23.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-39.7	17.7	26.6	-11.4	-60.3	52.1	44.3	-42.0
Long. Memb. P	-1.5	-1.5	-1.5	-1.5	-1.7	-1.7	-1.7	-1.7
Long. Bend. P	-6.6	6.6	-6.6	6.6	-4.8	4.8	-4.8	4.8
Long. Memb. MC	0.0	0.0	0.0	0.0	-4.1	-4.1	4.1	4.1
Long. Bend. MC	0.0	0.0	0.0	0.0	-28.3	28.3	28.3	-28.3
Long. Memb. ML	-2.6	-2.6	2.6	2.6	0.0	0.0	0.0	0.0
Long. Bend. ML	-38.0	38.0	38.0	-38.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-48.7	40.6	32.6	-30.2	-38.9	27.3	26.0	-21.1
Shear VC	1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.3	-1.3	1.3	1.3
Shear MT	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Tot. Shear	7.0	7.0	4.5	4.5	4.5	4.5	7.0	7.0
Str. Int.	52.6	42.6	35.0	31.2	61.2	52.9	46.7	44.2

Dimensionless Parameters used : Gamma = 24.35

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.418	4C	2.460	(A,B)
N(PHI) / (P/Rm)	0.418	3C	1.198	(C,D)
M(PHI) / (P)	0.418	2C1	0.014	(A,B)
M(PHI) / (P)	0.418	1C !	0.059	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.418	3A	0.869	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.418	1A	0.068	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.418	3B	1.572	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.418	1B	0.012	(A,B,C,D)
N(x) / (P/Rm)	0.418	3C	1.198	(A,B)
N(x) / (P/Rm)	0.418	4C	2.460	(C,D)
M(x) / (P)	0.418	1C1	0.030	(A,B)
M(x) / (P)	0.418	2C !	0.030	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.418	4A	2.422	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.418	2A	0.029	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.418	4B	0.816	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.418	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	-4.9	-4.9	-4.9	-4.9	-2.4	-2.4	-2.4	-2.4
Circ. Bend. P	-4.0	4.0	-4.0	4.0	-17.2	17.2	-17.2	17.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	-7.2	-7.2	7.2	7.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	-82.6	82.6	82.6	-82.6
Circ. Memb. ML	-13.1	-13.1	13.1	13.1	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.	-36.8	0.9	19.1	-2.8	-109.5	90.2	70.2	-60.5
Long. Memb. P	-2.4	-2.4	-2.4	-2.4	-4.9	-4.9	-4.9	-4.9
Long. Bend. P	-8.7	8.7	-8.7	8.7	-8.7	8.7	-8.7	8.7
Long. Memb. MC	0.0	0.0	0.0	0.0	-20.1	-20.1	20.1	20.1
Long. Bend. MC	0.0	0.0	0.0	0.0	-35.5	35.5	35.5	-35.5
Long. Memb. ML	-6.8	-6.8	6.8	6.8	0.0	0.0	0.0	0.0
Long. Bend. ML	-24.4	24.4	24.4	-24.4	0.0	0.0	0.0	0.0
Tot. Long. Str.	-42.3	24.0	20.1	-11.4	-69.2	19.2	41.9	-11.5
Shear VC	1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.3	-1.3	1.3	1.3
Shear MT	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Tot. Shear	4.2	4.2	1.5	1.5	1.5	1.5	4.2	4.2
Str. Int.	44.6	24.7	21.2	11.6	109.5	90.3	70.8	60.9

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)	25.5	28.0	25.5	28.0	25.5	28.0	25.5	28.0
Circ. Pl (SUS)	-11.0	-11.0	7.6	7.6	-4.1	-4.1	1.2	1.2
Circ. Q (SUS)	-28.7	28.7	19.0	-19.0	-56.2	56.2	43.2	-43.2
Long. Pm (SUS)	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8
Long. Pl (SUS)	-4.1	-4.1	1.2	1.2	-5.8	-5.8	2.4	2.4
Long. Q (SUS)	-44.7	44.7	31.4	-31.4	-33.1	33.1	23.5	-23.5
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.3	1.3	-1.3	-1.3	-1.3	-1.3	1.3	1.3
Shear Q (SUS)	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Pm (SUS)	25.5	28.0	25.5	28.0	25.5	28.0	25.5	28.0
Pm+Pl (SUS)	14.8	17.2	33.2	35.7	21.6	24.0	26.8	29.3
Pm+Pl+Q (Total)	38.1	57.5	54.4	35.2	36.7	80.7	71.4	18.8

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

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

Pm (SUS)	28.02	117.90	Passed
Pm+Pl (SUS)	35.71	176.86	Passed
Pm+Pl+Q (TOTAL)	80.66	353.71	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)	58.4	60.9	58.4	60.9	58.4	60.9	58.4	60.9
Circ. Pl (SUS)	-18.0	-18.0	8.1	8.1	-9.6	-9.6	4.8	4.8
Circ. Q (SUS)	-18.9	18.9	10.9	-10.9	-99.9	99.9	65.4	-65.4
Long. Pm (SUS)	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2
Long. Pl (SUS)	-9.2	-9.2	4.4	4.4	-25.0	-25.0	15.2	15.2
Long. Q (SUS)	-33.1	33.1	15.7	-15.7	-44.2	44.2	26.7	-26.7
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.3	1.3	-1.3	-1.3	-1.3	-1.3	1.3	1.3
Shear Q (SUS)	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Pm (SUS)	58.4	60.9	58.4	60.9	58.4	60.9	58.4	60.9
Pm+Pl (SUS)	40.5	43.0	66.6	69.1	48.8	51.3	63.3	65.8
Pm+Pl+Q (Total)	35.7	63.5	77.6	58.2	51.3	151.2	128.9	19.2

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	60.91	117.90	Passed
Pm+Pl (SUS)	69.10	176.86	Passed
Pm+Pl+Q (TOTAL)	151.17	353.71	Passed

INPUT VALUES, Nozzle Description: T1 From : 20

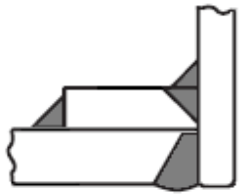
Pressure for Reinforcement Calculations	P	25.037	bars
Temperature for Internal Pressure	Temp	190	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	190	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	117.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	381.00	mm.
Design Length of Section	L	402.7500	mm.
Shell Finished (Minimum) Thickness	t	11.1125	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		210.00	mm.
User Entered Minimum Design Metal Temperature		-10.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
Diameter Basis (for tr calc only)		OD	
Layout Angle		180.00	deg
Diameter		3.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	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	8.3344	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
Diameter of Pad along vessel surface	Dp	214.3000	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	8.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		62.7000	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: T1

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

Actual Outside Diameter Used in Calculation	3.500	in.
Actual Thickness Used in Calculation	0.383	in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (25.04*193.5)/(118*1.0-0.6*25.04)
= 4.1623 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)
= (25.04*44.45)/(118*1.0+0.4*25.04)
= 0.9360 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.4135 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	150.8618	mm.
Parallel to Vessel Wall, opening length	d	75.4309	mm.
Normal to Vessel Wall (Thickness Limit), pad side	Tlwp	20.2812	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, 117.9/117.9)
= 1.000

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 117.9/117.9)
= 1.000

Weld Strength Reduction Factor [fr4]:
= min(1, Sp/Sv)
= min(1, 137.9/117.9)
= 1.000

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

= min(1.0, 1.0)
= 1.000

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	3.140	0.507	NA
Area in Shell	A1	2.980	5.106	NA
Area in Nozzle Wall	A2	2.352	2.564	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	4.647	4.647	NA
TOTAL AREA AVAILABLE	Atot	10.619	12.957	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.
The area available with the given pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (75.4309*4.1623*1.0+2*6.7345*4.1623*1.0*(1-1.0))
= 3.140 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)
= 75.431(1.0 * 8.1125 - 1.0 * 4.162) - 2 * 6.735
(1.0 * 8.1125 - 1.0 * 4.1623) * (1 - 1.0)
= 2.980 cm^2

Area Available in Nozzle Wall Projecting Outward [A2]:
= (2 * Tlwp) * (tn - trn) * fr2
= (2 * 20.28) * (6.73 - 0.94) * 1.0
= 2.352 cm^2

Area Available in Welds [A41 + A42 + A43]:
= Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
= 8.0² * 1.0 + (0.0)² * 1.0 + 0.0² * 1.0
= 0.640 cm^2

Area Available in Element, also see UG-37(h) [A5]:
= (min(Dp,DL)-(Nozzle OD))(min(tp,Tlwp,te)) * fr4 * 0.75
= (150.8618 - 88.9)10.0 * 1.0 * 0.75
= 4.647 cm^2

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

Wall Thickness for Internal/External pressures ta = 3.9360 mm.
Wall Thickness per UG16(b), tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 7.1623 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 7.1623 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(7.1623, 4.5)]
= 7.1623 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(3.936, 7.1623)
= 7.1623 mm.

Available Nozzle Neck Thickness = 9.7345 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	:	55.1,	Allowable :	117.9 N./mm^2	Passed
Expansion	:	0.0,	Allowable :	239.7 N./mm^2	Passed
Occasional	:	6.4,	Allowable :	156.8 N./mm^2	Passed
Shear	:	27.3,	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, Curve: B

Govrn. thk, tg = 9.735, tr = 0.936, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

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

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

Govrn. thk, tg = 9.735, tr = 0.936, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

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

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

Govrn. thk, tg = 9.735, tr = 0.936, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

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

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

Govrn. thk, tg = 10.0, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.513, Temp. Reduction = 31 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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

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

Govrn. thk, tg = 9.735, tr = 0.936, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

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

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:

```
 Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)      -29 °C
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)        -48 °C
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-c)       -104 °C
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
`Design Pressure/Ambient Rating = 25.04/51.10 = 0.490`

Note:
Using the min value from (b)(1)(-b) and (b)(1)(-c) above as the computed nozzle flange MDMT.

Weld Size Calculations, Description: T1

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      6.7345  mm.
 Intermediate Calc. for pad/shell Welds   TminPad      9.7000  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.7142 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.
Pad Weld	4.8500 = 0.5*TminPad	5.6560 = 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, (3.1397 - 2.9797 + 2 * 6.7345 * 1.0 *
    (1.0 * 8.1125 - 4.1623 ) )118)
  = 8.16 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 2.352 + 4.6471 + 0.64 - 0.0 * 1.0 ) * 118
  = 90.06 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 2.352 + 0.0 + 0.64 + ( 1.0927 ) ) * 118
  = 48.16 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 2.352 + 0.0 + 0.64 + 4.6471 + ( 1.0927 ) ) * 118
  = 102.94 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 88.9 * 8.0 * 0.49 * 118
  = 65. kN
```

Shear, Pad Element Weld [Spew]:
```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 214.3 * 8.0 * 0.49 * 118
  = 156. kN
```

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.1416 * 41.0827) * (9.7345 - 3.0) * 0.7 * 118
= 72. kN

Tension, Pad Groove Weld [Tpgw]:
= (pi/2) * Dlo * Wgpn * 0.74 * Seg
= (3.1416/2) * 88.9 * 10.0 * 0.74 * 138
= 142. kN

Tension, Shell Groove Weld [Tngw]:
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= (3.1416/2.0) * 88.9 * (8.3344 - 3.0) * 0.74 * 118
= 65. kN

Strength of Failure Paths:

PATH11 = (SPEW + SNW) = (156 + 72) = 227 kN
PATH22 = (Sonw + Tpgw + Tngw + Sinw)
= (65 + 142 + 65 + 0) = 272 kN
PATH33 = (Spew + Tngw + Sinw)
= (156 + 65 + 0) = 221 kN

Summary of Failure Path Calculations:

Path 1-1 = 227 kN , must exceed W = 8 kN or W1 = 90 kN
Path 2-2 = 272 kN , must exceed W = 8 kN or W2 = 48 kN
Path 3-3 = 220 kN , must exceed W = 8 kN or W3 = 102 kN

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

The Drop for this Nozzle is : 5.2584 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 216.3709 mm.

Input Echo, WRC107/537 Item 1, Description: T1 :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	381.000	mm.
Vessel Thickness	Tv	11.113	mm.
Design Temperature		190.00	°C
Vessel Material		SA-106 B	
Vessel Cold S.I. Allowable	Smc	117.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	117.90	N./mm^2
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	88.900	mm.
Nozzle Thickness	Tn	9.735	mm.
Nozzle Material		SA-106 B	
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	10.000	mm.
Diameter of Reinforcing Pad	Dpad	214.300	mm.
Design Internal Pressure	Dp	25.037	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	3.2	kN
Longitudinal Shear	(SUS)	Vl	3.2	kN
Circumferential Shear	(SUS)	Vc	3.2	kN
Circumferential Moment	(SUS)	Mc	1100.0	N-m
Longitudinal Moment	(SUS)	Ml	1100.0	N-m
Torsional Moment	(SUS)	Mt	1300.0	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 ) )
  = 88.9 + 2 * 1.65 * sqrt( 197.556 ( 11.113 - 3.0 ) )
  = 221.010 mm.
```

WRC 107 Stress Calculation for SUStained loads:

Radial Load		P	3.2	kN
Circumferential Shear		VC	3.2	kN
Longitudinal Shear		VL	3.2	kN
Circumferential Moment		MC	1100.0	N-m
Longitudinal Moment		ML	1100.0	N-m
Torsional Moment		MT	1300.0	N-m

Dimensionless Parameters used : Gamma = 11.18

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.192	4C	1.931	(A,B)
N(PHI) / (P/Rm)	0.192	3C	1.667	(C,D)
M(PHI) / (P)	0.192	2C1	0.083	(A,B)
M(PHI) / (P)	0.192	1C	0.111	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.192	3A	0.339	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.192	1A	0.096	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.192	3B	1.207	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.192	1B	0.046	(A,B,C,D)
N(x) / (P/Rm)	0.192	3C	1.667	(A,B)
N(x) / (P/Rm)	0.192	4C	1.931	(C,D)
M(x) / (P)	0.192	1C1	0.113	(A,B)
M(x) / (P)	0.192	2C	0.081	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.192	4A	0.535	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.192	2A	0.055	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.192	4B	0.342	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.192	2B	0.074	(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	-1.5	-1.5	-1.5	-1.5
Circ. Bend. P	-4.8	4.8	-4.8	4.8	-6.5	6.5	-6.5	6.5
Circ. Memb. MC	0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Circ. Memb. MC	0.0	0.0	0.0	0.0	-49.7	49.7	49.7	-49.7
Circ. Memb. ML	-9.3	-9.3	9.3	9.3	0.0	0.0	0.0	0.0
Circ. Bend. ML	-23.9	23.9	23.9	-23.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-39.7	17.7	26.6	-11.4	-60.3	52.1	44.3	-42.0
Long. Memb. P	-1.5	-1.5	-1.5	-1.5	-1.7	-1.7	-1.7	-1.7
Long. Bend. P	-6.6	6.6	-6.6	6.6	-4.8	4.8	-4.8	4.8
Long. Memb. MC	0.0	0.0	0.0	0.0	-4.1	-4.1	4.1	4.1
Long. Bend. MC	0.0	0.0	0.0	0.0	-28.3	28.3	28.3	-28.3
Long. Memb. ML	-2.6	-2.6	2.6	2.6	0.0	0.0	0.0	0.0
Long. Bend. ML	-38.0	38.0	38.0	-38.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-48.7	40.6	32.6	-30.2	-38.9	27.3	26.0	-21.1
Shear VC	1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.3	-1.3	1.3	1.3
Shear MT	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Tot. Shear	7.0	7.0	4.5	4.5	4.5	4.5	7.0	7.0
Str. Int.	52.6	42.6	35.0	31.2	61.2	52.9	46.7	44.2

Dimensionless Parameters used : Gamma = 24.35

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.475	4C	2.209	(A,B)
N(PHI) / (P/Rm)	0.475	3C	1.004	(C,D)
M(PHI) / (P)	0.475	2C1	0.010	(A,B)
M(PHI) / (P)	0.475	1C !	0.059	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.475	3A	0.764	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.475	1A	0.065	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.475	3B	1.311	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.475	1B	0.010	(A,B,C,D)
N(x) / (P/Rm)	0.475	3C	1.004	(A,B)
N(x) / (P/Rm)	0.475	4C	2.209	(C,D)
M(x) / (P)	0.475	1C1	0.023	(A,B)
M(x) / (P)	0.475	2C !	0.030	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.475	4A	2.479	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.475	2A	0.028	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.475	4B	0.698	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.475	2B	0.016	(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	-4.4	-4.4	-4.4	-4.4	-2.0	-2.0	-2.0	-2.0
Circ. Bend. P	-3.0	3.0	-3.0	3.0	-17.2	17.2	-17.2	17.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	-5.6	-5.6	5.6	5.6
Circ. Memb. MC	0.0	0.0	0.0	0.0	-69.6	69.6	69.6	-69.6
Circ. Memb. ML	-9.6	-9.6	9.6	9.6	0.0	0.0	0.0	0.0
Circ. Bend. ML	-10.7	10.7	10.7	-10.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-27.7	-0.3	12.9	-2.5	-94.5	79.3	56.0	-48.8
Long. Memb. P	-2.0	-2.0	-2.0	-2.0	-4.4	-4.4	-4.4	-4.4
Long. Bend. P	-6.8	6.8	-6.8	6.8	-8.7	8.7	-8.7	8.7
Long. Memb. MC	0.0	0.0	0.0	0.0	-18.1	-18.1	18.1	18.1
Long. Bend. MC	0.0	0.0	0.0	0.0	-30.1	30.1	30.1	-30.1
Long. Memb. ML	-5.1	-5.1	5.1	5.1	0.0	0.0	0.0	0.0
Long. Bend. ML	-17.4	17.4	17.4	-17.4	0.0	0.0	0.0	0.0
Tot. Long. Str.	-31.3	17.1	13.8	-7.5	-61.4	16.3	35.2	-7.7
Shear VC	1.2	1.2	-1.2	-1.2	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.2	-1.2	1.2	1.2
Shear MT	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Tot. Shear	3.4	3.4	1.0	1.0	1.0	1.0	3.4	3.4
Str. Int.	33.4	18.7	14.5	7.8	94.5	79.3	56.5	49.1

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)	25.6	28.1	25.6	28.1	25.6	28.1	25.6	28.1
Circ. Pl (SUS)	-11.0	-11.0	7.6	7.6	-4.1	-4.1	1.2	1.2
Circ. Q (SUS)	-28.7	28.7	19.0	-19.0	-56.2	56.2	43.2	-43.2
Long. Pm (SUS)	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8
Long. Pl (SUS)	-4.1	-4.1	1.2	1.2	-5.8	-5.8	2.4	2.4
Long. Q (SUS)	-44.7	44.7	31.4	-31.4	-33.1	33.1	23.5	-23.5
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.3	1.3	-1.3	-1.3	-1.3	-1.3	1.3	1.3
Shear Q (SUS)	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Pm (SUS)	25.6	28.1	25.6	28.1	25.6	28.1	25.6	28.1
Pm+Pl (SUS)	14.8	17.3	33.3	35.8	21.6	24.1	26.9	29.3
Pm+Pl+Q (Total)	38.0	57.6	54.4	35.2	36.7	80.7	71.4	18.7

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

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

Pm (SUS)	28.06	117.90	Passed
Pm+Pl (SUS)	35.75	176.86	Passed
Pm+Pl+Q (TOTAL)	80.71	353.71	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)	58.5	61.0	58.5	61.0	58.5	61.0	58.5	61.0
Circ. Pl (SUS)	-14.0	-14.0	5.2	5.2	-7.6	-7.6	3.6	3.6
Circ. Q (SUS)	-13.7	13.7	7.7	-7.7	-86.9	86.9	52.4	-52.4
Long. Pm (SUS)	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2
Long. Pl (SUS)	-7.1	-7.1	3.1	3.1	-22.6	-22.6	13.7	13.7
Long. Q (SUS)	-24.2	24.2	10.6	-10.6	-38.8	38.8	21.4	-21.4
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.2	1.2	-1.2	-1.2	-1.2	-1.2	1.2	1.2
Shear Q (SUS)	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Pm (SUS)	58.5	61.0	58.5	61.0	58.5	61.0	58.5	61.0
Pm+Pl (SUS)	44.6	47.1	63.7	66.2	50.9	53.4	62.2	64.7
Pm+Pl+Q (Total)	33.6	61.4	71.4	58.5	36.3	140.3	114.7	22.7

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	61.00	117.90	Passed
Pm+Pl (SUS)	66.22	176.86	Passed
Pm+Pl+Q (TOTAL)	140.30	353.71	Passed

INPUT VALUES, Nozzle Description: S2 From : 40

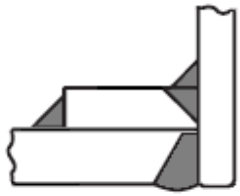
Pressure for Reinforcement Calculations	P	25.000	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	120	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	117.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	381.00	mm.
Design Length of Section	L	2908.0000	mm.
Shell Finished (Minimum) Thickness	t	11.1125	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		662.17	mm.
User Entered Minimum Design Metal Temperature		-10.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	N./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		3.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.3344	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
Diameter of Pad along vessel surface	Dp	214.3000	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	8.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		62.7000	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: S2

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

Actual Outside Diameter Used in Calculation	3.500	in.
Actual Thickness Used in Calculation	0.383	in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (25.0*193.5)/(118*1.0-0.6*25.0)
= 4.1560 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)
= (25.0*44.45)/(118*1.0+0.4*25.0)
= 0.9346 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.4091 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	150.8618	mm.
Parallel to Vessel Wall, opening length	d	75.4309	mm.
Normal to Vessel Wall (Thickness Limit), pad side	Tlwp	20.2812	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, 117.9/117.9)
= 1.000

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 117.9/117.9)
= 1.000

Weld Strength Reduction Factor [fr4]:
= min(1, Sp/Sv)
= min(1, 137.9/117.9)
= 1.000

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

= min(1.0, 1.0)
= 1.000

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	3.135	1.161	NA
Area in Shell	A1	2.984	3.798	NA
Area in Nozzle Wall	A2	2.353	2.566	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	6.196	6.196	NA
TOTAL AREA AVAILABLE	Atot	12.173	13.200	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.
The area available with the given pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (75.4309*4.156*1.0+2*6.7345*4.156*1.0*(1-1.0))
= 3.135 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)
= 75.431(1.0 * 8.1125 - 1.0 * 4.156) - 2 * 6.735
(1.0 * 8.1125 - 1.0 * 4.156) * (1 - 1.0)
= 2.984 cm^2

Area Available in Nozzle Wall Projecting Outward [A2]:
= (2 * Tlwp) * (tn - trn) * fr2
= (2 * 20.28) * (6.73 - 0.93) * 1.0
= 2.353 cm^2

Area Available in Welds [A41 + A42 + A43]:
= Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
= 8.0² * 1.0 + (0.0)² * 1.0 + 0.0² * 1.0
= 0.640 cm^2

Area Available in Element [A5]:
= (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
= (150.8618 - 88.9) * 10.0 * 1.0
= 6.196 cm^2

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

Wall Thickness for Internal/External pressures ta = 3.9346 mm.
Wall Thickness per UG16(b), tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 7.1560 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 7.1560 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(7.156, 4.5)]
= 7.1560 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(3.9346, 7.156)
= 7.1560 mm.

Available Nozzle Neck Thickness = 9.7345 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	:	55.1,	Allowable :	117.9 N./mm^2	Passed
Expansion	:	0.0,	Allowable :	239.7 N./mm^2	Passed
Occasional	:	6.4,	Allowable :	156.8 N./mm^2	Passed
Shear	:	27.3,	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, Curve: B

Govrn. thk, tg = 9.735, tr = 0.935, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

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

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

Govrn. thk, tg = 9.735, tr = 0.935, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

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

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

Govrn. thk, tg = 9.735, tr = 0.935, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

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

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

Govrn. thk, tg = 10.0, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.512, Temp. Reduction = 31 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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

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

Govrn. thk, tg = 9.735, tr = 0.935, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

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

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:

```
 Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -29 °C
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -48 °C
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-c)      -104 °C
```

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

```
 Design Pressure/Ambient Rating = 25.00/51.10 = 0.489
```

Note:
Using the min value from (b)(1)(-b) and (b)(1)(-c) above as the computed nozzle flange MDMT.

Weld Size Calculations, Description: S2

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      6.7345  mm.
 Intermediate Calc. for pad/shell Welds   TminPad      9.7000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
 Nozzle Weld          4.7142 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
 Pad Weld             4.8500 = 0.5*TminPad  5.6560 = 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, (3.1349 - 2.9844 + 2 * 6.7345 * 1.0 *
    (1.0 * 8.1125 - 4.156 ) )118)
  = 8.06 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 2.3526 + 6.1962 + 0.64 - 0.0 * 1.0 ) * 118
  = 108.33 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 2.3526 + 0.0 + 0.64 + ( 1.0927 ) ) * 118
  = 48.16 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 2.3526 + 0.0 + 0.64 + 6.1962 + ( 1.0927 ) ) * 118
  = 121.21 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 88.9 * 8.0 * 0.49 * 118
  = 65. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 214.3 * 8.0 * 0.49 * 118
  = 156. kN
```

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.1416 * 41.0827) * (9.7345 - 3.0) * 0.7 * 118
= 72. kN

Tension, Pad Groove Weld [Tpgw]:
= (pi/2) * Dlo * Wgpn * 0.74 * Seg
= (3.1416/2) * 88.9 * 10.0 * 0.74 * 138
= 142. kN

Tension, Shell Groove Weld [Tngw]:
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= (3.1416/2.0) * 88.9 * (8.3344 - 3.0) * 0.74 * 118
= 65. kN

Strength of Failure Paths:

PATH11 = (SPEW + SNW) = (156 + 72) = 227 kN
PATH22 = (Sonw + Tpgw + Tngw + Sinw)
= (65 + 142 + 65 + 0) = 272 kN
PATH33 = (Spew + Tngw + Sinw)
= (156 + 65 + 0) = 221 kN

Summary of Failure Path Calculations:

Path 1-1 = 227 kN , must exceed W = 8 kN or W1 = 108 kN
Path 2-2 = 272 kN , must exceed W = 8 kN or W2 = 48 kN
Path 3-3 = 220 kN , must exceed W = 8 kN or W3 = 121 kN

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

The Drop for this Nozzle is : 5.2584 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 216.3709 mm.

Input Echo, WRC107/537 Item 1, Description: S2 :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	381.000	mm.
Vessel Thickness	Tv	11.113	mm.
Design Temperature		120.00	°C
Vessel Material		SA-106 B	
Vessel Cold S.I. Allowable	Smc	117.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	117.90	N./mm^2
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	88.900	mm.
Nozzle Thickness	Tn	9.735	mm.
Nozzle Material		SA-106 B	
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	10.000	mm.
Diameter of Reinforcing Pad	Dpad	214.300	mm.
Design Internal Pressure	Dp	25.000	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	3.2	kN
Longitudinal Shear	(SUS)	Vl	3.2	kN
Circumferential Shear	(SUS)	Vc	3.2	kN
Circumferential Moment	(SUS)	Mc	1100.0	N-m
Longitudinal Moment	(SUS)	Ml	1100.0	N-m
Torsional Moment	(SUS)	Mt	1300.0	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 ) )
  = 88.9 + 2 * 1.65 * sqrt( 197.556 ( 11.113 - 3.0 ) )
  = 221.010 mm.
```

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	3.2	kN
Circumferential Shear	VC	3.2	kN
Longitudinal Shear	VL	3.2	kN
Circumferential Moment	MC	1100.0	N-m
Longitudinal Moment	ML	1100.0	N-m
Torsional Moment	MT	1300.0	N-m

Dimensionless Parameters used : Gamma = 11.18

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.192	4C	1.931	(A,B)
N(PHI) / (P/Rm)	0.192	3C	1.667	(C,D)
M(PHI) / (P)	0.192	2C1	0.083	(A,B)
M(PHI) / (P)	0.192	1C	0.111	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.192	3A	0.339	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.192	1A	0.096	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.192	3B	1.207	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.192	1B	0.046	(A,B,C,D)
N(x) / (P/Rm)	0.192	3C	1.667	(A,B)
N(x) / (P/Rm)	0.192	4C	1.931	(C,D)
M(x) / (P)	0.192	1C1	0.113	(A,B)
M(x) / (P)	0.192	2C	0.081	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.192	4A	0.535	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.192	2A	0.055	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.192	4B	0.342	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.192	2B	0.074	(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	-1.5	-1.5	-1.5	-1.5
Circ. Bend. P	-4.8	4.8	-4.8	4.8	-6.5	6.5	-6.5	6.5
Circ. Memb. MC	0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Circ. Memb. MC	0.0	0.0	0.0	0.0	-49.7	49.7	49.7	-49.7
Circ. Memb. ML	-9.3	-9.3	9.3	9.3	0.0	0.0	0.0	0.0
Circ. Bend. ML	-23.9	23.9	23.9	-23.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-39.7	17.7	26.6	-11.4	-60.3	52.1	44.3	-42.0
Long. Memb. P	-1.5	-1.5	-1.5	-1.5	-1.7	-1.7	-1.7	-1.7
Long. Bend. P	-6.6	6.6	-6.6	6.6	-4.8	4.8	-4.8	4.8
Long. Memb. MC	0.0	0.0	0.0	0.0	-4.1	-4.1	4.1	4.1
Long. Bend. MC	0.0	0.0	0.0	0.0	-28.3	28.3	28.3	-28.3
Long. Memb. ML	-2.6	-2.6	2.6	2.6	0.0	0.0	0.0	0.0
Long. Bend. ML	-38.0	38.0	38.0	-38.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-48.7	40.6	32.6	-30.2	-38.9	27.3	26.0	-21.1
Shear VC	1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.3	-1.3	1.3	1.3
Shear MT	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Tot. Shear	7.0	7.0	4.5	4.5	4.5	4.5	7.0	7.0
Str. Int.	52.6	42.6	35.0	31.2	61.2	52.9	46.7	44.2

Dimensionless Parameters used : Gamma = 24.35

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.475	4C	2.209	(A,B)
N(PHI) / (P/Rm)	0.475	3C	1.004	(C,D)
M(PHI) / (P)	0.475	2C1	0.010	(A,B)
M(PHI) / (P)	0.475	1C !	0.059	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.475	3A	0.764	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.475	1A	0.065	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.475	3B	1.311	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.475	1B	0.010	(A,B,C,D)
N(x) / (P/Rm)	0.475	3C	1.004	(A,B)
N(x) / (P/Rm)	0.475	4C	2.209	(C,D)
M(x) / (P)	0.475	1C1	0.023	(A,B)
M(x) / (P)	0.475	2C !	0.030	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.475	4A	2.479	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.475	2A	0.028	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.475	4B	0.698	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.475	2B	0.016	(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	-4.4	-4.4	-4.4	-4.4	-2.0	-2.0	-2.0	-2.0
Circ. Bend. P	-3.0	3.0	-3.0	3.0	-17.2	17.2	-17.2	17.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	-5.6	-5.6	5.6	5.6
Circ. Memb. MC	0.0	0.0	0.0	0.0	-69.6	69.6	69.6	-69.6
Circ. Memb. ML	-9.6	-9.6	9.6	9.6	0.0	0.0	0.0	0.0
Circ. Bend. ML	-10.7	10.7	10.7	-10.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-27.7	-0.3	12.9	-2.5	-94.5	79.3	56.0	-48.8
Long. Memb. P	-2.0	-2.0	-2.0	-2.0	-4.4	-4.4	-4.4	-4.4
Long. Bend. P	-6.8	6.8	-6.8	6.8	-8.7	8.7	-8.7	8.7
Long. Memb. MC	0.0	0.0	0.0	0.0	-18.1	-18.1	18.1	18.1
Long. Bend. MC	0.0	0.0	0.0	0.0	-30.1	30.1	30.1	-30.1
Long. Memb. ML	-5.1	-5.1	5.1	5.1	0.0	0.0	0.0	0.0
Long. Bend. ML	-17.4	17.4	17.4	-17.4	0.0	0.0	0.0	0.0
Tot. Long. Str.	-31.3	17.1	13.8	-7.5	-61.4	16.3	35.2	-7.7
Shear VC	1.2	1.2	-1.2	-1.2	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.2	-1.2	1.2	1.2
Shear MT	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Tot. Shear	3.4	3.4	1.0	1.0	1.0	1.0	3.4	3.4
Str. Int.	33.4	18.7	14.5	7.8	94.5	79.3	56.5	49.1

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)	25.5	28.0	25.5	28.0	25.5	28.0	25.5	28.0
Circ. Pl (SUS)	-11.0	-11.0	7.6	7.6	-4.1	-4.1	1.2	1.2
Circ. Q (SUS)	-28.7	28.7	19.0	-19.0	-56.2	56.2	43.2	-43.2
Long. Pm (SUS)	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8
Long. Pl (SUS)	-4.1	-4.1	1.2	1.2	-5.8	-5.8	2.4	2.4
Long. Q (SUS)	-44.7	44.7	31.4	-31.4	-33.1	33.1	23.5	-23.5
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.3	1.3	-1.3	-1.3	-1.3	-1.3	1.3	1.3
Shear Q (SUS)	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Pm (SUS)	25.5	28.0	25.5	28.0	25.5	28.0	25.5	28.0
Pm+Pl (SUS)	14.8	17.2	33.2	35.7	21.6	24.0	26.8	29.3
Pm+Pl+Q (Total)	38.1	57.5	54.4	35.2	36.7	80.7	71.4	18.8

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

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

Pm (SUS)	28.02	117.90	Passed
Pm+Pl (SUS)	35.71	176.86	Passed
Pm+Pl+Q (TOTAL)	80.66	353.71	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)	58.4	60.9	58.4	60.9	58.4	60.9	58.4	60.9
Circ. Pl (SUS)	-14.0	-14.0	5.2	5.2	-7.6	-7.6	3.6	3.6
Circ. Q (SUS)	-13.7	13.7	7.7	-7.7	-86.9	86.9	52.4	-52.4
Long. Pm (SUS)	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2
Long. Pl (SUS)	-7.1	-7.1	3.1	3.1	-22.6	-22.6	13.7	13.7
Long. Q (SUS)	-24.2	24.2	10.6	-10.6	-38.8	38.8	21.4	-21.4
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.2	1.2	-1.2	-1.2	-1.2	-1.2	1.2	1.2
Shear Q (SUS)	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Pm (SUS)	58.4	60.9	58.4	60.9	58.4	60.9	58.4	60.9
Pm+Pl (SUS)	44.5	47.0	63.6	66.1	50.8	53.3	62.1	64.6
Pm+Pl+Q (Total)	33.5	61.3	71.3	58.4	36.3	140.2	114.6	22.6

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	60.91	117.90	Passed
Pm+Pl (SUS)	66.13	176.86	Passed
Pm+Pl+Q (TOTAL)	140.21	353.71	Passed

INPUT VALUES, Nozzle Description: S1 From : 40

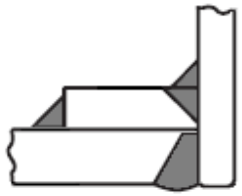
Pressure for Reinforcement Calculations	P	25.000	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	120	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	117.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	381.00	mm.
Design Length of Section	L	2908.0000	mm.
Shell Finished (Minimum) Thickness	t	11.1125	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3196.17	mm.
User Entered Minimum Design Metal Temperature		-10.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	N./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		3.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.3344	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
Diameter of Pad along vessel surface	Dp	214.3000	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	8.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		62.7000	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: S1

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

Actual Outside Diameter Used in Calculation	3.500	in.
Actual Thickness Used in Calculation	0.383	in.

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (25.0*193.5)/(118*1.0-0.6*25.0)
= 4.1560 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)
= (25.0*44.45)/(118*1.0+0.4*25.0)
= 0.9346 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.4091 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	150.8618	mm.
Parallel to Vessel Wall, opening length	d	75.4309	mm.
Normal to Vessel Wall (Thickness Limit), pad side	Tlwp	20.2812	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, 117.9/117.9)
= 1.000

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 117.9/117.9)
= 1.000

Weld Strength Reduction Factor [fr4]:
= min(1, Sp/Sv)
= min(1, 137.9/117.9)
= 1.000

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

= min(1.0, 1.0)
= 1.000

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	3.135	1.161	NA
Area in Shell	A1	2.984	3.798	NA
Area in Nozzle Wall	A2	2.353	2.566	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	6.196	6.196	NA
TOTAL AREA AVAILABLE	Atot	12.173	13.200	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.
The area available with the given pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (75.4309*4.156*1.0+2*6.7345*4.156*1.0*(1-1.0))
= 3.135 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)
= 75.431(1.0 * 8.1125 - 1.0 * 4.156) - 2 * 6.735
(1.0 * 8.1125 - 1.0 * 4.156) * (1 - 1.0)
= 2.984 cm^2

Area Available in Nozzle Wall Projecting Outward [A2]:
= (2 * Tlwp) * (tn - trn) * fr2
= (2 * 20.28) * (6.73 - 0.93) * 1.0
= 2.353 cm^2

Area Available in Welds [A41 + A42 + A43]:
= Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
= 8.0² * 1.0 + (0.0)² * 1.0 + 0.0² * 1.0
= 0.640 cm^2

Area Available in Element [A5]:
= (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
= (150.8618 - 88.9) * 10.0 * 1.0
= 6.196 cm^2

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

Wall Thickness for Internal/External pressures ta = 3.9346 mm.
Wall Thickness per UG16(b), tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 7.1560 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 7.1560 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(7.156, 4.5)]
= 7.1560 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(3.9346, 7.156)
= 7.1560 mm.

Available Nozzle Neck Thickness = 9.7345 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	:	55.1,	Allowable :	117.9 N./mm^2	Passed
Expansion	:	0.0,	Allowable :	239.7 N./mm^2	Passed
Occasional	:	6.4,	Allowable :	156.8 N./mm^2	Passed
Shear	:	27.3,	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, Curve: B

Govrn. thk, tg = 9.735, tr = 0.935, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

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

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

Govrn. thk, tg = 9.735, tr = 0.935, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

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

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

Govrn. thk, tg = 9.735, tr = 0.935, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

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

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

Govrn. thk, tg = 10.0, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.512, Temp. Reduction = 31 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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

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

Govrn. thk, tg = 9.735, tr = 0.935, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.139, Temp. Reduction = 78 °C

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

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:

```
 Unadjusted MDMT of ANSI B16.5/47 flanges per UCS-66(c)     -29 °C
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -48 °C
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-c)      -104 °C
```

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

```
 Design Pressure/Ambient Rating = 25.00/51.10 = 0.489
```

Note:
Using the min value from (b)(1)(-b) and (b)(1)(-c) above as the computed nozzle flange MDMT.

Weld Size Calculations, Description: S1

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      6.7345  mm.
 Intermediate Calc. for pad/shell Welds   TminPad      9.7000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
 Nozzle Weld          4.7142 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
 Pad Weld             4.8500 = 0.5*TminPad  5.6560 = 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, (3.1349 - 2.9844 + 2 * 6.7345 * 1.0 *
    (1.0 * 8.1125 - 4.156 ) )118)
  = 8.06 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 2.3526 + 6.1962 + 0.64 - 0.0 * 1.0 ) * 118
  = 108.33 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 2.3526 + 0.0 + 0.64 + ( 1.0927 ) ) * 118
  = 48.16 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 2.3526 + 0.0 + 0.64 + 6.1962 + ( 1.0927 ) ) * 118
  = 121.21 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 88.9 * 8.0 * 0.49 * 118
  = 65. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 214.3 * 8.0 * 0.49 * 118
  = 156. kN
```

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.1416 * 41.0827) * (9.7345 - 3.0) * 0.7 * 118
= 72. kN

Tension, Pad Groove Weld [Tpgw]:
= (pi/2) * Dlo * Wgpn * 0.74 * Seg
= (3.1416/2) * 88.9 * 10.0 * 0.74 * 138
= 142. kN

Tension, Shell Groove Weld [Tngw]:
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= (3.1416/2.0) * 88.9 * (8.3344 - 3.0) * 0.74 * 118
= 65. kN

Strength of Failure Paths:

PATH11 = (SPEW + SNW) = (156 + 72) = 227 kN
PATH22 = (Sonw + Tpgw + Tngw + Sinw)
= (65 + 142 + 65 + 0) = 272 kN
PATH33 = (Spew + Tngw + Sinw)
= (156 + 65 + 0) = 221 kN

Summary of Failure Path Calculations:

Path 1-1 = 227 kN , must exceed W = 8 kN or W1 = 108 kN
Path 2-2 = 272 kN , must exceed W = 8 kN or W2 = 48 kN
Path 3-3 = 220 kN , must exceed W = 8 kN or W3 = 121 kN

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

The Drop for this Nozzle is : 5.2584 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 216.3709 mm.

Input Echo, WRC107/537 Item 1, Description: S1 :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	381.000	mm.
Vessel Thickness	Tv	11.113	mm.
Design Temperature		120.00	°C
Vessel Material		SA-106 B	
Vessel Cold S.I. Allowable	Smc	117.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	117.90	N./mm^2
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	88.900	mm.
Nozzle Thickness	Tn	9.735	mm.
Nozzle Material		SA-106 B	
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	10.000	mm.
Diameter of Reinforcing Pad	Dpad	214.300	mm.
Design Internal Pressure	Dp	25.000	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	3.2	kN
Longitudinal Shear	(SUS)	Vl	3.2	kN
Circumferential Shear	(SUS)	Vc	3.2	kN
Circumferential Moment	(SUS)	Mc	1100.0	N-m
Longitudinal Moment	(SUS)	Ml	1100.0	N-m
Torsional Moment	(SUS)	Mt	1300.0	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 ) )
= 88.9 + 2 * 1.65 * sqrt( 197.556 ( 11.113 - 3.0 ) )
= 221.010 mm.
```

WRC 107 Stress Calculation for SUStained loads:

Radial Load		P	3.2	kN
Circumferential Shear		VC	3.2	kN
Longitudinal Shear		VL	3.2	kN
Circumferential Moment		MC	1100.0	N-m
Longitudinal Moment		ML	1100.0	N-m
Torsional Moment		MT	1300.0	N-m

Dimensionless Parameters used : Gamma = 11.18

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.192	4C	1.931	(A,B)
N(PHI) / (P/Rm)	0.192	3C	1.667	(C,D)
M(PHI) / (P)	0.192	2C1	0.083	(A,B)
M(PHI) / (P)	0.192	1C	0.111	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.192	3A	0.339	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.192	1A	0.096	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.192	3B	1.207	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.192	1B	0.046	(A,B,C,D)
N(x) / (P/Rm)	0.192	3C	1.667	(A,B)
N(x) / (P/Rm)	0.192	4C	1.931	(C,D)
M(x) / (P)	0.192	1C1	0.113	(A,B)
M(x) / (P)	0.192	2C	0.081	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.192	4A	0.535	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.192	2A	0.055	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.192	4B	0.342	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.192	2B	0.074	(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	-1.5	-1.5	-1.5	-1.5
Circ. Bend. P	-4.8	4.8	-4.8	4.8	-6.5	6.5	-6.5	6.5
Circ. Memb. MC	0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Circ. Memb. MC	0.0	0.0	0.0	0.0	-49.7	49.7	49.7	-49.7
Circ. Memb. ML	-9.3	-9.3	9.3	9.3	0.0	0.0	0.0	0.0
Circ. Bend. ML	-23.9	23.9	23.9	-23.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-39.7	17.7	26.6	-11.4	-60.3	52.1	44.3	-42.0
Long. Memb. P	-1.5	-1.5	-1.5	-1.5	-1.7	-1.7	-1.7	-1.7
Long. Bend. P	-6.6	6.6	-6.6	6.6	-4.8	4.8	-4.8	4.8
Long. Memb. MC	0.0	0.0	0.0	0.0	-4.1	-4.1	4.1	4.1
Long. Bend. MC	0.0	0.0	0.0	0.0	-28.3	28.3	28.3	-28.3
Long. Memb. ML	-2.6	-2.6	2.6	2.6	0.0	0.0	0.0	0.0
Long. Bend. ML	-38.0	38.0	38.0	-38.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-48.7	40.6	32.6	-30.2	-38.9	27.3	26.0	-21.1
Shear VC	1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.3	-1.3	1.3	1.3
Shear MT	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Tot. Shear	7.0	7.0	4.5	4.5	4.5	4.5	7.0	7.0
Str. Int.	52.6	42.6	35.0	31.2	61.2	52.9	46.7	44.2

Dimensionless Parameters used : Gamma = 24.35

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.475	4C	2.209	(A,B)
N(PHI) / (P/Rm)	0.475	3C	1.004	(C,D)
M(PHI) / (P)	0.475	2C1	0.010	(A,B)
M(PHI) / (P)	0.475	1C !	0.059	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.475	3A	0.764	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.475	1A	0.065	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.475	3B	1.311	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.475	1B	0.010	(A,B,C,D)
N(x) / (P/Rm)	0.475	3C	1.004	(A,B)
N(x) / (P/Rm)	0.475	4C	2.209	(C,D)
M(x) / (P)	0.475	1C1	0.023	(A,B)
M(x) / (P)	0.475	2C !	0.030	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.475	4A	2.479	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.475	2A	0.028	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.475	4B	0.698	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.475	2B	0.016	(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	-4.4	-4.4	-4.4	-4.4	-2.0	-2.0	-2.0	-2.0
Circ. Bend. P	-3.0	3.0	-3.0	3.0	-17.2	17.2	-17.2	17.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	-5.6	-5.6	5.6	5.6
Circ. Memb. MC	0.0	0.0	0.0	0.0	-69.6	69.6	69.6	-69.6
Circ. Memb. ML	-9.6	-9.6	9.6	9.6	0.0	0.0	0.0	0.0
Circ. Bend. ML	-10.7	10.7	10.7	-10.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-27.7	-0.3	12.9	-2.5	-94.5	79.3	56.0	-48.8
Long. Memb. P	-2.0	-2.0	-2.0	-2.0	-4.4	-4.4	-4.4	-4.4
Long. Bend. P	-6.8	6.8	-6.8	6.8	-8.7	8.7	-8.7	8.7
Long. Memb. MC	0.0	0.0	0.0	0.0	-18.1	-18.1	18.1	18.1
Long. Bend. MC	0.0	0.0	0.0	0.0	-30.1	30.1	30.1	-30.1
Long. Memb. ML	-5.1	-5.1	5.1	5.1	0.0	0.0	0.0	0.0
Long. Bend. ML	-17.4	17.4	17.4	-17.4	0.0	0.0	0.0	0.0
Tot. Long. Str.	-31.3	17.1	13.8	-7.5	-61.4	16.3	35.2	-7.7
Shear VC	1.2	1.2	-1.2	-1.2	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.2	-1.2	1.2	1.2
Shear MT	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Tot. Shear	3.4	3.4	1.0	1.0	1.0	1.0	3.4	3.4
Str. Int.	33.4	18.7	14.5	7.8	94.5	79.3	56.5	49.1

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)	25.5	28.0	25.5	28.0	25.5	28.0	25.5	28.0
Circ. Pl (SUS)	-11.0	-11.0	7.6	7.6	-4.1	-4.1	1.2	1.2
Circ. Q (SUS)	-28.7	28.7	19.0	-19.0	-56.2	56.2	43.2	-43.2
Long. Pm (SUS)	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8
Long. Pl (SUS)	-4.1	-4.1	1.2	1.2	-5.8	-5.8	2.4	2.4
Long. Q (SUS)	-44.7	44.7	31.4	-31.4	-33.1	33.1	23.5	-23.5
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.3	1.3	-1.3	-1.3	-1.3	-1.3	1.3	1.3
Shear Q (SUS)	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Pm (SUS)	25.5	28.0	25.5	28.0	25.5	28.0	25.5	28.0
Pm+Pl (SUS)	14.8	17.2	33.2	35.7	21.6	24.0	26.8	29.3
Pm+Pl+Q (Total)	38.1	57.5	54.4	35.2	36.7	80.7	71.4	18.8

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

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

Pm (SUS)	28.02	117.90	Passed
Pm+Pl (SUS)	35.71	176.86	Passed
Pm+Pl+Q (TOTAL)	80.66	353.71	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)	58.4	60.9	58.4	60.9	58.4	60.9	58.4	60.9
Circ. Pl (SUS)	-14.0	-14.0	5.2	5.2	-7.6	-7.6	3.6	3.6
Circ. Q (SUS)	-13.7	13.7	7.7	-7.7	-86.9	86.9	52.4	-52.4
Long. Pm (SUS)	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2
Long. Pl (SUS)	-7.1	-7.1	3.1	3.1	-22.6	-22.6	13.7	13.7
Long. Q (SUS)	-24.2	24.2	10.6	-10.6	-38.8	38.8	21.4	-21.4
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.2	1.2	-1.2	-1.2	-1.2	-1.2	1.2	1.2
Shear Q (SUS)	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Pm (SUS)	58.4	60.9	58.4	60.9	58.4	60.9	58.4	60.9
Pm+Pl (SUS)	44.5	47.0	63.6	66.1	50.8	53.3	62.1	64.6
Pm+Pl+Q (Total)	33.5	61.3	71.3	58.4	36.3	140.2	114.6	22.6

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	60.91	117.90	Passed
Pm+Pl (SUS)	66.13	176.86	Passed
Pm+Pl+Q (TOTAL)	140.21	353.71	Passed

INPUT VALUES, Nozzle Description: S3 From : 40

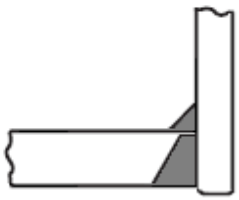
Pressure for Reinforcement Calculations	P	25.033	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	120	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	117.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	381.00	mm.
Design Length of Section	L	2908.0000	mm.
Shell Finished (Minimum) Thickness	t	11.1125	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		662.17	mm.
User Entered Minimum Design Metal Temperature		-10.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./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		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.3344	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: S3

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)
= (25.03*193.5)/(118*1.0-0.6*25.03)
= 4.1615 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)
= (25.03*28.4)/(138*1.0-0.6*25.03)
= 0.5212 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	113.6000	mm.
Parallel to Vessel Wall, opening length	d	56.8000	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	20.2812	mm.

Weld Strength Reduction Factor [fr1]:
= min(1, Sn/Sv)
= min(1, 137.9/117.9)
= 1.000

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 137.9/117.9)
= 1.000

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	2.364	0.874	NA
Area in Shell	A1	2.244	2.860	NA
Area in Nozzle Wall	A2	5.305	5.356	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	8.549	9.216	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*4.1615*1.0+2*13.6*4.1615*1.0*(1-1.0))
= 2.364 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)
= 56.8(1.0 * 8.1125 - 1.0 * 4.162) - 2 * 13.6
(1.0 * 8.1125 - 1.0 * 4.1615) * (1 - 1.0)
= 2.244 cm^2

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 20.28)(13.6 - 0.52)1.0
= 5.305 cm^2

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo² * fr2 + (Wi-can/0.707)² * fr2
= 10.0² * 1.0 + (0.0)² * 1.0
= 1.000 cm^2

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

Wall Thickness for Internal/External pressures ta = 3.5212 mm.
Wall Thickness per UG16(b), tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 7.1615 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 7.1615 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(7.1615, 4.5)]
= 7.1615 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(3.5212, 7.1615)
= 7.1615 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 :	15.1,	Allowable :	137.9 N./mm^2	Passed
Expansion :	0.0,	Allowable :	329.7 N./mm^2	Passed
Occasional :	2.1,	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 (UCS-66(a)1(b)), Curve: B

Govrn. thk, tg = 11.113, tr = 4.162, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.513, Temp. Reduction = 31 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -26 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -48 °C
Min Metal Temp. w/o impact per UG-20(f)                   -29 °C

Governing MDMT of all the sub-joints of this Junction  :  -48 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
`Design Pressure/Ambient Rating = 25.03/51.10 = 0.490`

Weld Size Calculations, Description: S3

`Intermediate Calc. for nozzle/shell Welds  Tmin  9.7000  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, (2.3637 - 2.2442 + 2 * 13.6 * 1.0 *
  (1.0 * 8.1125 - 4.1615 ) )118)
= 14.08 kN
```

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

Weld Load [W1]:
```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 5.3051 + 0.0 + 1. - 0.0 * 1.0 ) * 118
= 74.33 kN
```

Weld Load [W2]:
```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 5.3051 + 0.0 + 1. + ( 2.2066 ) ) * 118
= 100.35 kN
```

Weld Load [W3]:
```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 5.3051 + 0.0 + 1. + 0.0 + ( 2.2066 ) ) * 118
= 100.35 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 118
= 76. kN
```

Shear, Nozzle Wall [Snw]:

```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 138
= 145. kN
```

Tension, Shell Groove Weld [Tngw]:

```
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= ( 3.1416/2.0 ) * 84.0 * ( 8.3344 - 3.0 ) * 0.74 * 138
= 72. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 76 + 145 ) = 221 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 76 + 0 + 72 + 0 ) = 148 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 76 + 72 + 0 ) = 148 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 221 kN , must exceed W = 14 kN  or W1 = 74 kN
Path 2-2 = 148 kN , must exceed W = 14 kN  or W2 = 100 kN
Path 3-3 = 148 kN , must exceed W = 14 kN  or W3 = 100 kN

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

The Drop for this Nozzle is : 4.6876 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 215.8001 mm.

Input Echo, WRC107/537 Item 1, Description: S3 :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	381.000	mm.
Vessel Thickness	Tv	11.113	mm.
Design Temperature		120.00	°C
Vessel Material		SA-106 B	
Vessel Cold S.I. Allowable	Smc	117.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	117.90	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-105	
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	25.033	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( 197.556 ( 11.113 - 3.0 ) )
  = 216.110 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 =   24.35
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.186	4C	3.768	(A,B)
N(PHI) / (P/Rm)	0.186	3C	2.803	(C,D)
M(PHI) / (P)	0.186	2C1	0.055	(A,B)
M(PHI) / (P)	0.186	1C	0.086	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.186	3A	0.936	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.186	1A	0.089	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.186	3B	2.754	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.186	1B	0.035	(A,B,C,D)
N(x) / (P/Rm)	0.186	3C	2.803	(A,B)
N(x) / (P/Rm)	0.186	4C	3.768	(C,D)
M(x) / (P)	0.186	1C1	0.090	(A,B)
M(x) / (P)	0.186	2C	0.055	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.186	4A	1.486	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.186	2A	0.045	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.186	4B	0.885	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.186	2B	0.057	(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	-4.7	-4.7	-4.7	-4.7	-3.5	-3.5	-3.5	-3.5

Circ. Bend. P	-10.0	10.0	-10.0	10.0	-15.6	15.6	-15.6	15.6
Circ. Memb. MC	0.0	0.0	0.0	0.0	-6.4	-6.4	6.4	6.4
Circ. Memb. MC	0.0	0.0	0.0	0.0	-87.9	87.9	87.9	-87.9
Circ. Memb. ML	-18.7	-18.7	18.7	18.7	0.0	0.0	0.0	0.0
Circ. Bend. ML	-34.8	34.8	34.8	-34.8	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-68.1	21.3	38.8	-10.8	-113.4	93.7	75.1	-69.4
Long. Memb. P	-3.5	-3.5	-3.5	-3.5	-4.7	-4.7	-4.7	-4.7
Long. Bend. P	-16.4	16.4	-16.4	16.4	-10.0	10.0	-10.0	10.0
Long. Memb. MC	0.0	0.0	0.0	0.0	-10.1	-10.1	10.1	10.1
Long. Bend. MC	0.0	0.0	0.0	0.0	-44.6	44.6	44.6	-44.6
Long. Memb. ML	-6.0	-6.0	6.0	6.0	0.0	0.0	0.0	0.0
Long. Bend. ML	-56.5	56.5	56.5	-56.5	0.0	0.0	0.0	0.0
Tot. Long. Str.	-82.4	63.4	42.6	-37.5	-69.4	39.8	39.9	-29.2
Shear VC	1.9	1.9	-1.9	-1.9	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.9	-1.9	1.9	1.9
Shear MT	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6
Tot. Shear	7.4	7.4	3.7	3.7	3.7	3.7	7.4	7.4
Str. Int.	85.6	64.7	44.8	38.0	113.7	93.9	76.6	70.7

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)	58.5	61.0	58.5	61.0	58.5	61.0	58.5	61.0
Circ. Pl (SUS)	-23.4	-23.4	14.0	14.0	-9.9	-9.9	2.9	2.9
Circ. Q (SUS)	-44.7	44.7	24.8	-24.8	-103.5	103.5	72.3	-72.3
Long. Pm (SUS)	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2
Long. Pl (SUS)	-9.5	-9.5	2.5	2.5	-14.8	-14.8	5.4	5.4
Long. Q (SUS)	-72.9	72.9	40.1	-40.1	-54.6	54.6	34.6	-34.6
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.9	1.9	-1.9	-1.9	-1.9	-1.9	1.9	1.9
Shear Q (SUS)	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6
Pm (SUS)	58.5	61.0	58.5	61.0	58.5	61.0	58.5	61.0
Pm+Pl (SUS)	35.3	37.8	72.6	75.1	48.7	51.2	61.5	64.0
Pm+Pl+Q (Total)	54.4	96.5	97.8	58.9	55.8	154.8	134.5	17.1

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	60.99	117.90	Passed
Pm+Pl (SUS)	75.06	176.86	Passed
Pm+Pl+Q (TOTAL)	154.81	353.71	Passed

INPUT VALUES, Nozzle Description: T4 From : 60

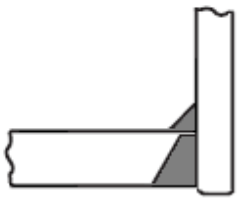
Pressure for Reinforcement Calculations	P	25.000	bars
Temperature for Internal Pressure	Temp	190	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	190	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	117.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	381.00	mm.
Design Length of Section	L	402.7500	mm.
Shell Finished (Minimum) Thickness	t	11.1125	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3693.35	mm.
User Entered Minimum Design Metal Temperature		-10.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Normalized]		SA-105	
Material UNS Number		K03504	
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		0.7500	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	14.3000	mm.
Flange Material [Normalized]		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
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: T4

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

Actual Inside Diameter Used in Calculation	0.750	in.
Actual Thickness Used in Calculation	0.563	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)
= (25.0*193.5)/(118*1.0-0.6*25.0)
= 4.1560 mm.

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]
= R(exp([P/(Sn*E)] - 1) per Appendix 1-2 (a)(1)
= 12.525(exp([25.0/(137.9*1.0]-1)
= 0.2292 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.2879 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	63.8750	mm.
Parallel to Vessel Wall	Rn+tn+t	31.9375	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	20.2812	mm.

Weld Strength Reduction Factor [fr1]:
= min(1, Sn/Sv)
= min(1, 137.9/117.9)
= 1.000

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 137.9/117.9)
= 1.000

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.041	0.168	NA
Area in Shell	A1	1.536	2.628	NA
Area in Nozzle Wall	A2	4.491	4.467	NA

Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.964	0.964	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	6.991	8.059	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)
= (25.05*4.156*1.0+2*11.3*4.156*1.0*(1-1.0))
= 1.041 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)
= 38.825(1.0 * 8.1125 - 1.0 * 4.156) - 2 * 11.3
(1.0 * 8.1125 - 1.0 * 4.156) * (1 - 1.0)
= 1.536 cm^2

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 20.28)(11.3 - 0.23)1.0
= 4.491 cm^2

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= (Wo² - Area Lost)*fr2 + ((Wi-can/0.707)² - Area Lost)*fr2
= (10.0² - 0.0356) * 1.0 + (0.0² -0.0) * 1.0
= 0.964 cm^2

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

Wall Thickness for Internal/External pressures ta = 3.2879 mm.
Wall Thickness per UG16(b), tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 7.1560 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 7.1560 mm.
Wall Thickness tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45 tb3 = 6.2200 mm.

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[6.22, max(7.156, 4.5)]
= 6.2200 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(3.2879, 6.22)
= 6.2200 mm.

Available Nozzle Neck Thickness = 14.3000 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 11.113, tr = 4.156, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.512, Temp. Reduction = 31 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -26 °C

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

 Governing MDMT of all the sub-joints of this Junction  :   -48 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

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

```
 Design Pressure/Ambient Rating = 25.00/51.10 = 0.489
```

Weld Size Calculations, Description: T4

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      9.7000  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, (1.0411 - 1.5361 + 2 * 11.3 * 1.0 *
    (1.0 * 8.1125 - 4.156 ) )118)
  = 4.71 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.4906 + 0.0 + 0.9644 - 0.0 * 1.0 ) * 118
  = 64.31 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.4906 + 0.0 + 0.9644 + ( 1.8334 ) ) * 118
  = 85.93 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.4906 + 0.0 + 0.9644 + 0.0 + ( 1.8334 ) ) * 118
  = 85.93 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 47.65 * 10.0 * 0.49 * 118
  = 43. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 18.175) * ( 14.3 - 3.0 ) * 0.7 * 138
  = 62. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 47.65 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 53. kN
```

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 43 + 62 ) = 106 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 43 + 0 + 53 + 0 ) = 97 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 43 + 53 + 0 ) = 97 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 105 kN , must exceed W = 4 kN  or W1 = 64 kN
Path 2-2 = 96 kN , must exceed W = 4 kN  or W2 = 85 kN
Path 3-3 = 96 kN , must exceed W = 4 kN  or W3 = 85 kN

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

The Drop for this Nozzle is : 1.4957 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 212.6082 mm.

INPUT VALUES, Nozzle Description: T3 From : 60

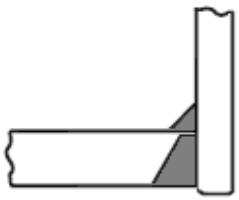
Pressure for Reinforcement Calculations	P	25.037	bars
Temperature for Internal Pressure	Temp	190	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	190	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	117.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	381.00	mm.
Design Length of Section	L	402.7500	mm.
Shell Finished (Minimum) Thickness	t	11.1125	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3693.35	mm.
User Entered Minimum Design Metal Temperature		-10.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Normalized]		SA-105	
Material UNS Number		K03504	
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		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	14.3000	mm.
Flange Material [Normalized]		SA-105	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
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: T3

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

Actual Inside Diameter Used in Calculation	1.000	in.
Actual Thickness Used in Calculation	0.563	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)
= (25.04*193.5)/(118*1.0-0.6*25.04)
= 4.1623 mm.

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]
= R(exp([P/(Sn*E)] - 1) per Appendix 1-2 (a)(1)
= 15.7(exp([25.04/(137.9*1.0]-1)
= 0.2877 mm.

Required Nozzle thickness under External Pressure per UG-28 : 0.3088 mm.

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

Parallel to Vessel Wall (Diameter Limit)	Dl	70.2250	mm.
Parallel to Vessel Wall	Rn+tn+t	35.1125	mm.
Normal to Vessel Wall (Thickness Limit), no pad	Tlnp	20.2812	mm.

Weld Strength Reduction Factor [fr1]:
= min(1, Sn/Sv)
= min(1, 137.9/117.9)
= 1.000

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 137.9/117.9)
= 1.000

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.307	0.211	NA
Area in Shell	A1	1.534	2.628	NA
Area in Nozzle Wall	A2	4.467	4.458	NA

Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.964	0.964	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	6.965	8.051	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)
= (31.4*4.1623*1.0+2*11.3*4.1623*1.0*(1-1.0))
= 1.307 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)
= 38.825(1.0 * 8.1125 - 1.0 * 4.162) - 2 * 11.3
(1.0 * 8.1125 - 1.0 * 4.1623) * (1 - 1.0)
= 1.534 cm^2

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 20.28)(11.3 - 0.29)1.0
= 4.467 cm^2

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= (Wo² - Area Lost)*fr2 + ((Wi-can/0.707)² - Area Lost)*fr2
= (10.0² - 0.0356) * 1.0 + (0.0² -0.0) * 1.0
= 0.964 cm^2

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

Wall Thickness for Internal/External pressures ta = 3.3088 mm.
Wall Thickness per UG16(b), tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure trb1 = 7.1623 mm.
Wall Thickness tb1 = max(trb1, tr16b) = 7.1623 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(7.1623, 4.5)]
= 6.4200 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(3.3088, 6.42)
= 6.4200 mm.

Available Nozzle Neck Thickness = 14.3000 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 11.113, tr = 4.162, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.513, Temp. Reduction = 31 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -26 °C

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-1 AB OIL COOLER
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for OIL COOLER E-PK6101-1AB
Nozzle Calcs.: T3 Nozl: 14 0:02am Feb 7,2022

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

Governing MDMT of all the sub-joints of this Junction : -48 °C

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 25.04/51.10 = 0.490

Weld Size Calculations, Description: T3

Intermediate Calc. for nozzle/shell Welds Tmin 9.7000 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, (1.307 - 1.5337 + 2 * 11.3 * 1.0 *
(1.0 * 8.1125 - 4.1623))118)
= 7.85 kN

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

Weld Load [W1]:
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= (4.4669 + 0.0 + 0.9644 - 0.0 * 1.0) * 118
= 64.03 kN

Weld Load [W2]:
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= (4.4669 + 0.0 + 0.9644 + (1.8334)) * 118
= 85.65 kN

Weld Load [W3]:
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= (4.4669 + 0.0 + 0.9644 + 0.0 + (1.8334)) * 118
= 85.65 kN

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
= (pi/2) * Dlo * Wo * 0.49 * Snw
= (3.1416/2.0) * 54.0 * 10.0 * 0.49 * 118
= 49. kN

Shear, Nozzle Wall [Snw]:
= (pi *(Dlr + Dlo)/4) * (Thk - Can) * 0.7 * Sn
= (3.1416 * 21.35) * (14.3 - 3.0) * 0.7 * 138
= 73. kN

Tension, Shell Groove Weld [Tngw]:
= (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
= (3.1416/2.0) * 54.0 * (10.0 - 3.0) * 0.74 * 138
= 61. kN

Strength of Failure Paths:

```
PATH11 = ( SONW + SNW ) = ( 49 + 73 ) = 122 kN
PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
       = ( 49 + 0 + 61 + 0 ) = 110 kN
PATH33 = ( Sonw + Tngw + Sinw )
       = ( 49 + 61 + 0 ) = 110 kN
```

Summary of Failure Path Calculations:

```
Path 1-1 = 122 kN , must exceed W = 7 kN  or W1 = 64 kN
Path 2-2 = 109 kN , must exceed W = 7 kN  or W2 = 85 kN
Path 3-3 = 109 kN , must exceed W = 7 kN  or W3 = 85 kN

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

The Drop for this Nozzle is : 1.9231 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 213.0356 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
T4	0.750 in	Actual	LWN	1.876	14.300	...	...	212.61	300
T3	1.000 in	Actual	LWN	2.126	14.300	...	...	213.04	300
S3	2.000 in	Actual	LWN	3.307	16.600	...	...	215.80	300
T2	3.000 in	160	WNF	3.500	11.125	188.90	10.00	216.37	300
T1	3.000 in	160	WNF	3.500	11.125	214.30	10.00	216.37	300
S2	3.000 in	160	WNF	3.500	11.125	214.30	10.00	216.37	300
S1	3.000 in	160	WNF	3.500	11.125	214.30	10.00	216.37	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
T4	SA-105	10.000	10.000	...	...	...
T3	SA-105	10.000	10.000	...	...	...
S3	SA-105	8.334	10.000	...	...	...
T2	SA-106 B	8.334	8.000	8.000	10.000	...
T1	SA-106 B	8.334	8.000	8.000	10.000	...
S2	SA-106 B	8.334	8.000	8.000	10.000	...
S1	SA-106 B	8.334	8.000	8.000	10.000	...

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

Nozzle Miscellaneous Data:

Description	Elev/Distance From Datum mm.	Layout Angle deg	Proj Outside mm.	Proj Inside mm.	Installed in Component
T4	3643.350	0.0	200.00	0.00	CHANNEL 002
T3	3643.350	180.0	200.00	0.00	CHANNEL 002

S3	612.175	180.0	200.00	0.00	SHELL
T2	160.000	0.0	200.00	0.00	CHANNEL 01
T1	160.000	180.0	200.00	0.00	CHANNEL 01
S2	612.175	0.0	200.00	0.00	SHELL
S1	3146.175	0.0	200.00	0.00	SHELL

Input Echo, Tubesheet Number 1, Description: TUBE SHEET

Shell Data:

Main Shell Description: SHELL

Shell Maximum Design Pressure	Psd,max	25.00	bars
Shell Maximum Operating Pressure	Psox,max	25.00	bars
Shell Minimum Operating Pressure	Psox,min	0.00	bars
Shell Thickness	ts	12.7000	mm.
Shell Internal Corrosion Allowance	cas	3.0000	mm.
Shell External Corrosion Allowance	caext	0.0000	mm.
Inside Diameter of Shell	Ds	381.000	mm.
Shell Circumferential Joint Efficiency	Esw	1.000	
Shell Temperature for Internal Pressure	Ts	190.00	°C
Shell Material		SA-106 B	

Note:
Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-106 B

Shell Material UNS Number		K03006	
Shell Allowable Stress at Temperature	Ss	117.90	N./mm^2
Shell Allowable Stress at Ambient		117.90	N./mm^2

Channel Description: CHANNEL 01

Channel Type:		Cylinder	
Channel Maximum Design Pressure	Ptd,max	25.00	bars
Channel Maximum Operating Pressure	Ptox,max	25.00	bars
Channel Minimum Operating Pressure	Ptox,min	0.00	bars
Channel Thickness	tc	12.7000	mm.
Channel Corrosion Allowance	cac	3.0000	mm.
Inside Diameter of Channel	Dc	381.000	mm.
Channel Design Temperature	TEMPC	190.00	°C
Channel Material		SA-106 B	

Note:
Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-106 B

Channel Material UNS Number		K03006	
Channel Allowable Stress at Temperature	Sc	117.90	N./mm^2
Channel Allowable Stress at Ambient		117.90	N./mm^2

Tube Data:

Number of Tube Holes	Nt	166	
Tube Wall Thickness	et	2.1080	mm.
Tube Outside Diameter	D	19.0500	mm.
Total Straight Tube Length	Lt	3000.00	mm.
Straight Tube Length (bet. inner tubsht faces)	L	2906.00	mm.
Design Temperature of the Tubes		190.00	°C
Tube Material		SA-179	
Tube Material UNS Number		K01200	
Is this a Welded Tube		No	
Tube Material Specification used		Smls. tube	
Tube Allowable Stress at Temperature		92.39	N./mm^2
Tube Allowable Stress At Ambient		92.39	N./mm^2
Tube Yield Stress At design Temperature	Syt	154.50	N./mm^2
Tube Pitch (Center to Center Spacing)	P	24.0000	mm.
Tube Layout Pattern		Triangular	

Fillet Weld Leg	af	1.5000	mm.
Groove Weld Leg	ag	1.5000	mm.
Tube-Tubesheet Joint Weld Type		Full Strength	
Method for Tube-Tubesheet Jt. Allow.		UW-20	
Tube-Tubesheet Joint Classification		f	
Radius to Outermost Tube Hole Center	ro	173.770	mm.
Largest Center-to-Center Tube Distance	Ul	34.9000	mm.
Length of Expanded Portion of Tube	ltx	0.0000	mm.
Tube-side pass partition groove depth	hg	5.0000	mm.

Tubesheet Data:

Tubesheet TYPE: Fixed Tubesheet Exchanger, Conf B

Tubesheet Design Metal Temperature	T	190.00	°C
Tubesheet Material		SA-266 2	

Note:
Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-266 2

Tubesheet Material UNS Number		K03506	
Tubesheet Allowable Stress at Temperature	S	137.90	N./mm^2
Tubesheet Allowable Stress at Ambient	Tt	137.90	N./mm^2
Thickness of Tubesheet	h	47.0000	mm.
Tubesheet Corr. Allowance (Shell side)	Cats	3.0000	mm.
Tubesheet Corr. Allowance (Channel side)	Catc	3.0000	mm.
Tubesheet Outside Diameter	A	515.000	mm.

Additional Data for Stepped Tubesheets:

Is the Tubesheet Stepped?		YES	
Is the Tubesheet Flat on Tubeside?		NO	
Step 1 Diameter on the Tubeside	dt1	444.00	mm.
Step 1 Depth on the Tubeside	ht1	6.00	mm.
Step 2 Diameter on the Tubeside	dt2	378.00	mm.
Step 2 Depth on the Tubeside	ht2	5.00	mm.
Is the Tubesheet Flat on Shellside?		NO	
Step 1 Diameter on the Shellside	ds1	0.00	mm.
Step 1 Depth on the Shellside	hs1	0.00	mm.
Step 2 Diameter on the Shellside	ds2	378.00	mm.
Step 2 Depth on the Shellside	hs2	5.00	mm.
Calculated Tubesheet Diameter as per UHX-10(b)		444.00	mm.

Note: Tubesheet diameter is now: 444.000 mm. per UHX-10(b).

Area of the Untubed Lanes	AL	128.0	cm^2

Additional Data for Fixed/Floating Tubesheet Exchangers:

Unsupported Tube Span under consideration	l	571.000	mm.
Tube End condition corresponding to Span (l)	k	0.80	
Ignore Radial Thermal Exp. effects (UHX-13.8/14.6)		YES	

Note: The Metal temperatures at the Rim are set to ambient (21 °C)

Tubesheet Metal Temp. at Rim	T'	21.11	°C
Shell Metal Temp. at Tubesheet	T'S	21.11	°C
Channel Metal Temp. at Tubesheet	T'C	21.11	°C
Perform Differential Pressure Design		N	
Run Multiple Load Cases		YES	
Shell Side Min. Design Pressure	Psd,min	1.0342	bars

Channel Side Min. Design Pressure	Ptd,min	1.0314	bars
Mean Shell Metal Temp. along Shell len.	Tsm	56.96	°C
Mean Tube Metal Temp. along Tube length	Ttm	49.96	°C
Junction Stress Reduction option	Perform Plastic Calculation		

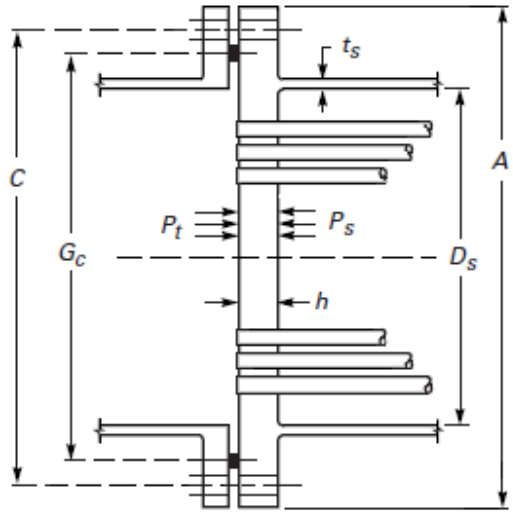
Additional Data for Gasketed Tubesheets:

Tubesheet Gasket on which Side		Channel	
Flange Outside Diameter	A	515.000	mm.
Flange Inside Diameter	B	381.000	mm.
Flange Face Outside Diameter	Fod	447.000	mm.
Flange Face Inside Diameter	Fid	381.000	mm.
Gasket Outside Diameter	Go	444.000	mm.
Gasket Inside Diameter	Gi	404.000	mm.
Small end Hub thk.	g0	11.1125	mm.
Large end Hub thk.	g1	17.0000	mm.
Gasket Factor,	m	3.78	
Gasket Design Seating Stress	y	62.05	N./mm^2
Flange Facing Sketch	Code Sketch 1a		
Column for Gasket Seating	Code Column II		
Gasket Thickness	tg	3.0000	mm.
Full face Gasket Flange Option	Program Selects		
Length of Partition Gasket	lp	1078.000	mm.
Width of Partition Gasket	wp	6.0000	mm.
Partition Gasket Factor,	mPart	3.7500	
Partition Gasket Design Seating Stress	yPart	62.05	N./mm^2
Partition Gasket Facing Sketch	Code Sketch 1a		
Partition Gasket Column for Gasket Seating	Code Column II		

Bolting Information:

Diameter of Bolt Circle	C	473.000	mm.
Nominal Bolt Diameter	dB	19.0500	mm.
Type of Thread Series	UNC Thread Series		
Number of Bolts	n	28	

Tubesheet Integral With Shell and Gasketed With Channel, Extended as a Flange



Configuration b:

Bolt Material			SA-193 B7
Bolt Allowable Stress At Temperature	Sb	172.38	N./mm^2

Bolt Allowable Stress At Ambient	Sa	172.38	N./mm^2
Weld between Flange and Shell/Channel		0.0000	mm.
Tubesheet Integral with		Shell	
Tubesheet Extended as Flange		Yes	
Thickness of Extended Portion of Tubesheet	Tf	30.0000	mm.
Is Bolt Load Transferred to the Tubesheet		Yes	
Is Exchanger in Creep range (skip EP, Use 3S for Sps)		NO	

ASME TubeSheet Results per Part UHX, 2017

Elasticity/Expansion Material Properties:

Shell - TE-1 Carbon & Low Alloy Steels, Group 1
Shell - TM-1 Carbon Steels with C<= 0.3%

Th. Exp. Coeff. Metal Temp. along Len	57.0 °C	0.0000118233 /°C	
Elastic Mod. at Design Temperature	190.0 °C	0.19308E+09	KPa.
Th. Exp. Coeff. Metal Temp. at Tubsht	21.1 °C	0.0000115190 /°C	
Elastic Mod. at Metal Temp. along Len	57.0 °C	0.20065E+09	KPa.
Elastic Mod. at Ambient Temperature	21.1 °C	0.20270E+09	KPa.

Channel - TE-1 Carbon & Low Alloy Steels, Group 1
Channel - TM-1 Carbon Steels with C<= 0.3%

Th. Exp. Coeff. Metal Temp. at Tubsht	21.1 °C	0.0000115190 /°C	
Elastic Mod. at Design Temperature	190.0 °C	0.19308E+09	KPa.
Elastic Mod. at Ambient Temperature	21.1 °C	0.20270E+09	KPa.

Tubes - TE-1 Carbon & Low Alloy Steels, Group 1
Tubes - TM-1 Carbon Steels with C<= 0.3%

Th. Exp. Coeff. Metal Temp. along Len	50.0 °C	0.0000117780 /°C	
Elastic Mod. at Design Temperature	190.0 °C	0.19308E+09	KPa.
Elastic Mod. at Metal Temp. along Len	50.0 °C	0.20105E+09	KPa.
Elastic Mod. at Tubsht. Design Temp.	190.0 °C	0.19308E+09	KPa.
Elastic Mod. at Ambient Temperature	21.1 °C	0.20270E+09	KPa.

TubeSheet - TE-1 Carbon & Low Alloy Steels, Group 1
TubeSheet - TM-1 Carbon Steels with C<= 0.3%

Th. Exp. Coeff. Metal Temp. at Rim	21.1 °C	0.0000115190 /°C	
Elastic Mod. at Design Temperature	190.0 °C	0.19308E+09	KPa.
Elastic Mod. at Metal Temp. at Rim	21.1 °C	0.20270E+09	KPa.
Elastic Mod. at Ambient Temperature	21.1 °C	0.20270E+09	KPa.

Note:
The Elasticity and Alpha values are taken from Tables in ASME II D.
Please insure these properties are consistent with the
type of Material for the tubes, shell, channel etc.

Tube Required Thickness under Internal Pressure (Tubeside pressure) :

Thickness Due to Internal Pressure:
= (P*(D/2-CAE)) / (S*E+0.4*P) per Appendix 1-1 (a)(1)
= (26.03*(19.05/2-0.0)/(92.39*1.0+0.4*26.03)
= 0.2654 + 0.0000 = 0.2654 mm.

Tube Required Thickness under External Pressure (Shellside pressure) :

```
External Pressure Chart     CS-1            at       190.00  °C
Elastic Modulus for Material                194843456.00  KPa.
```

Results for Max. Allowable External Pressure (Emawp):

TCA	ODCA	SLEN	D/T	L/D	Factor A	B
2.1080	19.05	2906.00	9.04	50.0000	0.0134693	93.80

EMAWP = (2.167/(D/T)-0.0833)*B = 146.7815 bars

Results for Reqd Thickness for Ext. Pressure (Tca):

TCA	ODCA	SLEN	D/T	L/D	Factor A	B
0.5486	19.05	2906.00	34.73	50.0000	0.0009121	67.81

EMAWP = (4*B)/(3*(D/T)) = (4 *67.811)/(3 *34.7278) = 26.0338 bars

Summary of Tube Required Thickness Results:

```
Total Required Thickness including Corrosion all.          0.5486  mm.
Allowable Internal Pressure at Corroded thickness          224.32  bars
Required Internal Design Pressure                           26.03  bars
Allowable External Pressure at Corroded thickness          146.78  bars
Required External Design Pressure                           26.03  bars
Required Thickness due to Shell Side pressure              0.5486  mm.
```

Detailed Results for load Case D3 un-corr. (Psd,max + Ptd,max)

Intermediate Calculations For Tubesheets Extended As Flanges:

ASME Code, Section VIII Division 1, 2017

```
Gasket Contact Width,       N = (Goc-Gic) / 2            20.000  mm.
Basic Gasket Width,        b0 = N / 2.0                  10.000  mm.
Effective Gasket Width,     b = SQRT(b0) * 2.5            7.966  mm.
Gasket Reaction Diameter,   G = Go-2.0*b                428.068  mm.
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:

```
= 2a + 6t/(m + 0.5)
= 2 * 19.05 + 6 * 30.0/(3.78 + 0.5)
= 80.156 mm.
```

Actual Circumferential Bolt Spacing [Bs]:

```
= C * sin( pi / n )
= 473.0 * sin( 3.142/28 )
= 52.959 mm.
```

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:

```
= max( sqrt( Bs/( 2a + t )), 1 )
= max( sqrt( 52.959/( 2 * 19.05 + 30.0 )), 1 )
= 1.0000
```

Bolting Information for UNC Thread Series (Non Mandatory):

```
Distance Across Corners for Nuts                    35.128  mm.
Circular Wrench End Diameter                   a    52.388  mm.
```

	Minimum	Actual	Maximum
Bolt Area, cm^2	50.206	54.555	
Radial Distance between Hub and Bolts:	20.637	33.300	
Radial Distance between Bolts and the Ed	20.637	21.000	
Circumferential Spacing between the Bolt	44.450	52.959	80.156

```
Flange Design Bolt Load, Seating Condition    W  :      902.83  kN
Flange Design Bolt Load, Operating Condition  Wm1:      622.88  kN
```

Results for ASME Fixed Tubesheet Calculations for Configuration b,

Results for Tubesheet Calculations Original Thickness :

UHX-13.5.1 Step 1:

Compute the Tube Expansion Depth Ratio [rho]:
= ltx / h (modified for corrosion if present)
= 0.0/47.0 = 0.0 (must be 0 <= rho <= 1)

Compute the Effective Tube Hole Diameter [d*]:
= Max(dt - 2tt*(Et/E)(StT/S)(rho), dt - 2tt)
= Max(19.05 -2*2.108 *(.19308E+09/.19308E+09)*
(92/137)*(0.0), 19.05 -2*2.108)
= 19.0500 mm.

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
= 2 * ro + dt = 2 * 173.77 + 19.05 = 366.59 mm.

Determine the Basic Ligament Efficiency for Shear [mu]:
= (p - dt)/p = (24.0 - 19.05)/24.0 = 0.2063

Compute the Equivalent Outer Tube Limit Radius [ao]:
= Do/2 = 366.59/2 = 183.295 mm.

Compute the Effective Tube Pitch [p*]:
= p / sqrt(1 - 4 * min(AL * CNV_factor, 4*Do*p)/(Pi * Do²))
= 24.0/sqrt(1 - 4 * min(128.0 *100.0, 4*366.59 *24.0)/(3.141 * 366.59²))
= 25.6026 mm.

Compute the Effective Ligament Efficiency for Bending [mu*]:
= (p* - d*)/p* = (25.6026 - 19.05)/25.6026 = 0.2559

Compute the Ratio [Rhos]:
= as/ao = 190.5/183.295 = 1.039308

Compute the Ratio [Rhoc]:
= ac/ao = 214.0342/183.295 = 1.167704

Compute Parameter [xt]:
= 1 - Nt * ((dt - 2 * tt)/(2 * ao))²
= 1 - 166 * ((19.05 - 2 * 2.108)/(2 * 183.295))² = 0.7282

Determine Parameter [xs]:
= 1 - Nt*(dt/(2*ao))²
= 1 - 166 *(19.05/(2*183.295))² = 0.5517

Determine the Value [h'g]:
= Max((hg - CATC), 0) (For pressure only cases)
= Max((5.0 - 0.0), 0) = 5.0 mm.

UHX-13.5.2 Step 2:

Determine the Axial Shell Stiffness [Ks]:
= pi * ts(Ds + ts)Es/L
= 3.1416 * 12.7 (381.0 + 12.7).19308E+09/2906.0

= 1043648704.0000 KPa. * mm.

Determine the Axial Tube Stiffness [Kt]:
= pi * tt(Dt - tt)Et/L
= 3.1416 * 2.108 (19.05 - 2.108).19308E+09/2906.0
= 7454535.0000 KPa. * mm.

Compute the Stiffness Factor [Ks,t]:
= Ks/(Nt * Kt) = 0.10436E+1/(166 * 7454535) = 0.84338

Rigidty Ratio [J]:
= 1 / (1 + Ks/Kj)
= 1/(1 + 0.10436E+1/0.0) = 1. (= 1 if No Exp. Jt.)

Compute Shell Coefficient [betas]:
= ((12 * (1-nus^2))$^{0.25}$)/((Ds + ts) * ts)$^{0.5}$
= ((12 * (1 - 0.3^2))$^{0.25}$)/((381.0 + 12.7) * 12.7)$^{0.5}$
= 0.0257 1/mm.

Determine Shell Coefficient [ks]:
= betas * Es * ts^3 / (6 * (1 - nus^2))
= 0.026 * 0.19308E+09 * 12.7^3/(6 * (1 - 0.3^2))
= 18621754.0000 bars*mm.^{2}

Determine Shell Coefficient [Lambdas]:
= (6*Ds*ks)/(h^3) * (1 + h*betas + 0.5*(h*betas)^2)
= 6*381.0 *18621754/(47.0^3) * (1 + 47.0 * 0.026 + 0.73)
= 1204739.8750 bars

Determine Shell Coefficient [deltaS]:
= Ds^2/(4 * Es * Ts) * (1 - nus/2)
= 381.0^2/(4 * 0.19308E+09 * 12.7) * (1 - 0.3/2)
= 0.0125790816 mm./N./mm^2

Intermediate parameters for Tubesheet Gasketed on the Channel Side:
betac, kc, deltaC, Lambdac = 0

UHX-13.5.3 Step 3:

E*/E and nu* for Triangular pattern from Fig. UHX-11.3.
h/p = 1.958333 ; mu* = 0.255935
E*/E = 0.225557 ; nu* = 0.388714 ; E* = 43550004. KPa.

Compute the Tube Bundle Stiffness Factor [Xa]:
= ((24 *(1 - nu*^{2})*Nt * Et* tt* (dt - tt)* ao^2) /
(E* * L * H^3))$^{0.25}$
= ((24 *(1 - 0.389^2)*166 *.19308E+09*2.108 *
(19.05 - 2.108)*183.295^2)/(43550004 *
2906.0 * 47.0^3))$^{0.25}$
= 2.7789

Values from Table UHX-13.1
Zd = 0.067404 ; Zv = 0.116146 ; Zm = 0.529458
Za = 0.173239E+01 ; Zw = 0.116146

UHX-13.5.4 Step 4:

Compute the Diameter Ratio [K]:
= A/Do = 444.0/366.59 = 1.2112

Compute Coefficient [F]:
= (1 - nu*) / (E*) * (Lambdas + Lambdac + E * ln(K))

```
  = (1 - 0.39 )/(43550004 ) * ( 1204739 + 0.0 +
    0.19308E+09 * ln(1.21 ) )
  = 2.2102
```

Compute Parameter [Phi]:
```
  = (1 + nu*) * F = (1 + 0.3887 ) * 2.2102 = 3.0694
```

Compute Parameter [Q1]:
```
  = (Rhos - 1 - Phi * Zv)/(1 + Phi * Zm)
  = (1.0393 - 1 - 3.0694 * 0.1161 )/(1 + 3.0694 * 0.5295 )
  = -0.120828770
```

Compute Parameter [Qz1]:
```
  = (Zd + Q1*Zw)/2 *Xa⁴
  = ( 0.0674 + -0.12083 * 0.11615 )/2 *2.77886⁴ = 1.5912
```

Compute Parameter [Qz2]:
```
  = (Zv + Q1*Zm)/2 *Xa⁴
  = ( 0.11615 + -0.12083 * 0.52946 )/2 *2.77886⁴ = 1.5555
```

Compute Parameter [U]:
```
  = (Zw + (Rhos - 1)*Zm)*Xa⁴ / (1 + Phi*Zm)
  = ( 0.1161 + (1.0393 - 1)* 0.5295 )*2.77886⁴/(1 + 3.0694 * 0.5295 )
  = 3.1111
```

UHX-13.5.5 Step 5:

Determine factor [gamab]:
```
  = ( Gc - C ) / Do (config b)
  = (428.0685 - 473.0 )/366.59 = -0.12257
```

Compute Parameter [gamma]:
```
  = 0.000 mm. (For Pressure only cases)
```

Calculate Parameter [OmegaS]:
```
  = rhos * ks * Betas * deltaS( 1 + h * Betas )
  = 1.0393 * 18621754 * 0.0257 * 0.012579 ( 1 + 47.0 * 0.0257 )
  = 1382.1816 mm.²
```

Calculate Parameter [Omega*S]:
```
  = Ao² * ( Rhos² - 1 ) * ( Rhos - 1 ) / 4 - OmegaS
  = 183.295² * ( 1.039² - 1 ) * ( 1.039 - 1 )/4 - 1382.182
  = -1355.7156 mm.²
```

Calculate Parameter [OmegaC]:
```
  = rhoc * kc * Betac * deltaC( 1 + h * Betac )
  = 1.1677 * 0.0 * 0.0 * 0. ( 1 + 47.0 * 0.0 )
  = 0.0000 mm.²
```

Calculate Parameter [Omega*C]:
```
  = ao²[( Rhoc²+1 )*( Rhoc-1 )/4 -(Rhos-1)/2]- OmegaC
  = 183.295²[( 1.1677²+1 )*( 1.1677 -1 )/4 -(1.03931 -1)/2]- 0.
  = 2668.9180 mm.²
```

Compute the Pressure [P*S]:
= 0 For Pressure only cases or Configurations d,e,f,A,B,C,D

Compute the Pressure [P*C]:
= 0 For Pressure only cases or Configurations b,c,d,B,C,D

UHX-13.5.6 Step 6:

Compute the Pressure [P's]:

= Ps * {xs + 2(1 - xs)nut + [2/Kst(Ds/Do)²]nus -
[(rhos²-1)/(J*Kst)]-[(1-J)/(2J*Kst)][(Dj²-(Ds)²)/Do²]}
= 25.0 * { 0.552 + 2(1 - 0.552) 0.3 +
[2/0.843 (381.0/366.59)²] 0.3 -
[(1.039²-1)/(1.0 * 0.843)] -
[(1 - 1.0)/(2 * 1.0 * 0.843)][(0.0²-(381.0)²)/366.59²]}
= 37.3523 bars

Compute the Pressure [P't]:

= [xt + 2(1 - xt)nut + 1/(J * Kst)]*Pt
= [0.728 + 2(1 - 0.728) 0.3 +
1/(1. * 0.843)]* 25.0
= 51.9244 bars

Compute the Pressure [Pgama]:

= Nt * Kt * gama / (pi * ao²)
= 166 * 7454535 * 0.0/(3.142 * 183.295²) = 0.0 bars

Compute the Pressure [Pw]:

= -gamab * U * W* / (2 * pi * ao²)
= --0.123 * 3.111 * 622.88/(2 * 3.142 * 183.295²)
= 11.2517 bars

Calculate the Pressure [Prim]:

= -(U/ao²)(Omega*S * Ps - Omega*C * Pt)
= -(3.111/183.295²)(-2.101 * 25.0 - 4.137 * 25.0)
= 9.3169 bars

Calculate the Pressure [POmega]:

= U/ao²(OmegaS * P*s - OmegaC * P*c)
= 3.111/183.295²(2.1424 * 0.0 - 0.0 * 0.0)
= 0.0000 bars

Determine the Effective Pressure [Pe]:

= J * Kst / (1 + J * Kst *(Qz1 + (Rhos - 1) * Qz2)) *
(P's - P't + Pgama + Pw + Prim)
= 0.1000E+01 * 0.843/(1 + 1.0 * 0.843 *(1.591 + (1.039 -
1) * 1.556)) * (37.352 - 51.924 + 0.0 + 11.252 + 9.317)
= 2.1129 bars

UHX-13.5.7 Step 7:

Determine Factor [Q2]:

= [((Omega*S*Ps - Omega*C*Pt) - (Omegas*P*s - Omegac P*c))CNV_FAC +
W* * gamab/(2*pi)]/(1 + Phi*Zm)
= [((-1355.716 * 25.0 - 2668.918 * 25.0) -
(1382.182 * 0.0 - 0.0 * 0.0)) * 0. +
622.9 * -0.123/(2*3.141)]/(1 + 3.06937 * 0.52946)
= -8.461345673 kN

Calculate Factor [Q3]:

= Q1 + 2 * Q2 / (Pe * ao²)
= -0.121 + 2 * -8.461/(2.113 * 183.295²)
= -2.504810

Fm Value from Table UHX-13.1 = 1.252405

The Tubesheet Bending Stress - Original Thickness [Sigma]:

= (1.5 * Fm / mu*) * (2 * ao/(H - h'g)² * Pe
= (1.5 * 1.2524/0.2559) * (2 * 183.295/(47.0 - 5.0))² * 2.11
= 118.1604 N./mm^2

The Allowable Tubesheet Bending Stress [Sigma allowed]:
= 1.5 * S = 1.5 * 137.9 = 206.85 N./mm^2

The Tubesheet Bending Stress - Final Thickness [Sigmaf]:
= (1.5 * Fm/mu*) * (2 * ao/(h - h'g)² * Pe
= (1.5 * 0.5155/0.2559) * (2 * 183.295/(34.665 - 5.0))² * 4.48
= 206.8393 N./mm^2

Reqd Tubesheet Thickness, for Bending Stress (Including CA) [HReqB]:
= h + Cats + Catc = 34.6645 + 0.0 + 0.0 = 34.6645 mm.

UHX-13.5.8 Step 8:

Shear Stress check [Tau_limit]:
= 1.6 * S * MU * h / ao
= 1.6 * 137.9 * 0.206 * 47.0/183.29
= 11.6688 N./mm^2

The Shear Stress is not required to be computed; [Pe] <= Tau_limit

Note: Tubesheet Shear Stress is probably low, use the following req. thk:
Tubesheet thickness (Incl. Corr.)= 3.8100 mm.
Tubesheet Shear Stress = 26.5267 N./mm^2

Reqd Tubesheet Thickness for Given Loadings (Including CA) [Hreqd] :
= Max(HreqB, HreqS) = Max(34.6645, 3.81) = 34.6645 mm.

UHX-13.5.9 Step 9:

The Ftmin and Ftmax Coefficients from Table UHX-13.2:
Ftmin = -6.6643, Ftmax = 7.0057

First Extreme Tube Axial Stress from among all the tubes [Sigmat1]:
= ((Ps * xs - Pt * xt) - Pe * Ftmin) / (Xt - Xs)
= ((25.0 * 0.5517 - 25.0 * 0.7282) - (2.113) * -6.664)/
(0.7282 - 0.5517))
= 5.4801 N./mm^2

Second Extreme value of Tube Axial Stress from among all the tubes [Sigmat2]:
= ((Ps * xs - Pt * xt) - Pe * Ftmax) / (Xt - Xs)
= ((25.0 * 0.5517 - 25.0 * 0.7282) - (2.113) * 7.006)/
(0.7282 - 0.5517))
= -10.8891 N./mm^2

Maximum Tube Axial Stress [Sigmat,max]:
= MAX(abs(Sigmat1), abs(Sigmat2)) = 10.889 N./mm^2

The Allowable Tube Stress, [SigmatA]:
= Sot = 92.3930 N./mm^2

Check for Buckling as some of the Tubes are in Compression

Determine the Factor of Safety [Fs]:
= Max((3.25 - 0.25*(Zd + Q3*Zw)*Xa^4), 1.25)
= Max((3.25 - 0.25*(0.067 + -2.505 * 0.116)*2.779^4), 1.25)
= 2.0000 (Should be <= 2)

Determine the Factor [rt]:
= ((dt^2 + (dt - 2*tt)^2)$^{.5}$)/4
= ((19.05^2 + (19.05 - 2*2.108)^2)$^{.5}$)/4 = 6.0361 mm.

Determine the Factor [Ct]:
= (2 * PI^2 * Et/Syt)$^{0.5}$
= (2 * 3.14^2 * 0.19308E+09/154)$^{0.5}$ = 157.0623

Determine the Factor [Ft]:
= k * L/r = 0.8 * 571.0/6.036 = 75.6781

The Buckling Allowable Stress [Stb]:
= Sy,t/Fs*(1 - Ft/(2*Ct))
= 154/2.0 *(1 - 75.678/(2*157.062))
= 58.641 N./mm^2 (Never greater than Sot)

Note: The Axial Compressive stress in Tubes is within limits.

The Largest tube-to-tubesheet Joint Load [Wt]:
= Sigmat,max * Tube Area = 10.89 * 1.122 = 1.22 kN

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:
= 3.1415 * t * (do - t) * Sa
= 3.1415 * 2.108 * (19.05 - 2.108) * 92.39 = 10.365 kN

Fillet Weld Strength [Ff]:
= 0.55 * 3.1415 * af * (do + 0.67*af) * Sw (but not > Ft)
= 0.55 * 3.1415 * 1.5 * (19.05 + 0.67*1.5) * 92.39
= 4.8021 kN

Groove Weld Strength [Fg]:
= 0.85 * 3.1415 * ag * (do + 0.67*ag) * Sw (but not > Ft)
= 0.85 * 3.1415 * 1.5 * (19.05 + 0.67*1.5) * 92.39
= 7.4214 kN

Max. Allow. Tube-Tubesheet Joint load, Lmax
= Ft = 10.3654 kN

Design Strength Ratio [fd]:
= 1.0000

Weld Strength Factor [fw]:
= Sot / (Min(Sot, S)) = 1.0000

Min Weld Length [ar]:
= 2 *(((0.75 * do)² + 1.07*t*(do - t)* fw * fd))½ - 0.75 * do)
= 2.5600 mm.

Minimum Required Fillet Weld Leg	afr	1.2800	mm.
Minimum Required Groove Weld Leg	agr	1.2800	mm.

Tube-Tubesheet Jt allowable, 10.37 is >= tube strength 10.37 kN
Note: This tube-tubesheet joint is a Full Strength joint

UHX-13.5.10 Step 10:

Shell Axial Membrane Allowable Stress:
= Ss * Esw = 117.9 * 1.0 = 117.9 N./mm^2

Axial Membrane Stress in Shell [Sigmas,m]:
= ao²/((Ds+ts)*ts)* [Pe + (Rhos²-1)(Ps-Pt)]+ as²*Pt/((Ds+ts)*ts)
= 183.295²/((381.0 +12.7)*12.7)* [2.11 + (1.039²-1)

```
    (25.0 -25.0 )] + 190.5²*25.0/((381.0 +12.7 )
    * 12.7 )
  = 19.5660 N./mm^2
```

UHX-13.5.11 Step 11:

Note:
For a given Shell thickness of 12.7 mm., the minimum Shell
length adjacent to the tubesheet should be 125.209 mm.

The Shell Membrane Stress due to Joint Interaction [Sigmas,m]:

```
  = ao²/((Ds+ts)*ts)[Pe + (Rhos²-1)(Ps-Pt)]+ as²*Pt/((Ds+ts)*ts)
  = 183.295²/((381.0 +12.7 )*12.7 )[2.11 + (1.039²-1)
    (25.0 -25.0 )] + 190.5²*25.0/((381.0 +12.7 )
    * 12.7 )
  = 19.5660 N./mm^2
```

The Shell Bending Stress due to Joint Interaction [Sigmasb]:

```
  = 6*ks/ts² {betas[deltaS*Ps + as²*PstarS/(Es*ts)] +
    6(1 - nu*²)/(E*)(ao/h)³(1 + h*betas/2)[Pe(Zv + Zm*Q1) +
    2/ao² * Zm * Q2 ]}
  = 6 * 18621754/12.7² { 0.026 [ 0.013 * 25.0 + 190.5²
    * 0.0/(.24521E+1 ) ] +
    6(1 - 0.39²)/(43550004 )(183.29/47.0 )³(1 + 47.0 *
    0.03/2)[ 2.1 ( 0.116 + 0.529 * -0.121 ) +
    2/183.29² * 0.529 * -8.461 ] }
  = -141.0901 N./mm^2
```

Shell Stress Summation vs. Allowable

```
  abs(Sigmasm) + abs(Sigmasb) <= 1.5 * Ss
  abs(19.6 ) + abs(-141.1 ) <= 176.86 N./mm^2
  160.66 must be < or = 176.86 N./mm^2
```

Computations Completed for ASME Tubesheet Configuration b

Stress/Force Summary for Loadcase D3 un-corr. (Psd,max + Ptd,max):

Stress Description	Actual		Allowable	Pass/Fail
Tubesheet Bend. Stress	118.2	<=	206.8 N./mm^2	Ok
Tubesheet Shear Stress	2.0	<=	110.3 N./mm^2	Ok
Maximum Tube Stress	10.9	<=	92.4 N./mm^2	Ok
Minimum Tube Stress (Buckling)	-10.9	<=	-58.6 N./mm^2	Ok
Maximum Force on any one Tube	1.2	<=	10.4 kN	Ok
Axial Membrane Stress in Shell	19.6	<=	117.9 N./mm^2	Ok
Shell Stress (jt. inter.)	160.7	<=	176.9 N./mm^2	Ok

Thickness Results for Loadcase D3 un-corr. (Psd,max + Ptd,max):

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	34.665	47.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.280	1.500	Ok
Tube-Tubesheet Groove Weld Leg :	1.280	1.500	Ok

Fixed Tubesheet results per ASME UHX-13 2017

Results for 16 Load Cases:

--Reqd. Thk. + CA	---- Tubesheet Stresses	Case	Pass/

Case#	Tbsht	Extnsn	Bend	Allwd	Shear	Allwd	Type	Fail
D1uc	27.416	25.552	101	207	12	110	Ps+Pt-Th	D1 Ok
D2uc	22.014	...	56	207	14	110	Ps+Pt-Th	D2 Ok
D3uc	34.665	...	118	207	2	110	Ps+Pt-Th	D3 Ok
D4uc	5.943	...	2	207	...	110	Ps+Pt-Th	D4 Ok
O1uc	3.810	...	111	428	19	110	Ps+Pt+Th	O1 Ok
O2uc	14.652	...	106	428	9	110	Ps+Pt+Th	O2 Ok
O3uc	7.577	...	107	428	6	110	Ps+Pt+Th	O3 Ok
O4uc	7.912	...	68	428	4	110	Ps+Pt+Th	O4 Ok
D1c	37.468	25.552	136	207	11	110	Ps+Pt-Th-c	D1 Ok
D2c	21.442	...	48	207	15	110	Ps+Pt-Th-c	D2 Ok
D3c	40.774	...	153	207	4	110	Ps+Pt-Th-c	D3 Ok
D4c	9.810	...	2	207	...	110	Ps+Pt-Th-c	D4 Ok
O1c	22.665	...	153	428	16	110	Ps+Pt+Th-c	O1 Ok
O2c	26.665	...	154	428	13	110	Ps+Pt+Th-c	O2 Ok
O3c	27.618	...	164	428	2	110	Ps+Pt+Th-c	O3 Ok
O4c	21.674	...	111	428	1	110	Ps+Pt+Th-c	O4 Ok
Max:	40.7739	25.552	mm.	0.741		0.175	(Str. Ratio)	

Load Case Definitions:

[Ps & Pt]:
Shell-side and Tube-side Design or Operating Pressures
derived from Psd,min Ptd,max, Psox,min, Ptox,max etc. per the
Load Case Tables

[(+-)Th]:
With or Without Thermal Expansion, Tt,mx & Ts,mx

[c]:
With or Without Corrosion Allowance

[D1, D2, D3]:
Design Load Cases using the Maximum and Minimum Design Pressures

[D4]:
Design Load Case using the Minimum (Vacuum) Pressures (if specified)

[O1, O2, O3, O4]:
Operating Load Cases using the Maximum and Minimum Operating Pressures and
Operating Temperatures

Shell Axial Membrane Stress Summary:

	Shell Stresses				Shell Band Stress				Pass
Case#	Ten	Allwd	Cmp	Allwd	Ten	Allwd	Cmp	Allwd	Fail
D1uc	8	117	...	...	...	...	...	...	Ok
D2uc	11	117	...	...	...	...	...	...	Ok
D3uc	20	117	...	...	...	...	...	...	Ok
D4uc	1	117	-1	-114	...	...	...	...	Ok
O1uc	3	416	...	...	...	...	...	...	Ok
O2uc	8	416	...	...	...	...	...	...	Ok
O3uc	14	416	...	...	...	...	...	...	Ok
O4uc	3	416	-3	-114	...	...	...	...	Ok
D1c	13	117	...	...	...	...	...	...	Ok
D2c	13	117	...	...	...	...	...	...	Ok
D3c	27	117	...	...	...	...	...	...	Ok
D4c	1	117	-1	-111	...	...	...	...	Ok

O1c	9	416	...	...	...	...	...	...	Ok
O2c	13	416	...	...	...	...	...	...	Ok
O3c	22	416	...	...	...	...	...	...	Ok
O4c	...	416	...	-111	...	...	...	...	Ok
Max RATIO	0.233		0.026		...		...		

Tube, Shell and Channel Stress Summary:

	---- Tube Stresses				Tube Loads		Shell Stress		Channel Stress		Pass
Case#	Ten	Allwd	Cmp	Allwd	Ld	Allwd	Stress	Allwd	Stress	Allwd	Fail
D1uc	16	92	-16	-62	2	10	235	416	...	...	Ok
D2uc	5	92	-4	-58	1	10	98	176	...	...	Ok
D3uc	11	92	-11	-58	1	10	161	176	...	...	Ok
D4uc	...	92	...	-92	...	10	3	176	...	...	Ok
O1uc	19	184	-16	-58	2	20	310	416	...	...	Ok
O2uc	8	184	-1	-58	1	20	106	416	...	...	Ok
O3uc	15	184	-12	-92	2	20	239	416	...	...	Ok
O4uc	12	184	-6	-92	1	20	183	416	...	...	Ok
D1c	20	92	-20	-92	2	10	306	416	...	...	Ok
D2c	7	92	-4	-58	1	10	136	176	...	...	Ok
D3c	13	92	-13	-58	1	10	200	416	...	...	Ok
D4c	...	92	...	-92	...	10	3	176	...	...	Ok
O1c	23	184	-23	-85	3	20	400	416	...	...	Ok
O2c	8	184	-2	-58	1	20	128	416	...	...	Ok
O3c	18	184	-16	-92	2	20	299	416	...	...	Ok
O4c	13	184	-9	-92	1	20	231	416	...	...	Ok
Max RATIO	0.216		0.276		0.216		0.962		...		

Summary of Thickness Comparisons for 16 Load Cases:

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	40.774	47.000	Ok
Tubesheet Thickness Flanged Extension :	25.552	30.000	Ok
Tube Thickness :	0.549	2.108	Ok
Tube-Tubesheet Fillet Weld Leg :	1.280	1.500	Ok
Tube-Tubesheet Groove Weld Leg :	1.280	1.500	Ok

Min Shell length of thk, (12.700) adj. to tubesheet: 125.209 mm.

Note: This is a full strength Tube to Tubesheet Joint.

Summary of Axial Differential Expansion between Shell and Tubes :

Due to Thermal Expansion Shell Compresses by : -0.245 mm.
Due to Pressure Shell Compresses by : -0.045 mm.
Due to Pressure + Thermal Shell Compresses by : -0.289 mm.

Tubesheet MAWP used to Compute Hydrotest Pressure:

Stress / Force Condition	Tubeside MAWP	0 shellside Stress Rat.	Shellside MAWP	0 tubeside Stress Rat.
Tubesheet Bending Stress	40.783	1.000	95.817	0.998
Tubesheet Shear Stress	193.792	1.000	197.344	1.000
Tube Tensile Stress	117.260	1.000	346.751	1.000
Tube Compressive Stress	99.710	1.000	359.142	1.000
Tube-Tubesheet Joint load	117.260	1.000	346.751	1.000
Shell Stress (Axial, Junction)	27.070	0.996	80.443	1.000
Tube Pressure Stress	224.322	1.000	146.781	1.000
Tubesheet Extension Stress	37.739	...	No Calc	No Calc

Minimum MAWP	27.070		80.443	

Tubesheet MAPnc used to Compute Hydrotest Pressure:

Stress / Force Condition	Tubeside MAPnc	0 shellside Stress Rat.	Shellside MAPnc	0 tubeside Stress Rat.
Tubesheet Bending Stress	45.838	0.997	94.405	0.999
Tubesheet Shear Stress	240.003	1.000	204.459	1.000
Tube Tensile Stress	149.226	1.000	503.284	1.000
Tube Compressive Stress	117.104	1.000	472.613	1.000
Tube-Tubesheet Joint load	149.226	1.000	503.284	1.000
Shell Stress (Axial, Junction)	45.838	0.997	94.405	0.999
Tube Pressure Stress	224.322	1.000	149.973	1.000
Tubesheet Extension Stress	37.739	...	No Calc	No Calc
Minimum MAPnc	37.739		94.405	

Tubesheet MDMT Calculations:

Note: The loading conditions from this case will be used to determine the tubesheet MDMT.

Shell Side MDMT calculation:

Governing thickness on the shell side per figure UCS-66.3 (e):
= max(tubesheet thk/4, min(tubesheet thk, shell thickness))
= max(47.0/4, min(47.0, 12.7))
= 12.700 mm.

Thickness Ratio = 0.662, Temperature Reduction per Fig. UCS 66.1 = 19 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -21 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -40 °C
Min Metal Temp. w/o impact per UG-20(f)                   -29 °C
```

Channel Side MDMT calculation:

Governing thickness for the channel side:
= tubesheet thickness/4
= 47.0/4
= 11.750 mm.

Thickness Ratio = 0.662, Temperature Reduction per Fig. UCS 66.1 = 19 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve C            -40 °C
Min Metal Temp. at Required thickness (UCS 66.1)          -48 °C
```

where the MDMT reduction ratio per UCS 66 (b)(1)(b) is:
= max(pt/Tubeside MAPnc, ps/Shellside MAPnc), must be <= 1
= max(25.0/37.74, 25.0/94.41)
= 0.662

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
SHELL	[8]	B	-26	-48	-29	0.513	11.113	1.00	No
S2	[1]	B	-29	-48	-29	0.512	10.000	1.00	No
Nozzle Flg	[4]	B	-29	-104					
S1	[1]	B	-29	-48	-29	0.512	10.000	1.00	No
Nozzle Flg	[4]	B	-29	-104					
S3	[1]	B	-26	-48	-29	0.513	11.113	1.00	No
Nozzle Flg	[5]	B	-29	-48					
Tubesheet: SS	[13]	B	-21	-40	-29	0.662	12.700	1.00	No
Warmest MDMT:			-21	-40					
BODY FLANGE 0	[11]	C	-41	-48	-29	0.766	11.113	1.00	No
BODY FLANGE 0	[11]	C	-41	-48	-29	0.766	11.113	1.00	No
HEAD 1	[10]	D	-48	-48	-29	0.425	11.113	1.00	No
HEAD 1	[7]	D	-48	-104	-29	0.323	14.000	1.00	No
CHANNEL 01	[8]	B	-26	-48	-29	0.513	11.113	1.00	No
CHANNEL 002	[8]	B	-26	-48	-29	0.513	11.113	1.00	No
HEAD 002	[10]	D	-48	-48	-29	0.425	11.113	1.00	No
HEAD 002	[7]	D	-48	-104	-29	0.323	14.000	1.00	No
T2	[1]	B	-29	-48	-29	0.512	10.000	1.00	No
Nozzle Flg	[4]	B	-29	-104					
T1	[1]	B	-29	-48	-29	0.513	10.000	1.00	No
Nozzle Flg	[4]	B	-29	-104					
T4	[1]	B	-26	-48	-29	0.512	11.113	1.00	No
Nozzle Flg	[5]	C	-29	-48					
T3	[1]	B	-26	-48	-29	0.513	11.113	1.00	No
Nozzle Flg	[5]	C	-29	-48					
Tubesheet: CS	[14]	C	-40	-48	-29	0.662	11.750	1.00	No
Warmest MDMT:			-26	-48					

Exchanger Side	Computed MDMT °C	Required MDMT °C	Pass/Fail
Shell	-40	-10	Pass
Channel/Tube	-48	-10	Pass

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

[18] - Impact Testing not required, see UCS-66(b)(3)

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.

ASME Code, Section VIII Division 1, 2017

Diameter Spec : 381.000 mm. ID
Vessel Design Length, Tangent to Tangent 3904.35 mm.

Specified Datum Line Distance 50.00 mm.

Shell Material SA-106 B
Head Material SA-516 70 [Normalized]
Nozzle Material SA-105
Re-Pad Material SA-516 70

Shell Side Design Temperature 120 °C
Channel Side Design Temperature 190 °C

Shell Side Design Pressure 25.000 bars
Channel Side Design Pressure 25.000 bars

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 1	25.038	1.10No Calc	70	3.0000	No
CHANNEL 01	25.038	1.10No Calc	70	3.0000	N/A
BODY FLANGE 01	25.037	1.10No Calc	70	3.0000	N/A
SHELL	25.033	1.10No Calc	70	3.0000	N/A
BODY FLANGE 002	25.037	1.10No Calc	70	3.0000	N/A
CHANNEL 002	25.038	1.10No Calc	70	3.0000	N/A
HEAD 002	25.038	1.10No Calc	70	3.0000	No

Liquid Level: 381.00 mm. Dens.: 0.001 kg./cm^3 Sp. Gr.: 1.000

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	14.0	6.4	4.5	1.00	0.85
Cylinder	321.0	321.0	12.7	7.2	4.3	1.00	1.00
Body Flg	395.0	74.0	79.0	41.4	41.4	1.00	1.00
Cylinder	3356.2	2908.0	12.7	7.2	6.1	1.00	1.00
Body Flg	3436.4	74.0	79.0	41.4	41.4	1.00	1.00
Cylinder	3804.4	321.0	12.7	7.2	4.3	1.00	1.00
Ellipse	3854.4	50.0	14.0	6.4	4.5	1.00	1.00

Element thicknesses are shown as Nominal if specified, otherwise are Minimum

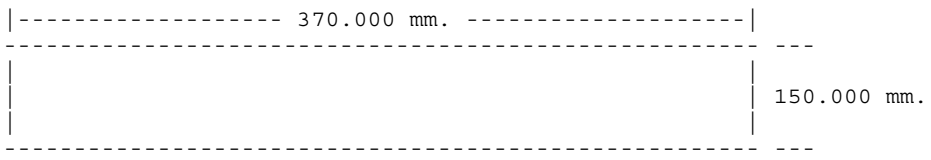
Saddle Parameters:

Saddle Width 140.000 mm.
Saddle Bearing Angle 120.000 deg.
Centerline Dimension 500.000 mm.
Wear Pad Width 200.000 mm.
Wear Pad Thickness 10.000 mm.
Wear Pad Bearing Angle 132.000 deg.
Distance from Saddle to Tangent 500.000 mm.

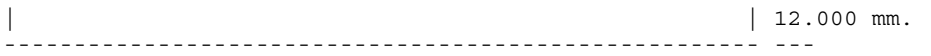
Baseplate Length 370.000 mm.

Baseplate Thickness	12.000	mm.
Baseplate Width	150.000	mm.
Number of Ribs (including outside ribs)	2	
Rib Thickness	10.000	mm.
Web Thickness	10.000	mm.
Height of Center Web	275.000	mm.
Number of Bolts in Baseplate	2	

Baseplate Sketch



Baseplate Plan View



Baseplate Side View

Summary of Maximum Saddle Loads, Operating Case :

Maximum Vertical Saddle Load	15.38	kN
Maximum Transverse Saddle Shear Load	1.36	kN
Maximum Longitudinal Saddle Shear Load	3.47	kN

Summary of Maximum Saddle Loads, Hydrotest Case :

Maximum Vertical Saddle Load	10.21	kN
Maximum Transverse Saddle Shear Load	0.18	kN
Maximum Longitudinal Saddle Shear Load	0.06	kN

Weights:

Fabricated - Bare W/O Removable Internals	1440.1	kg.
Shop Test - Fabricated + Water (Full)	1843.6	kg.
Shipping - Fab. + Rem. Intls.+ Shipping App.	1440.1	kg.
Erected - Fab. + Rem. Intls.+ Insul. (etc)	1440.1	kg.
Empty - Fab. + Intls. + Details + Wghts.	1440.1	kg.
Operating - Empty + Operating Liquid (No CA)	1819.3	kg.
Field Test - Empty Weight + Water (Full)	1734.8	kg.