	DEHDASHT PETROCHEMICAL INDUSTRY COMPANY DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT	
NARGAN	DOCUMENT TITLE: Mechanical Calculation for Condenser	POI: IFA
Contract No.: DPIC/98-12	DOCUMENT NUMBER: DPIC9812-000-VD-1002-ME-CLN-0093	Rev. No.: D1

Regarding last meeting with vendor, please revise calculation as per thermal calculation comment for considering 1.1x748000 for flowrate and duty of 1750 kw and please size all equipment inside package for mentioned design duty of chiller

DOCUMENT TITLE:

Mechanical Calculation for Condenser

(E-PK6101-2)

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-PK6101-2
4	RJ: Rejected	
5	NR: Not be Returned	Vendor Doc. No.: DPIC9812-000-VD-1002-ME-CLN-0093-D1
	Date: 06.03.2022 ignature: A.AB	

D1	06.Feb.2022	A.VOSOUGH	DR.A.NEJATI	DR.A.NEJATI
D0	23.Dec.21	A.VOSOUGH	DR.A.NEJATI	DR.A.NEJATI
REV	DATE ISSUE	PREPARED	CHECKED	APPROVED

KASRAVAND Engineering & Construction

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			

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			

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	x			
150	x	x			
151	x	x			
152	x	x			
153	x	x			
154	x	x			
155	x	x			
156	x	x			
157	x	x			
158	x	x			
159	x	x			
160	x	x			
161	x	x			
162	x				
163	x				
164	x				
165	x				
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:CONDENSER E-PK6101-2

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 6,2022    10:31pm

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:CONDENSER E-PK6101-2

Exchanger Design Pressures and Temperatures

Shell Side Design Pressure	23	bars
Channel Side Design Pressure	23	bars
Shell Side Design Temperature	125.0	°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		1.500	
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		2.500	
Site Class		C	
Component Elevation Ratio	z/h	1.000	
Amplification Factor	Ap	2.500	
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	1180	mm.
Element Thickness	13	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	15	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	23	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                     235.8  N./mm^2
    Material Density                              0.00775  kg./cm^3
    P Number Thickness                             29.997  mm.
    Yield Stress, Operating                         226.1  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                          1180  mm.
    Liquid Density                               0.000994  kg./cm^3

    Element From Node                                  10
    Detail Type                                Insulation
    Detail ID                                     Ins: 10
    Dist. from "FROM" Node / Offset dist             -295  mm.
    Height/Length of Insulation                       345  mm.
    Thickness of Insulation                            80  mm.
    Density                                       0.00012  kg./cm^3

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

Element From Node                                      20
Element To Node                                        30
Element Type                                     Cylinder
Description                                    CHANNEL 01
Distance "FROM" to "TO"                               749  mm.
Inside Diameter                                      1180  mm.
Element Thickness                                      15  mm.
Internal Corrosion Allowance                            3  mm.
Nominal Thickness                                      15  mm.
External Corrosion Allowance                            0  mm.
Design Internal Pressure                               23  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-516 70 [Normalized]
Efficiency, Longitudinal Seam                        0.85
Efficiency, Circumferential Seam                     0.85
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                          1180  mm.
    Liquid Density                               0.000994  kg./cm^3

    Element From Node                                  20
    Detail Type                                Insulation
    Detail ID                                     Ins: 20
```

Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	749	mm.
Thickness of Insulation	80	mm.
Density	0.00012	kg./cm^3

Element From Node	20	
Detail Type	Nozzle	
Detail ID	T1	
Dist. from "FROM" Node / Offset dist	375	mm.
Nozzle Diameter	12	in.
Nozzle Schedule	80	
Nozzle Class	300	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	1.6136	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6	[Impact Tested]

Element From Node	20	
Detail Type	Nozzle	
Detail ID	T2	
Dist. from "FROM" Node / Offset dist	375	mm.
Nozzle Diameter	12	in.
Nozzle Schedule	80	
Nozzle Class	300	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	1.6136	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-333 6	[Impact Tested]

Element From Node	30	
Element To Node	40	
Element Type	Flange	
Description	BODY FLANGE 01	
Distance "FROM" to "TO"	146	mm.
Flange Inside Diameter	1180	mm.
Element Thickness	110	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	79	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	23	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-350 LF2	[Impact Tested]
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	31.75	mm.
Yield Stress, Operating	214.16	N./mm^2
UCS-66 Chart Curve Designation	Impact Tested	
External Pressure Chart Name	CS-2	
UNS Number	K03011	
Class / Thickness / Grade 1::		
Product Form	Forgings	
Perform Flange Stress Calculation (Y/N)	Y	
Weight of 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                             1180  mm.
        Liquid Density                                  0.000994  kg./cm^3

        Element From Node                                     30
        Detail Type                                   Insulation
        Detail ID                                        Ins: 30
        Dist. from "FROM" Node / Offset dist                   0  mm.
        Height/Length of Insulation                          146  mm.
        Thickness of Insulation                               80  mm.
        Density                                          0.00012  kg./cm^3

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

    Element From Node                                         40
    Element To Node                                           50
    Element Type                                        Cylinder
    Description                                            SHELL
    Distance "FROM" to "TO"                                 4844  mm.
    Inside Diameter                                         1180  mm.
    Element Thickness                                         15  mm.
    Internal Corrosion Allowance                               3  mm.
    Nominal Thickness                                         15  mm.
    External Corrosion Allowance                               0  mm.
    Design Internal Pressure                                  23  bars
    Design Temperature Internal Pressure                     125  °C
    Design External Pressure                                 1.1  bars
    Design Temperature External Pressure                     125  °C
    Effective Diameter Multiplier                            1.2
    Material Name                                      SA-516 70 [Impact Tested]
        Allowable Stress, Ambient                          137.9  N./mm^2
        Allowable Stress, Operating                        137.9  N./mm^2
        Allowable Stress, Hydrotest                        235.8  N./mm^2
        Material Density                                 0.00775  kg./cm^3
        P Number Thickness                                29.997  mm.
        Yield Stress, Operating                            235.2  N./mm^2
        UCS-66 Chart Curve Designation             Impact Tested
        External Pressure Chart Name                        CS-2
        UNS Number                                        K02700
        Product Form                                       Plate
    Efficiency, Longitudinal Seam                            1.0
    Efficiency, Circumferential Seam                         1.0
    Weld is pre-Heated                                        No

        Element From Node                                     40
        Detail Type                                       Saddle
        Detail ID                                   FIXED SADDLE
        Dist. from "FROM" Node / Offset dist                 920  mm.
        Width of Saddle                                      172  mm.
        Height of Saddle at Bottom                           950  mm.
        Saddle Contact Angle                               120.0
        Height of Composite Ring Stiffener                     0  mm.
        Width of Wear Plate                                  305  mm.
        Thickness of Wear Plate                               15  mm.
        Contact Angle, Wear Plate (degrees)                132.0

        Element From Node                                     40
```

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for CONDENSER E-PK6101-2
Input Echo: Step: 1 10:31pm Feb 6,2022

```
Detail Type                                    Saddle
Detail ID                                     New Sdl
Dist. from "FROM" Node / Offset dist             3920  mm.
Width of Saddle                                   172  mm.
Height of Saddle at Bottom                        950  mm.
Saddle Contact Angle                            120.0
Height of Composite Ring Stiffener                  0  mm.
Width of Wear Plate                               305  mm.
Thickness of Wear Plate                            15  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                          1180  mm.
Liquid Density                               0.000468  kg./cm^3

Element From Node                                  40
Detail Type                                Insulation
Detail ID                                     Ins: 40
Dist. from "FROM" Node / Offset dist                0  mm.
Height/Length of Insulation                      4844  mm.
Thickness of Insulation                            80  mm.
Density                                       0.00012  kg./cm^3

Element From Node                                  40
Detail Type                                    Nozzle
Detail ID                                          S2
Dist. from "FROM" Node / Offset dist              265  mm.
Nozzle Diameter                                     8  in.
Nozzle Schedule                                    80
Nozzle Class                                      300
Layout Angle                                    270.0
Blind Flange (Y/N)                                  N
Weight of Nozzle ( Used if > 0 )               0.8717  kN
Grade of Attached Flange                       GR 1.1
Nozzle Matl                                 SA-333 6 [Impact Tested]

Element From Node                                  40
Detail Type                                    Nozzle
Detail ID                                          S1
Dist. from "FROM" Node / Offset dist             4480  mm.
Nozzle Diameter                                    12  in.
Nozzle Schedule                                    80
Nozzle Class                                      300
Layout Angle                                     90.0
Blind Flange (Y/N)                                  N
Weight of Nozzle ( Used if > 0 )               1.6205  kN
Grade of Attached Flange                       GR 1.1
Nozzle Matl                                 SA-333 6 [Impact Tested]

Element From Node                                  40
Detail Type                                    Nozzle
Detail ID                                          S3
Dist. from "FROM" Node / Offset dist              265  mm.
Nozzle Diameter                                     2  in.
Nozzle Schedule                                  None
Nozzle Class                                      300
Layout Angle                                     90.0
Blind Flange (Y/N)                                  N
Weight of Nozzle ( Used if > 0 )               0.1175  kN
Grade of Attached Flange                       GR 1.1
```

```
        Nozzle Matl                                   SA-350 LF2 [Impact Tested]

        Element From Node                                     40
        Detail Type                                       Weight
        Detail ID                                  WEIGHT BAFFLE
        Dist. from "FROM" Node / Offset dist                2422  mm.
        Miscellaneous Weight                              2.9418  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"                                  146  mm.
    Flange Inside Diameter                                  1180  mm.
    Element Thickness                                        110  mm.
    Internal Corrosion Allowance                               3  mm.
    Nominal Thickness                                         79  mm.
    External Corrosion Allowance                               0  mm.
    Design Internal Pressure                                  23  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-350 LF2 [Impact Tested]
        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                                 31.75  mm.
        Yield Stress, Operating                           214.16  N./mm^2
        UCS-66 Chart Curve Designation             Impact Tested
        External Pressure Chart Name                        CS-2
        UNS Number                                        K03011
        Class / Thickness / Grade     1::
        Product Form                                    Forgings
    Perform Flange Stress Calculation (Y/N)                    Y
    Weight of 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                             1180  mm.
        Liquid Density                                  0.000994  kg./cm^3

        Element From Node                                     50
        Detail Type                                   Insulation
        Detail ID                                        Ins: 50
        Dist. from "FROM" Node / Offset dist                   0  mm.
        Height/Length of Insulation                          146  mm.
        Thickness of Insulation                               80  mm.
        Density                                          0.00012  kg./cm^3

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

    Element From Node                                         60
    Element To Node                                           70
```

Element Type	Cylinder	
Description	CHANNEL 002	
Distance "FROM" to "TO"	299	mm.
Inside Diameter	1180	mm.
Element Thickness	15	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	15	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	23	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	235.8	N./mm^2
Material Density	0.00775	kg./cm^3
P Number Thickness	29.997	mm.
Yield Stress, Operating	226.1	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	
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	1180	mm.
Liquid Density	0.000994	kg./cm^3

Element From Node	60	
Detail Type	Insulation	
Detail ID	Ins: 60	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Insulation	299	mm.
Thickness of Insulation	80	mm.
Density	0.00012	kg./cm^3

Element From Node	60	
Detail Type	Nozzle	
Detail ID	T4	
Dist. from "FROM" Node / Offset dist	150	mm.
Nozzle Diameter	0.75	in.
Nozzle Schedule	None	
Nozzle Class	300	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.04826	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-350 LF2	[Impact Tested]

Element From Node	60	
Detail Type	Nozzle	
Detail ID	T3	
Dist. from "FROM" Node / Offset dist	150	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	300	


```
    Layout Angle                                     270.0
    Blind Flange (Y/N)                                   N
    Weight of Nozzle ( Used if > 0 )               0.05845  kN
    Grade of Attached Flange                        GR 1.1
    Nozzle Matl                                SA-350 LF2 [Impact Tested]

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

Element From Node                                       70
Element To Node                                         80
Element Type                                    Elliptical
Description                                       HEAD 002
Distance "FROM" to "TO"                                 50  mm.
Inside Diameter                                       1180  mm.
Element Thickness                                       13  mm.
Internal Corrosion Allowance                             3  mm.
Nominal Thickness                                       15  mm.
External Corrosion Allowance                             0  mm.
Design Internal Pressure                                23  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]
Efficiency, Longitudinal Seam                          1.0
Efficiency, Circumferential Seam                      0.85
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                           1180  mm.
    Liquid Density                                0.000994  kg./cm^3

    Element From Node                                   70
    Detail Type                                 Insulation
    Detail ID                                      Ins: 70
    Dist. from "FROM" Node / Offset dist                 0  mm.
    Height/Length of Insulation                        345  mm.
    Thickness of Insulation                             80  mm.
    Density                                        0.00012  kg./cm^3
```

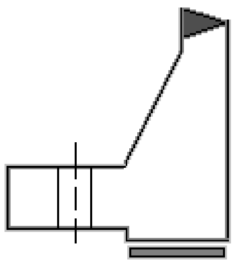

XY Coordinate Calculations:

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
	HEAD 1	50	...	50	...
	CHANNEL 01	799	...	749	...
	BODY FLANGE 01	945	...	146	...
	SHELL	5875.17	...	4844	...
	BODY FLANGE 002	6027.35	...	146	...
	CHANNEL 002	6406.35	...	299	...
	HEAD 002	6456.35	...	50	...

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

BODY FLANGE 01

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	23.12	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	1180.000	mm.
Flange Outside Diameter	A	1350.000	mm.
Flange Thickness	t	110.0000	mm.
Thickness of Hub at Small End	go	15.0000	mm.
Thickness of Hub at Large End	g1	27.0000	mm.
Length of Hub	h	36.0000	mm.
Flange Material		SA-350 LF2	
Flange Material UNS number		K03011	
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-320 L7	
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	1298.000	mm.
Nominal Bolt Diameter	a	22.2250	mm.
Type of Threads		UNC Thread Series	
Number of Bolts		76	
Flange Face Outside Diameter	Fod	1266.000	mm.
Flange Face Inside Diameter	Fid	1180.000	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	1263.000	mm.
Gasket Inside Diameter	Gi	1223.000	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	10.0000	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)
  = (23.12*(1180.0/2+3.0))/(137.9*1.0-0.6*23.12)+Ca
  = 13.0415 mm.
```

Hub Small End Hub MAWP:

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9 * 1.0 * 12.0)/(593.0 + 0.6 * 12.0 )
  = 27.569 bars
```

```
 Corroded Flange Thickness, tc = T-ci                     107.000  mm.
 Corroded Flange ID,      Bcor = B+2*Fcor                1186.000  mm.
 Corroded Large Hub,     g1Cor = g1-ci                     24.000  mm.
 Corroded Small Hub,     g0Cor = go-ci                     12.000  mm.
 Code R Dimension,           R = ((C-Bcor)/2)-g1cor        32.000  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              1247.063  mm.
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:

```
  = 0.785 * G² * Peq
  = 0.785 * 1247.0626² * 23.115
  = 2823.246 kN
```

Contact Load on Gasket Surfaces [Hp]:

```
  = 2 * b * Pi * G * m * P + 2 * lp * bPart * mPart * P
  = 2 * 7.9687 * 3.1416 * 1247.0626 * 3.78 * 23.12
    + 2.0 * 1078.0 * 5.0 * 3.75 * 23.115
  = 638.983 kN
```

Hydrostatic End Load at Flange ID [Hd]:

```
  = Pi * Bcor² * P  / 4
  = 3.1416 * 1186.0² *23.115/4
  = 2553.534 kN
```

Pressure Force on Flange Face [Ht]:

```
  = H - Hd
  = 2823 - 2554
  = 269.713 kN
```

Operating Bolt Load [Wm1]:

```
  = max( H + Hp + H'p, 0 )
  = max( 2823 + 639 + 0, 0 )
  = 3462.229 kN
```

Gasket Seating Bolt Load [Wm2]:

```
  = y * b * Pi * G  + yPart * bPart * lp
  = 62.05*7.9687*3.141*1247.063+62.05*5.0*1078.0
  = 2271.524 kN
```

Required Bolt Area [Am]:

```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 3462/172, 2272/172
  = 200.872 cm^2
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:

```
  = 2a + 6t/(m + 0.5)
  = 2 * 22.225 + 6 * 107.0/(3.78 + 0.5)
  = 194.450 mm.
```

Actual Circumferential Bolt Spacing [Bs]:

```
  = C * sin( pi / n )
  = 1298.0 * sin( 3.142/76 )
```


= 53.640 mm.

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
= max(sqrt(Bs/(2a + t)), 1)
= max(sqrt(53.64/(2 * 22.225 + 107.0)), 1)
= 1.0000

Bolting Information for UNC Thread Series (Non Mandatory):

	Minimum	Actual	Maximum
Bolt Area, cm^2	200.872	205.445	
Radial Distance between Hub and Bolts:	31.750	32.000	
Radial Distance between Bolts and the Ed	23.812	26.000	
Circumferential Spacing between the Bolt	52.400	53.640	194.450

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
= Ab * Sa/(y * Pi * (Go + Gi))
= 205.445 * 172.38/(62.05 * 3.14 * (1263.0 + 1223.0))
= 7.307 mm.

Note: Recommended Min. Width for Sheet and Composite Gaskets per table 2-4 :
= 32.000 mm.[Note: Exceeds actual gasket width, 20.000]

Flange Design Bolt Load, Gasket Seating [W]:
= Sa * (Am + Ab) / 2
= 172.38 * (200.8716 + 205.4447)/2
= 3501.64 kN

Gasket Load for the Operating Condition [HG]:
= Wm1 - H
= 3462 - 2823
= 638.98 kN

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
= (C - G) / 2
= (1298.0 - 1247.0626)/2
= 25.4687 mm.

Distance to Face Pressure Reaction [ht]:
= (R + g1 + hg) / 2
= (32.0 + 24.0 + 25.4687)/2
= 40.7344 mm.

Distance to End Pressure Reaction [hd]:
= R + (g1 / 2)
= 32.0 + (24.0/2.0)
= 44.0000 mm.

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

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	2554.	44.0000	1.0000	112401.
Face Pressure,	Mt	270.	40.7344	1.0000	10991.
Gasket Load,	Mg	639.	25.4687	1.0000	16281.
Gasket Seating,	Matm	3502.	25.4687	1.0000	89218.

Total Moment for Operation, Mop 139673. N-m
Total Moment for Gasket seating, Matm 89218. N-m

Effective Hub Length, ho = sqrt(Bcor*goCor) 119.298 mm.
Hub Ratio, h/h0 = HL / H0 0.302

```
 Thickness Ratio,   g1/g0 = (g1Cor/goCor)              2.000
```

Flange Factors for Integral Flange:

```
 Factor F                                              0.870
 Factor V                                              0.302
 Factor f                                              2.068
 Factors from Figure 2-7.1                   K =       1.138
                    T =      1.863           U =      16.510
                    Y =     15.024           Z =       7.764
                    d = 0.94014E+06 mm.³      e =      0.0073 mm.^-1
 Stress Factors                          ALPHA =       1.780
                 BETA =      2.040       GAMMA =       0.955
                DELTA =      1.303       Lamda =       2.259
```

Longitudinal Hub Stress, Operating [SHo]:

```
  = ( f * Mop / Bcor ) / ( L * g1² )
  = (2.0679*139673/1186.0)/(2.2585*24.0²)
  = 187.14 N./mm^2
```

Longitudinal Hub Stress, Seating [SHa]:

```
  = ( f * Matm / Bcor ) / ( L * g1² )
  = (2.0679*89218/1186.0)/(2.2585*24.0²)
  = 119.54 N./mm^2
```

Radial Flange Stress, Operating [SRo]:

```
  = ( Beta * Mop / Bcor ) / ( L * t² )
  = (2.0403*139673/1186.0)/(2.2585*107.0²)
  = 9.29 N./mm^2
```

Radial Flange Stress, Seating [SRa]:

```
  = ( Beta * Matm/Bcor ) / ( L * t² )
  = (2.0403*89218/1186.0)/(2.2585*107.0²)
  = 5.93 N./mm^2
```

Tangential Flange Stress, Operating [STo]:

```
  = ( Y * Mo / (t² * Bcor) ) - Z * SRo
  = (15.0244*139673/(107.0²*1186.0))-7.764*9
  = 82.37 N./mm^2
```

Tangential Flange Stress, Seating [STa]:

```
  = ( y * Matm / (t² * Bcor) ) - Z * SRa
  = (15.0244*89218/(107.0²*1186.0))-7.764*6
  = 52.62 N./mm^2
```

Average Flange Stress, Operating [SAo]:

```
  = ( SHo + max( SRo, STo ) ) / 2
  = (187+max(9,82))/2
  = 134.76 N./mm^2
```

Average Flange Stress, Seating [SAa]:

```
  = ( SHa + max( SRa, STa ) ) / 2
  = (120+max(6,53))/2
  = 86.08 N./mm^2
```

Bolt Stress, Operating [BSo]:

```
  = Wm1 / Ab
  = 3462/205.4447
  = 168.54 N./mm^2
```

Bolt Stress, Seating [BSa]:

```
  = ( Wm2 / Ab )
  = (2272/205.4447)
  = 110.58 N./mm^2
```

Flange Stress Analysis Results: N./mm^2

```
                                 Operating |      Gasket Seating |
```


	Actual	Allowed	Actual	Allowed
Longitudinal Hub	187.	207.	120.	207.
Radial Flange	9.	138.	6.	138.
Tangential Flange	82.	138.	53.	138.
Maximum Average	135.	138.	86.	138.
Bolting	169.	172.	111.	172.

```
Minimum Required Flange Thickness [Rigidity]          108.737  mm.
Estimated M.A.W.P. ( Operating )                        23.641  bars
Estimated Finished Weight of Flange at given Thk.        310.1  kg.
Estimated Unfinished Weight of Forging at given Thk      382.2  kg.
```

Flange Rigidity Based on Required Thickness [ASME]:

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

$= 52.14 * Ma / Bsc * Cnv\_fac * V / (Lambda * Eamb * go^2 * ho * Ki)$
$= 52.14 * 89218.4/1.0 * 999.68 * 0.302/(2.207 * 202713 * 12.0^2 * 119.298 * 0.3)$
$= 0.608$ (should be <= 1)

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

$= 52.14 * Mo / Bsc * Cnv\_fac * V / (Lambda * Eop * goc^2 * ho * Ki)$
$= 52.14 * 139672.8/1.0 * 999.68 * 0.302/(2.207 * 193088 * 12.0^2 * 119.298 * 0.3)$
$= 1.000$ (should be <= 1)

Flange Rigidity Based on Given Thickness [ASME]:

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

$= 52.14 * Ma / Bsc * Cnv\_fac * V / (Lambda * Eamb * go^2 * ho * Ki)$
$= 52.14 * 89218.4/1.0 * 999.68 * 0.302/(2.259 * 202713 * 12.0^2 * 119.298 * 0.3)$
$= 0.595$ (should be <= 1)

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

$= 52.14 * Mo / Bsc * Cnv\_fac * V / (Lambda * Eop * goc^2 * ho * Ki)$
$= 52.14 * 139672.8/1.0 * 999.68 * 0.302/(2.259 * 193088 * 12.0^2 * 119.298 * 0.3)$
$= 0.977$ (should be <= 1)

Minimum Design Metal Temperature Results:

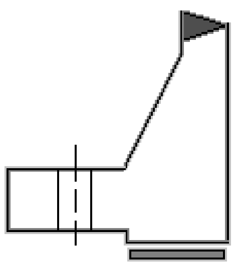
Note:
This Material was specified as being an Impact Tested (Low Temperature) Material.

Impact Test Temperature provided per Specification -46 °C

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

BODY FLANGE 002

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	23.12	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	1180.000	mm.
Flange Outside Diameter	A	1346.000	mm.
Flange Thickness	t	110.0000	mm.
Thickness of Hub at Small End	go	15.0000	mm.
Thickness of Hub at Large End	g1	27.0000	mm.
Length of Hub	h	36.0000	mm.
Flange Material		SA-350 LF2	
Flange Material UNS number		K03011	
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-320 L7	
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	1298.000	mm.
Nominal Bolt Diameter	a	22.2250	mm.
Type of Threads		UNC Thread Series	
Number of Bolts		76	
Flange Face Outside Diameter	Fod	1266.000	mm.
Flange Face Inside Diameter	Fid	1180.000	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	1263.000	mm.
Gasket Inside Diameter	Gi	1223.000	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	10.0000	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)
  = (23.12*(1180.0/2+3.0))/(137.9*1.0-0.6*23.12)+Ca
  = 13.0415 mm.
```

Hub Small End Hub MAWP:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9 * 1.0 * 12.0)/(593.0 + 0.6 * 12.0 )
  = 27.569 bars
```

```
 Corroded Flange Thickness, tc = T-ci                     107.000  mm.
 Corroded Flange ID,      Bcor = B+2*Fcor                1186.000  mm.
 Corroded Large Hub,     g1Cor = g1-ci                     24.000  mm.
 Corroded Small Hub,     g0Cor = go-ci                     12.000  mm.
 Code R Dimension,           R = ((C-Bcor)/2)-g1cor        32.000  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              1247.063  mm.
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.785 * 1247.0626² * 23.115
  = 2823.246 kN
```
Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * Pi * G * m * P + 2 * lp * bPart * mPart * P
  = 2 * 7.9687 * 3.1416 * 1247.0626 * 3.78 * 23.12
    + 2.0 * 1078.0 * 5.0 * 3.75 * 23.115
  = 638.983 kN
```
Hydrostatic End Load at Flange ID [Hd]:
```
  = Pi * Bcor² * P  / 4
  = 3.1416 * 1186.0² *23.115/4
  = 2553.534 kN
```
Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 2823 - 2554
  = 269.713 kN
```
Operating Bolt Load [Wm1]:
```
  = max( H + Hp + H'p, 0 )
  = max( 2823 + 639 + 0, 0 )
  = 3462.229 kN
```
Gasket Seating Bolt Load [Wm2]:
```
  = y * b * Pi * G  + yPart * bPart * lp
  = 62.05*7.9687*3.141*1247.063+62.05*5.0*1078.0
  = 2271.524 kN
```
Required Bolt Area [Am]:
```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 3462/172, 2272/172
  = 200.872 cm^2
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
```
  = 2a + 6t/(m + 0.5)
  = 2 * 22.225 + 6 * 107.0/(3.78 + 0.5)
  = 194.450 mm.
```

Actual Circumferential Bolt Spacing [Bs]:
```
  = C * sin( pi / n )
  = 1298.0 * sin( 3.142/76 )
```


= 53.640 mm.

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
= max(sqrt(Bs/(2a + t)), 1)
= max(sqrt(53.64/(2 * 22.225 + 107.0)), 1)
= 1.0000

Bolting Information for UNC Thread Series (Non Mandatory):

	Minimum	Actual	Maximum
Bolt Area, cm^2	200.872	205.445	
Radial Distance between Hub and Bolts:	31.750	32.000	
Radial Distance between Bolts and the Ed	23.812	24.000	
Circumferential Spacing between the Bolt	52.400	53.640	194.450

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
= Ab * Sa/(y * Pi * (Go + Gi))
= 205.445 * 172.38/(62.05 * 3.14 * (1263.0 + 1223.0))
= 7.307 mm.

Note: Recommended Min. Width for Sheet and Composite Gaskets per table 2-4 :
= 32.000 mm.[Note: Exceeds actual gasket width, 20.000]

Flange Design Bolt Load, Gasket Seating [W]:
= Sa * (Am + Ab) / 2
= 172.38 * (200.8716 + 205.4447)/2
= 3501.64 kN

Gasket Load for the Operating Condition [HG]:
= Wm1 - H
= 3462 - 2823
= 638.98 kN

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
= (C - G) / 2
= (1298.0 - 1247.0626)/2
= 25.4687 mm.

Distance to Face Pressure Reaction [ht]:
= (R + g1 + hg) / 2
= (32.0 + 24.0 + 25.4687)/2
= 40.7344 mm.

Distance to End Pressure Reaction [hd]:
= R + (g1 / 2)
= 32.0 + (24.0/2.0)
= 44.0000 mm.

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

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	2554.	44.0000	1.0000	112401.
Face Pressure,	Mt	270.	40.7344	1.0000	10991.
Gasket Load,	Mg	639.	25.4687	1.0000	16281.
Gasket Seating,	Matm	3502.	25.4687	1.0000	89218.

Total Moment for Operation, Mop 139673. N-m
Total Moment for Gasket seating, Matm 89218. N-m

Effective Hub Length, ho = sqrt(Bcor*goCor) 119.298 mm.
Hub Ratio, h/h0 = HL / H0 0.302

```
 Thickness Ratio,   g1/g0 = (g1Cor/goCor)              2.000
```

Flange Factors for Integral Flange:

```
 Factor F                                              0.870
 Factor V                                              0.302
 Factor f                                              2.068
 Factors from Figure 2-7.1                   K =       1.135
                    T =      1.864           U =      16.891
                    Y =     15.370           Z =       7.944
                    d = 0.96179E+06 mm.³       e =     0.0073 mm.^-1
 Stress Factors                          ALPHA =       1.780
                 BETA =      2.040       GAMMA =       0.955
                DELTA =      1.274       Lamda =       2.229
```

Longitudinal Hub Stress, Operating [SHo]:

```
  = ( f * Mop / Bcor ) / ( L * g1² )
  = (2.0679*139673/1186.0)/(2.2286*24.0²)
  = 189.66 N./mm^2
```

Longitudinal Hub Stress, Seating [SHa]:

```
  = ( f * Matm / Bcor ) / ( L * g1² )
  = (2.0679*89218/1186.0)/(2.2286*24.0²)
  = 121.15 N./mm^2
```

Radial Flange Stress, Operating [SRo]:

```
  = ( Beta * Mop / Bcor ) / ( L * t² )
  = (2.0403*139673/1186.0)/(2.2286*107.0²)
  = 9.41 N./mm^2
```

Radial Flange Stress, Seating [SRa]:

```
  = ( Beta * Matm/Bcor ) / ( L * t² )
  = (2.0403*89218/1186.0)/(2.2286*107.0²)
  = 6.01 N./mm^2
```

Tangential Flange Stress, Operating [STo]:

```
  = ( Y * Mo / (t² * Bcor) ) - Z * SRo
  = (15.3704*139673/(107.0²*1186.0))-7.9441*9
  = 83.27 N./mm^2
```

Tangential Flange Stress, Seating [STa]:

```
  = ( y * Matm / (t² * Bcor) ) - Z * SRa
  = (15.3704*89218/(107.0²*1186.0))-7.9441*6
  = 53.19 N./mm^2
```

Average Flange Stress, Operating [SAo]:

```
  = ( SHo + max( SRo, STo ) ) / 2
  = (190+max(9,83))/2
  = 136.46 N./mm^2
```

Average Flange Stress, Seating [SAa]:

```
  = ( SHa + max( SRa, STa ) ) / 2
  = (121+max(6,53))/2
  = 87.17 N./mm^2
```

Bolt Stress, Operating [BSo]:

```
  = Wm1 / Ab
  = 3462/205.4447
  = 168.54 N./mm^2
```

Bolt Stress, Seating [BSa]:

```
  = ( Wm2 / Ab )
  = (2272/205.4447)
  = 110.58 N./mm^2
```

Flange Stress Analysis Results: N./mm^2

```
                                  Operating |       Gasket Seating |
```

	Actual	Allowed	Actual	Allowed
Longitudinal Hub	190.	207.	121.	207.
Radial Flange	9.	138.	6.	138.
Tangential Flange	83.	138.	53.	138.
Maximum Average	136.	138.	87.	138.
Bolting	169.	172.	111.	172.

```
Minimum Required Flange Thickness [Rigidity]          109.474  mm.
Estimated M.A.W.P. ( Operating )                       23.339  bars
Estimated Finished Weight of Flange at given Thk.       302.9  kg.
Estimated Unfinished Weight of Forging at given Thk     372.7  kg.
```

Flange Rigidity Based on Required Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
= 52.14 * Ma / Bsc * Cnv_fac * V / (Lambda * Eamb * go² * ho * Ki)
= 52.14 * 89218.4/1.0 * 999.68 * 0.302/(2.207 * 202713 * 12.0² * 119.298 * 0.3)
= 0.608 (should be <= 1)

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:
= 52.14 * Mo / Bsc * Cnv_fac * V / (Lambda * Eop * goc² * ho * Ki)
= 52.14 * 139672.8/1.0 * 999.68 * 0.302/(2.207 * 193088 * 12.0² * 119.298 * 0.3)
= 1.000 (should be <= 1)

Flange Rigidity Based on Given Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
= 52.14 * Ma / Bsc * Cnv_fac * V / (Lambda * Eamb * go² * ho * Ki)
= 52.14 * 89218.4/1.0 * 999.68 * 0.302/(2.229 * 202713 * 12.0² * 119.298 * 0.3)
= 0.603 (should be <= 1)

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:
= 52.14 * Mo / Bsc * Cnv_fac * V / (Lambda * Eop * goc² * ho * Ki)
= 52.14 * 139672.8/1.0 * 999.68 * 0.302/(2.229 * 193088 * 12.0² * 119.298 * 0.3)
= 0.990 (should be <= 1)

Minimum Design Metal Temperature Results:

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

Impact Test Temperature provided per Specification -46 °C

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for CONDENSER E-PK6101-2
Internal Pressure Calculations: Step: 5 10:31pm Feb 6,2022

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		23.115	15	3	1180	137.9
CHANNEL 01		23.115	15	3	1180	117.21
BODY FLANGE 01		23.115	79	3	1180	137.9
SHELL		23.054	15	3	1180	137.9
BODY FLANGE 002		23.115	79	3	1180	137.9
CHANNEL 002		23.115	15	3	1180	137.9
HEAD 002		23.115	15	3	1180	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		23	No Calc	No Calc	13	12.8907
CHANNEL 01		23	No Calc	No Calc	15	14.8349
BODY FLANGE 01		23	No Calc	No Calc	110	108.737
SHELL		23	No Calc	No Calc	15	13.0149
BODY FLANGE 002		23	No Calc	No Calc	110	109.474
CHANNEL 002		23	No Calc	No Calc	15	13.0417
HEAD 002		23	No Calc	No Calc	13	12.8907

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      =    40.431 bars
Shell Side MAPnc     =    51.100 bars
Channel Side  MAWP   =    23.641 bars
Channel Side  MAPnc  =    23.641 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)

```
 = (23.115*1186.0*0.993)/(2*137.9*1.0-0.2*23.115)
 = 9.8907 + 3.0000 = 12.8907 mm.
```

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

```
 = (P*(Kcor*D+0.2*t))/(2*E*t)
 = (23.115*(0.993*1186.0+0.2*10.0))/(2*1.0*10.0)
 = 136.395 N./mm^2
```

Straight Flange Required Thickness:

```
 = (P*R)/(S*E-0.6*P) + c    per UG-27 (c)(1)
 = (23.115*593.0)/(137.9*1.0-0.6*23.115)+3.0
 = 13.042 mm.
```

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.115 bars

```
 = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
 = (137.9 * 1.0 * 12.0)/(593.0 + 0.6 * 12.0 )
 = 27.569 - 0.115 = 27.454  bars
```

Factor K, corroded condition [Kcor]:

```
 = ( 2 + ( Inside Diameter/( 2 * Inside Head Depth ))²)/6
 = ( 2 + ( 1186.0/( 2 * 298.0 ))²)/6
 = 0.993306
```

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 5.406 %
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 13.0, tr = 9.891, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.989, Temp. Reduction = 1 °C

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

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 15.0, tr = 10.042, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.837, Temp. Reduction = 9 °C

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

Cylindrical Shell From 20 To 30 SA-516 70 , UCS-66 Crv. D at 120 °C

CHANNEL 01

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
 = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
 = (23.115*593.0)/(137.9*0.85-0.6*23.115)
 = 11.8349 + 3.0000 = 14.8349 mm.
```

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

```
 = (P*(R+0.6*t))/(E*t)
 = (23.115*(593.0+0.6*12.0))/(0.85*12.0)
 = 136.026 N./mm^2
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.255 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 15.0, tr = 11.835, c = 3.0 mm., E* = 0.85
Thickness Ratio = tr * (E*)/(tg - c) = 0.838, Temp. Reduction = 9 °C

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

Cylindrical Shell From 40 To 50 SA-516 70 at 125 °C

SHELL

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (23.054*593.0)/(137.9*1.0-0.6*23.054)
  = 10.0149 + 3.0000 = 13.0149 mm.
```

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

```
  = (P*(R+0.6*t))/(E*t)
  = (23.054*(593.0+0.6*12.0))/(1.0*12.0)
  = 115.317 N./mm^2
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.255 %

Minimum Design Metal Temperature Results:

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

Cylindrical Shell From 60 To 70 SA-516 70 , UCS-66 Crv. D at 190 °C

CHANNEL 002

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (23.115*593.0)/(137.9*1.0-0.6*23.115)
  = 10.0417 + 3.0000 = 13.0417 mm.
```

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

```
  = (P*(R+0.6*t))/(E*t)
  = (23.115*(593.0+0.6*12.0))/(1.0*12.0)
  = 115.622 N./mm^2
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.255 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 15.0, tr = 10.042, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.837, Temp. Reduction = 9 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D          -47 °C
 Min Metal Temp. at Required thickness (UCS 66.1)        -48 °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)
  = (23.115*1186.0*0.993)/(2*137.9*1.0-0.2*23.115)
  = 9.8907 + 3.0000 = 12.8907 mm.
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(Kcor*D+0.2*t))/(2*E*t)
  = (23.115*(0.993*1186.0+0.2*10.0))/(2*1.0*10.0)
  = 136.395 N./mm^2
```

Straight Flange Required Thickness:
```
  = (P*R)/(S*E-0.6*P) + c    per UG-27 (c)(1)
  = (23.115*593.0)/(137.9*1.0-0.6*23.115)+3.0
  = 13.042 mm.
```

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.115 bars
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9 * 1.0 * 12.0)/(593.0 + 0.6 * 12.0 )
  = 27.569 - 0.115 = 27.454  bars
```

Factor K, corroded condition [Kcor]:
```
  = ( 2 + ( Inside Diameter/( 2 * Inside Head Depth ))²)/6
  = ( 2 + ( 1186.0/( 2 * 298.0 ))²)/6
  = 0.993306
```

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 5.406 %
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 13.0, tr = 9.891, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.989, Temp. Reduction = 1 °C

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

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 15.0, tr = 10.042, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.837, Temp. Reduction = 9 °C

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

Hydrostatic Test Pressure Results:

Exchanger Shell Side Hydrostatic Test Pressures:

```
 Pressure per UG99b      = 1.30 * M.A.W.P. * Sa/S         52.560  bars
 Pressure per UG99b[36]  = 1.30 * Design Pres * Sa/S      29.900  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         44.474  bars
 Pressure per PED        = max(1.43*DP, 1.25*DP*ratio)    32.775  bars
 Pressure per App 27-4   = 1.30 * M.A.W.P. * Sa/S         52.560  bars
```

Exchanger Channel Side Hydrostatic Test Pressures:

```
 Pressure per UG99b      = 1.30 * M.A.W.P. * Sa/S         30.734  bars
```

Internal Pressure Calculations: Step: 5 10:31pm Feb 6,2022

Pressure per UG99b[36]	= 1.30 * Design Pres * Sa/S	29.900	bars
Pressure per UG99c	= 1.30 * M.A.P. - Head(Hyd)	30.618	bars
Pressure per UG100	= 1.10 * M.A.W.P. * Sa/S	26.006	bars
Pressure per PED	= max(1.43*DP, 1.25*DP*ratio)	32.775	bars
Pressure per App 27-4	= 1.30 * M.A.W.P. * Sa/S	30.734	bars

UG-99(b) Note 36, Test Pressure Calculation [Shell Side]:
= Test Factor * Design Pressure * Stress Ratio
= 1.3 * 23.0 * 1.0
= 29.900 bars

UG-99(b) Note 36, Test Pressure Calculation [Channel Side]:
= Test Factor * Design Pressure * Stress Ratio
= 1.3 * 23.0 * 1.0
= 29.900 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	177.1	235.8	0.751	30.02
CHANNEL 01	176.6	235.8	0.749	30.02
SHELL	150.1	235.8	0.637	30.02
CHANNEL 002	150.1	235.8	0.637	30.02
HEAD 002	177.1	235.8	0.751	30.02

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

Description	Pad/Nozzle	Ambient	Operating	Ratio
T1	Nozzle	117.90	117.90	1.000
T1	Pad	137.90	137.90	1.000
T2	Nozzle	117.90	117.90	1.000
T2	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	137.90	137.90	1.000
BODY FLANGE 01	137.90	137.90	1.000
SHELL	137.90	137.90	1.000
BODY FLANGE 002	137.90	137.90	1.000
CHANNEL 002	137.90	137.90	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	117.90	117.90	1.000
Tubesheet Material	137.90	137.90	1.000
Minimum			1.000

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

Description	Ambient	Operating	Ratio
T1	38.42	217.19	0.177
T2	38.42	217.19	0.177
S2	39.33	217.19	0.181
S1	38.42	217.19	0.177
S3	8.07	223.40	0.036
T4	5.14	223.40	0.023
T3	5.97	223.40	0.027

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	1206	10	0.0011516	82.603
20	30	897.333	1210	12	0.0018252	101.647
30	40	No Calc	...	107	No Calc	No Calc
40	50	4844	1210	12	0.00030147	30.1399
50	60	No Calc	...	107	No Calc	No Calc
60	70	447.333	1210	12	0.0039525	106.227
70	80	No Calc	1206	10	0.0011516	82.603

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	13	6.26226	1.1	7.60993
20	30	15	6.49927	1.1	13.4402
30	40	110	69.7738	1.1	No Calc
40	50	15	10.0794	1.1	3.98521
50	60	110	70.2056	1.1	No Calc
60	70	15	5.65111	1.1	14.0457
70	80	13	6.26226	1.1	7.60993
Minimum					3.985

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	897.333	19354.8	No Calc	No Calc
30	40	No Calc	No Calc	No Calc	No Calc
40	50	4844	102403	No Calc	No Calc
50	60	No Calc	No Calc	No Calc	No Calc
60	70	447.333	9164.93	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
10.000	1206.00	120.60	0.0011516	82.60

```
 EMAP = B/(K0*D/t) = 82.603/( 0.9 *120.6 ) = 7.6099 bars
```

Results for Required Thickness (Tca):

```
      Tca          OD          D/t     Factor A           B
    3.262     1206.00       369.68    0.0003757        36.60
 EMAP = B/(K0*D/t) = 36.6032/( 0.9 *369.6828 ) = 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*1186.0*0.993)/(2*137.9*1.0-0.2*1.837)
  = 0.7848 + 3.0000 = 3.7848 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*10.0)/(0.993*1186.0+0.2*10.0))/1.67
  = 13.994 bars
```

Maximum Allowable External Pressure [MAEP]:

```
  = min( MAEP, MAWP )
  = min( 7.61, 13.9942 )
  = 7.610 bars
```

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

Cylindrical Shell From 20 to 30 Ext. Chart: CS-2 at 120 °C

CHANNEL 01

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
   12.000     1210.00      897.33      100.83      0.7416   0.0018252     101.65
 EMAP = (4*B)/(3*(D/t)) = (4*101.6474)/(3*100.8333) = 13.4402 bars
```

Results for Required Thickness (Tca):

```
      Tca          OD        SLEN         D/t         L/D    Factor A          B
    3.499     1210.00      897.33      345.79      0.7416   0.0002854      28.53
 EMAP = (4*B)/(3*(D/t)) = (4*28.5301)/(3*345.7867) = 1.1 bars
```

Results for Maximum Stiffened Length (Slen):

```
      Tca          OD        SLEN         D/t         L/D    Factor A          B
   12.000     1210.00    19354.77      100.83     15.9957   0.0001115      11.15
 EMAP = (4*B)/(3*(D/t)) = (4*11.1462)/(3*100.8333) = 1.4738 bars
```

Cylindrical Shell From 40 to 50 Ext. Chart: CS-2 at 125 °C

SHELL

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

Results for Maximum Allowable External Pressure (MAEP):

```
      Tca          OD        SLEN         D/t         L/D    Factor A          B
   12.000     1210.00     4844.00      100.83      4.0033   0.0003015      30.14
 EMAP = (4*B)/(3*(D/t)) = (4*30.1399)/(3*100.8333) = 3.9852 bars
```

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
7.079	1210.00	4844.00	170.92	4.0033	0.0001411	14.10

EMAP = (4*B)/(3*(D/t)) = (4*14.1022)/(3*170.9189) = 1.1 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
12.000	1210.00	102403.33	100.83	50.0000	0.0001084	10.84

EMAP = (4*B)/(3*(D/t)) = (4*10.841)/(3*100.8333) = 1.4334 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
12.000	1210.00	447.33	100.83	0.3697	0.0039525	106.23

EMAP = (4*B)/(3*(D/t)) = (4*106.2269)/(3*100.8333) = 14.0457 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
2.651	1210.00	447.33	456.41	0.3697	0.0003865	37.66

EMAP = (4*B)/(3*(D/t)) = (4*37.658)/(3*456.4122) = 1.1001 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
12.000	1210.00	9164.93	100.83	7.5743	0.0001492	14.54

EMAP = (4*B)/(3*(D/t)) = (4*14.5391)/(3*100.8333) = 1.9224 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
10.000	1206.00	120.60	0.0011516	82.60

EMAP = B/(K0*D/t) = 82.603/(0.9 *120.6) = 7.6099 bars

Results for Required Thickness (Tca):

Tca	OD	D/t	Factor A	B
3.262	1206.00	369.68	0.0003757	36.60

EMAP = B/(K0*D/t) = 36.6032/(0.9 *369.6828) = 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*1186.0*0.993)/(2*137.9*1.0-0.2*1.837)
= 0.7848 + 3.0000 = 3.7848 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*10.0)/(0.993*1186.0+0.2*10.0))/1.67

```
  = 13.994 bars
```

Maximum Allowable External Pressure [MAEP]:

```
  = min( MAEP, MAWP )
  = min( 7.61, 13.9942 )
  = 7.610 bars
```

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

Element and Detail Weights:

From	To	Element Metal Wgt. kg.	Element ID Volume Cm3	Corroded Metal Wgt. kg.	Corroded ID Volume Cm3	Extra due Misc % kg.
10	20	220.523	269800	176.418	273656	11.0261
20	30	326.905	819244	262.18	827597	16.3452
30	40	310.101	160919	297.484	161321	15.505
40	50	2114.19	2809912	1695.59	2863930	105.709
50	60	302.88	160919	290.263	161321	15.144
60	70	130.5	327042	104.662	330376	6.525
70	80	220.523	269800	176.418	273656	11.0261
Total		3625	4817636.00	3003	4891856.00	181

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	268.112	-98.3333	-0.00004	1
10	Insl	22.6473	-122.5	...	Ins: 10
20	Liqd	814.119	374.5	...	2
20	Insl	29.1379	374.5	...	Ins: 20
20	Nozl	172.777	375	751.925	T1
20	Nozl	172.777	375	751.925	T2
30	Liqd	159.912	73	...	3
30	Insl	4.20609	73	...	Ins: 30
40	Sadl	203.713	920	755	FIXED SADDLE
40	Sadl	203.713	3920	755	New Sdl
40	Liqd	1314.7	2422	...	4
40	Insl	188.443	2422	...	Ins: 40
40	Nozl	93.335	265	699.537	S2
40	Nozl	173.514	4480	751.925	S1
40	Nozl	12.585	265	615.4	S3
40	Wght	300	2422	...	WEIGHT BAFFLE
50	Liqd	159.912	73	...	5
50	Insl	4.10815	73	...	Ins: 50
60	Liqd	324.995	149.5	...	5
60	Insl	11.6318	149.5	...	Ins: 60
60	Nozl	5.16718	150	599.525	T4
60	Nozl	6.25877	150	602.7	T3
70	Liqd	268.112	148.333	-0.00004	6
70	Insl	22.6473	172.5	...	Ins: 70
30	FTsh	597.512	192	...	TUBE SHEET
30	Tube	8226.77	2652	...	
30	RTsh	597.512	5112	...	

Total Weight of Each Detail Type

Total Weight of Saddles	407.4
Total Weight of Liquid	3309.9
Total Weight of Insulation	282.8
Total Weight of Nozzles	636.4
Total Weight of Weights	300.0

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for CONDENSER E-PK6101-2
Element and Detail Weights: Step: 7 10:31pm Feb 6,2022

```
 Total Weight of Exchanger Components              9421.8
 Total Weight of Liquid in Tubes                   1089.5
 ---------------------------------------------------------------
 Sum of the Detail Weights                        15447.8 kg.
```

Weight Summation: kg.

Fabricated	Shop Test	Shipping	Erected	Empty	Operating
3806.9	14572.5	3806.9	14572.5	3806.9	14855.3
407.4	4814.7	407.4	...	407.4	3309.9
636.4	...	636.4	...	...	...
...	1556.5	...	282.8	...	...
...	...	...	...	282.8	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	636.4	1089.5
9421.8	...	9421.8	...	...	...
300.0	...	300.0	...	...	...
...	...	...	...	9421.8	...
...	...	...	...	300.0	...
14572.5	20943.7	14572.5	14855.3	14855.3	19254.7

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       14572.5 kg.
 Shop Test Wt.    - Fabricated Weight + Water ( Full )        20943.7 kg.
 Shipping Wt.     - Fab. Wt + Rem. Intls.+ Shipping App.      14572.5 kg.
 Erected  Wt.     - Fab. Wt + Rem. Intls.+ Insul. (etc)       14855.3 kg.
 Ope. Wt. no Liq  - Fab. Wt + Intls. + Details + Wghts.       14855.3 kg.
 Operating Wt.    - Empty Wt + Operating Liq. Uncorroded      19254.7 kg.
 Oper. Wt. + CA   - Corr Wt. + Operating Liquid               18601.0 kg.
 Field Test Wt.   - Empty Weight + Water (Full)               20647.0 kg.
```

Exchanger Tube Data

```
 Volume of Exchanger tubes   :                   1557431.8 Cm3
 Weight of Ope Liq in tubes  :                      1089.5 kg.
 Weight of Water in tubes    :                      1556.5 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	17771.3
20	30	28471.9
30	40	9438.89
40	50	184136

50	60	9340.36
60	70	11366
70	80	17771.3

Total 278296.031 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
T1	46.0	51.1	120	300	GR 1.1	...	...	...	...
T2	46.0	51.1	120	300	GR 1.1	...	...	...	...
S2	45.8	51.1	125	300	GR 1.1	...	...	...	...
S1	45.8	51.1	125	300	GR 1.1	...	...	...	...
S3	45.8	51.1	125	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]: 45.850 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*0.836)/(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] 0.570
Structure Height to Diameter ratio                  5.196
```

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
  = 950.0 + 123000. = 123950. mm.
  = 406.66 ft. Imperial Units
```

Velocity Pressure coefficient evaluated at height z [Kz]:

Because z (406.66 ft.) > 15 ft.

$= 2.01 * (z / Zg)^{2 / Alpha}$

$= 2.01 * (406.66/900.0)^{2/9.5}$

= 1.7

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]:
$= max(16, 0.00256 * Kz * Kzt * Kd * V(mph)^2)$
$= max(16, 0.00256 * 1.7 * 1.0 * 0.95 * 124.278^2)$
= 63.9 psf [311.856] Kgs/m^2

Force on the first element [F]:
= qz * G * Cf * WindArea
= 63.872 * 0.85 * 0.57 * 5.363
= 165.9 lbs. [0.7] kN

Element	Hgt (z) mm.	K1	K2	K3	Kz	Kzt	qz Kgs/m^2
HEAD 1	*******	0.000	0.000	0.000	1.700	1.000	311.856
CHANNEL 01	*******	0.000	0.000	0.000	1.700	1.000	311.856
BODY FLANGE 01	*******	0.000	0.000	0.000	1.700	1.000	311.856
SHELL	*******	0.000	0.000	0.000	1.700	1.000	311.856
BODY FLANGE 002	*******	0.000	0.000	0.000	1.700	1.000	311.856
CHANNEL 002	*******	0.000	0.000	0.000	1.700	1.000	311.856
HEAD 002	*******	0.000	0.000	0.000	1.700	1.000	311.856

Wind Loads on Masses/Equipment/Piping

ID	Wind Area cm^2	Elevation mm.	Pressure Kgs/m^2	Force kN
WEIGHT BAFFLE	0.00	125422.01	311.86	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	123950	1639.2	4982.27	311.856	0.44286
20	30	123950	1644	12313.6	311.856	1.09451
30	40	123950	1608	2347.68	311.856	0.20868
40	50	123950	1644	79635.4	311.856	7.07852
50	60	123950	1608	2347.68	311.856	0.20868
60	70	123950	1644	4915.56	311.856	0.43693
70	80	123950	1639.2	4982.27	311.856	0.44286

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

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

Earthquake Load Calculation:

Input Values:

Seismic Design Code		ASCE 7-2010
Seismic Load Reduction Scale Factor		0.700
Importance Factor		1.500
Table Value Fa		1.000
Table Value Fv		1.300
Short Period Acceleration value Ss		0.900
Long Period Acceleration Value Sl		0.537
Moment Reduction Factor Tau		1.000
Force Modification Factor R		2.500
Site Class		C
Component Elevation Ratio	z/h	1.000
Amplification Factor	Ap	2.500
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 * ($5.0525^{0.75}$)
= 0.067 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 * 0.067, 0.03 ) per 12.8.2
= 0.030
```

Compute the Seismic Force per equation 13.3-1, [Fp]:

```
= 0.4 * Ap * Sds * W * ( 1 + 2*(z/h) ) / ( R / Ie )
= 0.4 * 2.5 * 0.624 * 182 * ( 1 + 2*1.0 )/( 2.5/1.5 )
= 204.873 kN
```

Check the Maximum value of Fp per equation 13.3-2:

```
= 1.6 * Sds * I * W
= 1.6 * 0.624 * 1.5 * 182 = 273.16 kN
```

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for CONDENSER E-PK6101-2
Earthquake Load Calculation: Step: 10 10:31pm Feb 6,2022

Check the Minimum value of Fp per equation 13.3-3:
 = 0.3 * 0.62 * 1.5 * 182
 = 51.218 kN

Compute the Total Base Shear V = Fp, [V]:
 = 204.873 kN

Vertical load per 12.4-4, [YEq]:
 = 0.2 * Sds * W
 = 0.2 * 0.624 * 182 = 22.76 kN

Final Base Shear, V = 143.41 kN
Final Vertical Load, YEq = 15.93 kN

Earthquake Load Calculation:

From	To	Earthquake Height mm.	Earthquake Weight kN	Element Ope Load kN
10	20	590	20.2668	15.9346
20	30	590	20.2668	15.9346
30	40	590	20.2668	15.9346
40	Sadl	590	20.2668	15.9346
Sadl	50	590	20.2668	15.9346
40	50	590	20.2668	15.9346
50	60	590	20.2668	15.9346
60	70	590	20.2668	15.9346
70	80	590	20.2668	15.9346

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

Shop/Field Installation Options :

Insulation is installed in the Field.

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

Center of Gravity of Saddles	3451.175 mm.
Center of Gravity of Liquid	2943.195 mm.
Center of Gravity of Insulation	3218.363 mm.
Center of Gravity of Nozzles	2061.410 mm.
Center of Gravity of Added Weights (Operating)	3453.175 mm.
Center of Gravity of Added Weights (Empty)	3453.175 mm.
Center of Gravity of Tubesheet(s)	3451.000 mm.
Center of Gravity of Tubes	3451.000 mm.
Center of Gravity of Bare Shell New and Cold	3241.814 mm.
Center of Gravity of Bare Shell Corroded	3246.094 mm.
Vessel CG in the Operating Condition	3274.865 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition	3335.716 mm.
Vessel CG in the Test Condition	3290.232 mm.

Warning: CG of Vessel is too near or Outside the Lift Points!

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

Input and Calculated Values:

```
Vessel Mean Radius                          Rm       599.00  mm.
Stiffened Vessel Length per 4.15.6           L      4844.00  mm.
Distance from Saddle to Vessel tangent       a       992.00  mm.

Saddle Width                                 b       172.00  mm.
Saddle Bearing Angle                     theta       120.00  degrees

Wear Plate Width                            b1       305.00  mm.
Wear Plate Bearing Angle                theta1       132.00  degrees
Wear Plate Thickness                        tr         15.0  mm.
Wear Plate Allowable Stress                 Sr       137.90  N./mm^2

Shell Allowable Stress used in Calculation           137.90  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                       304.87  kN
```

Horizontal Vessel Analysis Results:	Actual N./mm^2	Allowable N./mm^2
Long. Stress at Top of Midspan	51.70	137.90
Long. Stress at Bottom of Midspan	63.25	137.90
Long. Stress at Top of Saddles	92.60	137.90
Long. Stress at Bottom of Saddles	38.01	137.90
Tangential Shear in Shell	29.32	110.32
Circ. Stress at Horn of Saddle	42.43	172.37
Circ. Compressive Stress in Shell	6.35	137.90

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:

```
= Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
= 3.0 * ( 9.9/2 + 0 ) * 950.0/1037.4984
= 13.6 kN
```

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

```
= max( Fl, Friction Load, Sum of X Forces) * B / Ls
= max( 2.53, 0.0, 0 ) * 950.0/3000.0
= 0.8 kN
```

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

```
= max( Fl, Friction Force, Sum of X Forces ) * B / Ls
= max( 143.41, 0.0, 0 ) * 950.0/3000.0
= 45.4 kN
```

Saddle Reaction Force due to Earthquake Ft [Fst]:

```
= Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
= 3.0 * ( 143/2 + 0 ) * 950.0/1037.4984
= 197.0 kN
```

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

```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 108 + Max( 0.8, 14, 45, 197 )
  = 304.9 kN
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	306.86	kN
Transverse Shear Load Saddle	71.71	kN
Longitudinal Shear Load Saddle	143.41	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	K6p = 0.0434
K7p = 0.0434			

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

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

Moment per Equation 4.15.3 [M1]:

```
  = -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -305*992.0[1-(1-992.0/4844.0+(599.0²-0.0²)/
    (2*992.0*4844.0))/(1+(4*0.0)/(3*4844.0))]
  = -50663.4 N-m
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 305*4844/4(1+2(599²-0²)/(4844²))/(1+(4*0)/
    (3*4844))-4*992/4844
  = 78087.9 N-m
```

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

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 23.027 * 599.0/(2*12.0) - 78087.9/(pi*599.0²*12.0)
  = 51.70 N./mm^2
```

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

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 23.027 * 599.0/(2 * 12.0) + 78087.9/(pi * 599.0² * 12.0 )
  = 63.25 N./mm^2
```

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

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 23.027*599.0/(2*12.0)--50663.4/(0.1066*pi*599.0²*12.0)
  = 92.60 N./mm^2
```

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

```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 23.027*599.0/(2*12.0)+-50663.4/(0.1923*pi*599.0²*12.0)
  = 38.01 N./mm^2
```

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

```
  = Q(L-2a)/(L+(4*h2/3))
  = 305( 4844.0 - 2 * 992.0)/(4844.0 + ( 4 * 0.0/3))
  = 180.0 kN
```

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

```
  = K2 * T / ( Rm * t )
  = 1.1707 * 180.0/( 599.0 * 12.0 )
  = 29.32 N./mm^2
```

Decay Length (4.15.22) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 599.0 * 12.0 )
  = 66.130 mm.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 305 * 0.1/( 12.0 * ( 172.0 + 66.13 + 66.13 ) )
  = -6.35 N./mm^2
```

Effective reinforcing plate width (4.15.1) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 172.0 + 1.56 * sqrt( 599.0 * 12.0 ), 2 * 992.0 )
  = 304.26 mm.
```

Wear Plate/Shell Stress ratio (4.15.29) [eta]:
```
  = min( Sr/S, 1 )
  = min( 137.9/137.9, 1 )
  = 1.0000
```

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [sigma6,r]:
```
  = -K5 * Q * k / ( B1( t + eta * tr ) )
  = - 0.7603 * 305 * 0.1/( 304.26( 12.0 + 1.0 * 15.0 ) )
  = -2.82 N./mm^2
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.27) [sigma7,r]:
```
  = -Q/(4(t+eta*tr)b1) - 3*K7*Q/(2(t+eta*tr)²)
  = -305/(4(12.0 + 1.0 * 15.0)304.26) -
     3 * 0.053 * 305/(2(12.0 + 1.0 * 15.0)²)
  = -42.43 N./mm^2
```

Free Un-Restrained Thermal Expansion between the Saddles [Exp]:
```
  = Alpha * Ls * ( Design Temperature - Ambient Temperature )
  = 0.000012 * 3000.0 * ( 125.0 - 21.1 )
  = 3.822 mm.
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1050.0000	mm.
Baseplate Thickness	Bpthk	20.0000	mm.
Baseplate Width	Bpwid	220.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	15.0000	mm.
Web Thickness	Webtk	15.0000	mm.
Web Location	Webloc	Center	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	437.	12.	6.	52.	31435.	25.1
Wearplate	305.	15.	20.	46.	89212.	183.
Web	15.	310.	182.	47.	846300.	0.191E+05
BasePlate	220.	20.	347.	44.	1526800.	0.530E+05
Totals	...	...	...	189.	2493748.	0.723E+05

```
Value  C1 = Sumof(Ay)/Sumof(A)          =     132.      mm.
Value   I = Sumof(Io) - C1*Sumof(Ay)    =    0.394E+05  cm**4
Value  As = Sumof(A) - Ashell           =     136.      cm^2
```

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

Fh = K1 * Q = 0.2035 * 304.865 = 62.0467 kN

Tension Stress, St = ( Fh/As )        =         4.5543  N./mm^2
Allowed Stress, Sa = 0.6 * Yield Str =       124.1100  N./mm^2
```

Saddle Splitting Dimension [d]:

```
  = B - R * sin( theta )/ theta
  = 950.0 - 593.0 * sin( 1.0472 )/1.0472
  = 459.593 mm.

Bending Moment, M  = Fh * d          =     28527.7695  N-m

Bending Stress, Sb = ( M * C1 / I  ) =         9.5776  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 / ( 4 * BasePlateLength * AllStress ))½
  = ( 3(305 + 2)220.0/( 4 * 1050.0 * 137.9 ))½
  = 18.701 mm.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 1079.0676/( 4 - 1 )
  = 359.689 mm.
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 359.6892 * 220.0/2
  = 395.658 cm^2
```

Axial Load [P]:

```
  = Ap * Bp
  = 395.7 * 0.13
  = 52.217 kN
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 23.55 + 26.977
  = 50.527 cm^2
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 52.2/50.5267
  = 10.336 N./mm^2
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	15.0	172.0	...	25.8	...	636.

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * rl / 2
  = 143.4/( 2 * 1050.0 ) * 359.689 * 619.79/2
  = 7615.189 N-m
```

Compressive Allowable, KL/R < Cc (17.4685 < 138.1347) per AISC E2-1 [Sca]:

```
  = (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 17.47 )²/(2 * 138.13² )) * 207/
    ( 5/3+3*(17.47)/(8* 138.13)-( 17.47³)/(8*138.13³)
  = 119.729 N./mm^2
```

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

```
  = Sc/Sca + ( Rm * Distance Side/I )/Sba
  = 10.34/119.73 + ( 7615.19 * 86.0/6360561 )/137.9
  = 0.833
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	15.0	157.0	0.0	23.6	0.0	636.
Web	359.7	15.0	0.0	54.0	0.0	10.1
Values	...	...	...	77.5	...	646.

```
 Compressive Allowable, KL/R < Cc ( 11.5546 < 138.1347 ) per AISC E2-1 [Sca]:
  = (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 11.55 )²/(2 * 138.13² )) * 207/
    ( 5/3+3*(11.55)/(8* 138.13)-( 11.55³)/(8*138.13³)
  = 121.396 N./mm^2
```

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

```
  = Sc/Sca + ( Rm * Distance Center/I )/Sba
  = 12.91/121.4 + ( 8195.84 * 86.0/645.75 )/137.9
  = 0.898
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	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	24.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	3.1275	cm^2
Saddle Load QO (Weight)	QO	109.9	kN
Saddle Load QL (Wind/Seismic contribution)	QL	45.4	kN
Maximum Transverse Force	Ft	71.7	kN
Maximum Longitudinal Force	Fl	143.4	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)
  = 143.41/(172.38 * 4.0)
  = 2.0801 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
  = B * Ft + Sum of X Moments
```

```
  = 950.0 * 71.71 + 0.0
  = 68148.02 N-m
```

Eccentricity (e):

```
  = Rmom / QO
  = 68148.02/109.89
  = 619.91 mm. > Bplen/6 --> Uplift in Transverse direction

 f = Bplen / 2 - Edgedis
   = 1050.0/2 - 85.0
   = 440.00 mm.

 K1 = 3 (e - 0.5 * Bplen)
    = 3 (619.91 - 0.5*1050.0)
    = 284.73 mm.

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 1.0 * 6.25/220.0 * (440.0 + 619.91)
    = 18080.96 mm.²

 K3 = -K2 * (0.5 * Bplen + f)
    = -18080.96 * (0.5 * 1050.0 + 440.0)
    = -17448129.25 mm.³
```

Iteratively Solving for the Effective Bearing Length:

```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + 284.73 * Y² + 18080.96 * Y + -0.2E+08 = 0
 Y  = 175.97 mm.

 Num = (Bplen / 2 - Y / 3 - e)
     = (1050.0/2 - 175.97/3 - 619.91)
     = -153.57

 Denom = (Bplen / 2 - Y / 3 + f)
       = (1050.0/2 - 175.97/3 + 440.0)
       = 906.34
```

Total Bolt Tension Force [Tforce]:

```
  = - QO * Num / Denom
  = - 109.89 * -153.57/906.34
  = 18.62 kN
```

Bolt Area Required due to Transverse Load [Bltareart]:

```
  = Tforce / (Stba * Nbt)
  = 18.62/( 172.38 * 2.0 )
  = 0.5401 cm^2
```

Required Area of a Single Bolt [Bltarear]:

```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0.0, 2.0801, 0.5401]
  = 2.0801 cm^2
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)

```
  = 2(QO + Tforce) / (Y * Bpwid)
  = 2(109.89 + 18.62)/(175.97 * 220.0)
  = 66.39 bars
```

Distance from Baseplate Edge to the Web [ADIST]:

```
  = (Bplen - Weblngth) / 2
```

```
  = (1050.0 - 999.2)/2
  = 25.4000 mm.
```

Overturning Moment due To Bolt Tension [Mt]:

```
  = Tforce * Adist
  = 18.62 * 25.4
  = 473.11 N-m
```

Equivalent Bearing Pressure (f1):

```
  = fc * (Y - Adist) / Y
  = 66.39 * (175.97 - 25.4)/175.97
  = 56.81 bars
```

Overturning Moment due to Bearing Pressure [Mc]:

```
  = (Adist² * Bpwid / 6) * (f1 + 2 * fc)
  = (25.4² * 220.0/6) * (56.81 + 2 * 66.39)
  = 448.65 N-m
```

Baseplate Required Thickness [Treq]:

```
  = (6 * max(Mt,Mc) / (Bpwid * Sba))½
  = (6 *max(473.11,448.65/(220.0 * 162.38))½
  = 8.9128 mm.
```

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

Input and Calculated Values:

```
 Vessel Mean Radius                             Rm      599.00  mm.
 Stiffened Vessel Length per 4.15.6              L     4844.00  mm.
 Distance from Saddle to Vessel tangent          a      346.00  mm.

 Saddle Width                                    b      172.00  mm.
 Saddle Bearing Angle                        theta      120.00  degrees

 Wear Plate Width                               b1      305.00  mm.
 Wear Plate Bearing Angle                   theta1      132.00  degrees
 Wear Plate Thickness                           tr        15.0  mm.
 Wear Plate Allowable Stress                    Sr      137.90  N./mm^2

 Shell Allowable Stress used in Calculation             137.90  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                         283.43  kN

 Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                         N./mm^2 |      N./mm^2 |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan         38.57 |       137.90 |
 Long. Stress at Bottom of Midspan         76.38 |       137.90 |
 Long. Stress at Top    of Saddles         55.05 |       137.90 |
 Long. Stress at Bottom of Saddles         58.82 |       137.90 |
 ----------------------------------------------------------------
 Tangential Shear in Shell                 39.57 |       110.32 |
 Circ. Stress at Horn of Saddle            19.92 |       172.37 |
 Circ. Compressive Stress in Shell          5.90 |       137.90 |
 ----------------------------------------------------------------
```

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:
```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0 * ( 9.9/2 + 0 ) * 950.0/1037.4984
  = 13.6 kN
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 2.53, 0.0, 0 ) * 950.0/3000.0
  = 0.8 kN
```

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:
```
  = max( Fl, Friction Force, Sum of X Forces ) * B / Ls
  = max( 143.41, 0.0, 0 ) * 950.0/3000.0
  = 45.4 kN
```

Saddle Reaction Force due to Earthquake Ft [Fst]:
```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0 * ( 143/2 + 0 ) * 950.0/1037.4984
  = 197.0 kN
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 86 + Max( 0.8, 14, 45, 197 )
  = 283.4 kN
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	285.42	kN
Transverse Shear Load Saddle	71.71	kN
Longitudinal Shear Load Saddle	143.41	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 = 0.0194	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	K6p = 0.0434
K7p = 0.0159			

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

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

Moment per Equation 4.15.3 [M1]:
```
  = -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -283*346.0[1-(1-346.0/4844.0+(599.0²-0.0²)/
    (2*346.0*4844.0))/(1+(4*0.0)/(3*4844.0))]
  = 3493.6 N-m
```

Moment per Equation 4.15.4 [M2]:
```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 283*4844/4(1+2(599²-0²)/(4844²))/(1+(4*0)/
    (3*4844))-4*346/4844
  = 255763.7 N-m
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 23.027 * 599.0/(2*12.0) - 255763.7/(pi*599.0²*12.0)
  = 38.57 N./mm^2
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 23.027 * 599.0/(2 * 12.0) + 255763.7/(pi * 599.0² * 12.0 )
  = 76.38 N./mm^2
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 23.027*599.0/(2*12.0)-3493.6/(0.1066*pi*599.0²*12.0)
  = 55.05 N./mm^2
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 23.027*599.0/(2*12.0)+3493.6/(0.1923*pi*599.0²*12.0)
  = 58.82 N./mm^2
```

Maximum Shear Force in the Saddle (4.15.5) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 283( 4844.0 - 2 * 346.0)/(4844.0 + ( 4 * 0.0/3))
  = 242.9 kN
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 242.94/( 599.0 * 12.0 )
  = 39.57 N./mm^2
```

Decay Length (4.15.22) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 599.0 * 12.0 )
  = 66.130 mm.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 283 * 0.1/( 12.0 * ( 172.0 + 66.13 + 66.13 ) )
  = -5.90 N./mm^2
```

Effective reinforcing plate width (4.15.1) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 172.0 + 1.56 * sqrt( 599.0 * 12.0 ), 2 * 346.0 )
  = 304.26 mm.
```

Wear Plate/Shell Stress ratio (4.15.29) [eta]:
```
  = min( Sr/S, 1 )
  = min( 137.9/137.9, 1 )
  = 1.0000
```

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [sigma6,r]:
```
  = -K5 * Q * k / ( B1( t + eta * tr ) )
  = - 0.7603 * 283 * 0.1/( 304.26( 12.0 + 1.0 * 15.0 ) )
  = -2.62 N./mm^2
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.27) [sigma7,r]:
```
  = -Q/(4(t+eta*tr)b1) - 3*K7*Q/(2(t+eta*tr)²)
  = -283/(4(12.0 + 1.0 * 15.0)304.26) -
     3 * 0.019 * 283/(2(12.0 + 1.0 * 15.0)²)
  = -19.92 N./mm^2
```

Results for Vessel Ribs, Web and Base

Baseplate Length	Bplen	1050.0000	mm.
Baseplate Thickness	Bpthk	20.0000	mm.
Baseplate Width	Bpwid	220.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	

```
Rib Thickness                        Ribtk          15.0000  mm.
Web Thickness                        Webtk          15.0000  mm.
Web Location                        Webloc           Center
```

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	437.	12.	6.	52.	31435.	25.1
Wearplate	305.	15.	20.	46.	89212.	183.
Web	15.	310.	182.	47.	846300.	0.191E+05
BasePlate	220.	20.	347.	44.	1526800.	0.530E+05
Totals	...	...	...	189.	2493748.	0.723E+05

```
Value  C1 = Sumof(Ay)/Sumof(A)            =     132.      mm.
Value   I = Sumof(Io) - C1*Sumof(Ay)      =    0.394E+05  cm**4
Value  As = Sumof(A) - Ashell             =     136.      cm^2

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

Fh = K1 * Q = 0.2035 * 283.426 = 57.6833 kN

Tension Stress, St = ( Fh/As )       =          4.2340  N./mm^2
Allowed Stress, Sa = 0.6 * Yield Str =        124.1100  N./mm^2
```

Saddle Splitting Dimension [d]:

```
  = B - R * sin( theta )/ theta
  = 950.0 - 593.0 * sin( 1.0472 )/1.0472
  = 459.593 mm.

Bending Moment, M  = Fh * d          =      26521.5703  N-m

Bending Stress, Sb = ( M * C1 / I  ) =          8.9041  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 / ( 4 * BasePlateLength * AllStress ))½
  = ( 3(283 + 2)220.0/( 4 * 1050.0 * 137.9 ))½
  = 18.036 mm.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 1079.0676/( 4 - 1 )
  = 359.689 mm.
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 359.6892 * 220.0/2
  = 395.658 cm^2
```

Axial Load [P]:

```
  = Ap * Bp
  = 395.7 * 0.12
  = 48.545 kN
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 23.55 + 26.977
  = 50.527 cm^2
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 48.5/50.5267
  = 9.609 N./mm^2
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	15.0	172.0	...	25.8	...	636.

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * rl / 2
  = 143.4/( 2 * 1050.0 ) * 359.689 * 619.79/2
  = 7615.189 N-m
```

Compressive Allowable, KL/R < Cc (17.4685 < 138.1347) per AISC E2-1 [Sca]:

```
  = (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 17.47 )²/(2 * 138.13² )) * 207/
    ( 5/3+3*(17.47)/(8* 138.13)-( 17.47³)/(8*138.13³)
  = 119.729 N./mm^2
```

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

```
  = Sc/Sca + ( Rm * Distance Side/I )/Sba
  = 9.61/119.73 + ( 7615.19 * 86.0/6360561 )/137.9
  = 0.827
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	15.0	157.0	0.0	23.6	0.0	636.
Web	359.7	15.0	0.0	54.0	0.0	10.1
Values	...	...	...	77.5	...	646.

```
 Compressive Allowable, KL/R < Cc ( 11.5546 < 138.1347 ) per AISC E2-1 [Sca]:
  = (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 11.55 )²/(2 * 138.13² )) * 207/
    ( 5/3+3*(11.55)/(8* 138.13)-( 11.55³)/(8*138.13³)
  = 121.396 N./mm^2
```

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

```
  = Sc/Sca + ( Rm * Distance Center/I )/Sba
  = 12.0/121.4 + ( 8195.84 * 86.0/645.75 )/137.9
  = 0.890
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	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	24.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	3.1275	cm^2
Saddle Load QO (Weight)	QO	88.4	kN
Saddle Load QL (Wind/Seismic contribution)	QL	45.4	kN
Maximum Transverse Force	Ft	71.7	kN

```
Maximum Longitudinal Force                        Fl       143.4  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)
  = 143.41/(172.38 * 4.0)
  = 2.0801 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
  = B * Ft + Sum of X Moments
  = 950.0 * 71.71 + 0.0
  = 68148.02 N-m
```

Eccentricity (e):

```
  = Rmom / QO
  = 68148.02/88.45
  = 770.17 mm. > Bplen/6 --> Uplift in Transverse direction

 f = Bplen / 2 - Edgedis
   = 1050.0/2 - 85.0
   = 440.00 mm.

 K1 = 3 (e - 0.5 * Bplen)
    = 3 (770.17 - 0.5*1050.0)
    = 735.52 mm.

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 1.0 * 6.25/220.0 * (440.0 + 770.17)
    = 20644.30 mm.²

 K3 = -K2 * (0.5 * Bplen + f)
    = -20644.3 * (0.5 * 1050.0 + 440.0)
    = -19921745.99 mm.³
```

Iteratively Solving for the Effective Bearing Length:

```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + 735.52 * Y² + 20644.3 * Y + -0.2E+08 = 0
 Y  = 139.55 mm.

 Num = (Bplen / 2 - Y / 3 - e)
     = (1050.0/2 - 139.55/3 - 770.17)
     = -291.69

 Denom = (Bplen / 2 - Y / 3 + f)
       = (1050.0/2 - 139.55/3 + 440.0)
       = 918.48
```

Total Bolt Tension Force [Tforce]:

```
  = - QO * Num / Denom
  = - 88.45 * -291.69/918.48
  = 28.09 kN
```

Bolt Area Required due to Transverse Load [Bltareart]:

```
  = Tforce / (Stba * Nbt)
  = 28.09/( 172.38 * 2.0 )
```



```
  = 0.8148 cm^2
```

Required Area of a Single Bolt [Bltarear]:

```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0.0, 2.0801, 0.8148]
  = 2.0801 cm^2
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)

```
  = 2(QO + Tforce) / (Y * Bpwid)
  = 2(88.45 + 28.09)/(139.55 * 220.0)
  = 75.92 bars
```

Distance from Baseplate Edge to the Web [ADIST]:

```
  = (Bplen - Weblngth) / 2
  = (1050.0 - 999.2)/2
  = 25.4000 mm.
```

Overturning Moment due To Bolt Tension [Mt]:

```
  = Tforce * Adist
  = 28.09 * 25.4
  = 713.75 N-m
```

Equivalent Bearing Pressure (f1):

```
  = fc * (Y - Adist) / Y
  = 75.92 * (139.55 - 25.4)/139.55
  = 62.10 bars
```

Overturning Moment due to Bearing Pressure [Mc]:

```
  = (Adist² * Bpwid / 6) * (f1 + 2 * fc)
  = (25.4² * 220.0/6) * (62.1 + 2 * 75.92)
  = 506.29 N-m
```

Baseplate Required Thickness [Treq]:

```
  = (6 * max(Mt,Mc) / (Bpwid * Sba))½
  = (6 *max(713.75,506.29/(220.0 * 162.38))½
  = 10.9472 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

Input and Calculated Values:

Vessel Mean Radius	Rm	599.00	mm.
Stiffened Vessel Length per 4.15.6	L	4844.00	mm.
Distance from Saddle to Vessel tangent	a	992.00	mm.
Saddle Width	b	172.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	305.00	mm.
Wear Plate Bearing Angle	theta1	132.00	degrees
Wear Plate Thickness	tr	15.0	mm.
Wear Plate Allowable Stress	Sr	137.90	N./mm^2
Shell Allowable Stress used in Calculation		235.81	N./mm^2
Head Allowable Stress used in Calculation		235.81	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		114.43	kN

Horizontal Vessel Analysis Results:	Actual N./mm^2	Allowable N./mm^2
Long. Stress at Top of Midspan	72.61	235.81
Long. Stress at Bottom of Midspan	76.94	235.81
Long. Stress at Top of Saddles	87.96	235.81
Long. Stress at Bottom of Saddles	67.47	235.81
Tangential Shear in Shell	11.00	188.65
Circ. Stress at Horn of Saddle	15.93	353.71
Circ. Compressive Stress in Shell	2.38	235.81

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:
```
= Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
= 3.0 * ( 2.0/2 + 0 ) * 950.0/1037.4984
= 2.7 kN
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
= max( Fl, Friction Load, Sum of X Forces) * B / Ls
= max( 0.51, 0.0, 0 ) * 950.0/3000.0
= 0.2 kN
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
= Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
= 112 + Max( 0.2, 3, 0, 0 )
= 114.4 kN
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	116.43	kN
Transverse Shear Load Saddle	0.99	kN
Longitudinal Shear Load Saddle	0.51	kN

Hydrostatic Test Pressure at center of Vessel: 29.959 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     K6p = 0.0434
K7p = 0.0434
```

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

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

Moment per Equation 4.15.3 [M1]:
```
  = -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -114*992.0[1-(1-992.0/4844.0+(599.0²-0.0²)/
    (2*992.0*4844.0))/(1+(4*0.0)/(3*4844.0))]
  = -19016.3 N-m
```

Moment per Equation 4.15.4 [M2]:
```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 114*4844/4(1+2(599²-0²)/(4844²))/(1+(4*0)/
    (3*4844))-4*992/4844
  = 29310.1 N-m
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 29.959 * 599.0/(2*12.0) - 29310.1/(pi*599.0²*12.0)
  = 72.61 N./mm^2
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 29.959 * 599.0/(2 * 12.0) + 29310.1/(pi * 599.0² * 12.0 )
  = 76.94 N./mm^2
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 29.959*599.0/(2*12.0)--19016.3/(0.1066*pi*599.0²*12.0)
  = 87.96 N./mm^2
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 29.959*599.0/(2*12.0)+-19016.3/(0.1923*pi*599.0²*12.0)
  = 67.47 N./mm^2
```

Maximum Shear Force in the Saddle (4.15.5) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 114( 4844.0 - 2 * 992.0)/(4844.0 + ( 4 * 0.0/3))
  = 67.6 kN
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 67.56/( 599.0 * 12.0 )
  = 11.00 N./mm^2
```

Decay Length (4.15.22) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 599.0 * 12.0 )
  = 66.130 mm.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
= -K5 * Q * k / ( t * ( b + X1 + X2 ) )
= - 0.7603 * 114 * 0.1/( 12.0 * ( 172.0 + 66.13 + 66.13 ) )
= -2.38 N./mm^2
```

Effective reinforcing plate width (4.15.1) [B1]:
```
= min( b + 1.56 * sqrt( Rm * t ), 2a  )
= min( 172.0 + 1.56 * sqrt( 599.0 * 12.0 ), 2 * 992.0 )
= 304.26 mm.
```

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

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [sigma6,r]:
```
= -K5 * Q * k / ( B1( t + eta * tr ) )
= - 0.7603 * 114 * 0.1/( 304.26( 12.0 + 1.0 * 15.0 ) )
= -1.06 N./mm^2
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.27) [sigma7,r]:
```
= -Q/(4(t+eta*tr)b1) - 3*K7*Q/(2(t+eta*tr)²)
= -114/(4(12.0 + 1.0 * 15.0)304.26) -
   3 * 0.053 * 114/(2(12.0 + 1.0 * 15.0)²)
= -15.93 N./mm^2
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1050.0000	mm.
Baseplate Thickness	Bpthk	20.0000	mm.
Baseplate Width	Bpwid	220.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	15.0000	mm.
Web Thickness	Webtk	15.0000	mm.
Web Location	Webloc	Center	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	437.	12.	6.	52.	31435.	25.1
Wearplate	305.	15.	20.	46.	89212.	183.
Web	15.	310.	182.	47.	846300.	0.191E+05
BasePlate	220.	20.	347.	44.	1526800.	0.530E+05
Totals	...	...	...	189.	2493748.	0.723E+05

```
Value  C1 = Sumof(Ay)/Sumof(A)          =     132.      mm.
Value   I = Sumof(Io) - C1*Sumof(Ay)    =    0.394E+05  cm**4
Value  As = Sumof(A) - Ashell           =     136.      cm^2

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

Fh = K1 * Q = 0.2035 * 114.43 = 23.289 kN

Tension Stress, St = ( Fh/As )       =         1.7094  N./mm^2
Allowed Stress, Sa = 0.6 * Yield Str =       124.1100  N./mm^2
```

Saddle Splitting Dimension [d]:
```
= B - R * sin( theta )/ theta
= 950.0 - 593.0 * sin( 1.0472 )/1.0472
= 459.593 mm.
```

```
Bending Moment, M  = Fh * d          =      10707.8164  N-m
```

```
 Bending Stress, Sb = ( M * C1 / I  ) =          3.5949  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 / ( 4 * BasePlateLength * AllStress ))½
  = ( 3(114 + 2)220.0/( 4 * 1050.0 * 137.9 ))½
  = 11.519 mm.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 1079.0676/( 4 - 1 )
  = 359.689 mm.
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 359.6892 * 220.0/2
  = 395.658 cm^2
```

Axial Load [P]:

```
  = Ap * Bp
  = 395.7 * 0.05
  = 19.600 kN
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 23.55 + 26.977
  = 50.527 cm^2
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 19.6/50.5267
  = 3.879 N./mm^2
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	15.0	172.0	...	25.8	...	636.

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * rl / 2
  = 0.5/( 2 * 1050.0 ) * 359.689 * 619.79/2
  = 26.889 N-m
```

Compressive Allowable, KL/R < Cc (17.4685 < 138.1347) per AISC E2-1 [Sca]:

```
  = (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 17.47 )²/(2 * 138.13² )) * 207/
    ( 5/3+3*(17.47)/(8* 138.13)-( 17.47³)/(8*138.13³)
  = 119.729 N./mm^2
```

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

```
  = Sc/Sca + ( Rm * Distance Side/I )/Sba
  = 3.88/119.73 + ( 26.89 * 86.0/6360561 )/137.9
  = 0.035
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io

Rib	15.0	157.0	0.0	23.6	0.0	636.
Web	359.7	15.0	0.0	54.0	0.0	10.1
Values	...	...	...	77.5	...	646.

```
Compressive Allowable, KL/R < Cc ( 11.5546 < 138.1347 ) per AISC E2-1 [Sca]:
 = (1-(Klr)²/(2*Cc²))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
 = ( 1-( 11.55 )²/(2 * 138.13² )) * 207/
   ( 5/3+3*(11.55)/(8* 138.13)-( 11.55³)/(8*138.13³)
 = 121.396 N./mm^2
```

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

```
 = Sc/Sca + ( Rm * Distance Center/I )/Sba
 = 4.85/121.4 + ( 28.94 * 86.0/645.75 )/137.9
 = 0.043
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	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	24.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	3.1275	cm^2
Saddle Load QO (Weight)	QO	113.7	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.2	kN
Maximum Transverse Force	Ft	1.0	kN
Maximum Longitudinal Force	Fl	0.5	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)
 = 0.51/(172.38 * 4.0)
 = 0.0073 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
 = B * Ft + Sum of X Moments
 = 950.0 * 0.99 + 0.0
 = 942.12 N-m
```

Eccentricity (e):

```
 = Rmom / QO
 = 942.12/113.7
 = 8.28 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, 0.0073, 0.0]
 = 0.0073 cm^2
```

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

Input and Calculated Values:

Vessel Mean Radius	Rm	599.00	mm.
Stiffened Vessel Length per 4.15.6	L	4844.00	mm.
Distance from Saddle to Vessel tangent	a	346.00	mm.
Saddle Width	b	172.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	305.00	mm.
Wear Plate Bearing Angle	theta1	132.00	degrees
Wear Plate Thickness	tr	15.0	mm.
Wear Plate Allowable Stress	Sr	137.90	N./mm^2
Shell Allowable Stress used in Calculation		235.81	N./mm^2
Head Allowable Stress used in Calculation		235.81	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		92.39	kN

Horizontal Vessel Analysis Results:	Actual N./mm^2	Allowable N./mm^2
Long. Stress at Top of Midspan	68.61	235.81
Long. Stress at Bottom of Midspan	80.94	235.81
Long. Stress at Top of Saddles	73.99	235.81
Long. Stress at Bottom of Saddles	75.21	235.81
Tangential Shear in Shell	12.90	188.65
Circ. Stress at Horn of Saddle	6.49	353.71
Circ. Compressive Stress in Shell	1.92	235.81

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:
```
= Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
= 3.0 * ( 2.0/2 + 0 ) * 950.0/1037.4984
= 2.7 kN
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
= max( Fl, Friction Load, Sum of X Forces) * B / Ls
= max( 0.51, 0.0, 0 ) * 950.0/3000.0
= 0.2 kN
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
= Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
= 90 + Max( 0.2, 3, 0, 0 )
= 92.4 kN
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	94.39	kN
Transverse Shear Load Saddle	0.99	kN
Longitudinal Shear Load Saddle	0.51	kN

Hydrostatic Test Pressure at center of Vessel: 29.959 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  = 0.0194     K8  = 0.3405
K9  = 0.2711     K10 = 0.0581     K1* = 0.1923     K6p = 0.0434
K7p = 0.0159
```

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

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

Moment per Equation 4.15.3 [M1]:

```
= -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
= -92*346.0[1-(1-346.0/4844.0+(599.0²-0.0²)/
  (2*346.0*4844.0))/(1+(4*0.0)/(3*4844.0))]
= 1138.9 N-m
```

Moment per Equation 4.15.4 [M2]:

```
= Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
= 92*4844/4(1+2(599²-0²)/(4844²))/(1+(4*0)/
  (3*4844))-4*346/4844
= 83377.1 N-m
```

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

```
= P * Rm/(2t) - M2/(pi*Rm²t)
= 29.959 * 599.0/(2*12.0) - 83377.1/(pi*599.0²*12.0)
= 68.61 N./mm^2
```

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

```
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 29.959 * 599.0/(2 * 12.0) + 83377.1/(pi * 599.0² * 12.0 )
= 80.94 N./mm^2
```

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

```
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 29.959*599.0/(2*12.0)-1138.9/(0.1066*pi*599.0²*12.0)
= 73.99 N./mm^2
```

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

```
= P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
= 29.959*599.0/(2*12.0)+1138.9/(0.1923*pi*599.0²*12.0)
= 75.21 N./mm^2
```

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

```
= Q(L-2a)/(L+(4*h2/3))
= 92( 4844.0 - 2 * 346.0)/(4844.0 + ( 4 * 0.0/3))
= 79.2 kN
```

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

```
= K2 * T / ( Rm * t )
= 1.1707 * 79.2/( 599.0 * 12.0 )
= 12.90 N./mm^2
```

Decay Length (4.15.22) [x1,x2]:

```
= 0.78 * sqrt( Rm * t )
= 0.78 * sqrt( 599.0 * 12.0 )
= 66.130 mm.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 92 * 0.1/( 12.0 * ( 172.0 + 66.13 + 66.13 ) )
  = -1.92 N./mm^2
```

Effective reinforcing plate width (4.15.1) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 172.0 + 1.56 * sqrt( 599.0 * 12.0 ), 2 * 346.0 )
  = 304.26 mm.
```

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

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [sigma6,r]:
```
  = -K5 * Q * k / ( B1( t + eta * tr ) )
  = - 0.7603 * 92 * 0.1/( 304.26( 12.0 + 1.0 * 15.0 ) )
  = -0.86 N./mm^2
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.27) [sigma7,r]:
```
  = -Q/(4(t+eta*tr)b1) - 3*K7*Q/(2(t+eta*tr)²)
  = -92/(4(12.0 + 1.0 * 15.0)304.26) -
     3 * 0.019 * 92/(2(12.0 + 1.0 * 15.0)²)
  = -6.49 N./mm^2
```

Results for Vessel Ribs, Web and Base

Baseplate Length	Bplen	1050.0000	mm.
Baseplate Thickness	Bpthk	20.0000	mm.
Baseplate Width	Bpwid	220.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	15.0000	mm.
Web Thickness	Webtk	15.0000	mm.
Web Location	Webloc	Center	

Moment of Inertia of Saddle - Lateral Direction

	B	D	Y	A	AY	Io
Shell	437.	12.	6.	52.	31435.	25.1
Wearplate	305.	15.	20.	46.	89212.	183.
Web	15.	310.	182.	47.	846300.	0.191E+05
BasePlate	220.	20.	347.	44.	1526800.	0.530E+05
Totals	...	...	...	189.	2493748.	0.723E+05

```
Value  C1 = Sumof(Ay)/Sumof(A)           =     132.      mm.
Value   I = Sumof(Io) - C1*Sumof(Ay)     =    0.394E+05  cm**4
Value  As = Sumof(A) - Ashell            =     136.      cm^2

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

Fh = K1 * Q = 0.2035 * 92.395 = 18.8043 kN

Tension Stress, St = ( Fh/As )       =        1.3803  N./mm^2
Allowed Stress, Sa = 0.6 * Yield Str =      124.1100  N./mm^2
```

Saddle Splitting Dimension [d]:
```
  = B - R * sin( theta )/ theta
  = 950.0 - 593.0 * sin( 1.0472 )/1.0472
  = 459.593 mm.
```

```
Bending Moment, M  = Fh * d          =       8645.8369  N-m
```

```
Bending Stress, Sb = ( M * C1 / I  ) =          2.9027  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 / ( 4 * BasePlateLength * AllStress ))½
= ( 3(92 + 2)220.0/( 4 * 1050.0 * 137.9 ))½
= 10.372 mm.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Distance between Ribs [e]:

```
= Web Length / ( Nribs - 1 )
= 1079.0676/( 4 - 1 )
= 359.689 mm.
```

Baseplate Pressure Area [Ap]:

```
= e * Bpwid / 2
= 359.6892 * 220.0/2
= 395.658 cm^2
```

Axial Load [P]:

```
= Ap * Bp
= 395.7 * 0.04
= 15.825 kN
```

Area of the Rib and Web [Ar]:

```
= Rib Area + Web Area
= 23.55 + 26.977
= 50.527 cm^2
```

Compressive Stress [Sc]:

```
= P/Ar
= 15.8/50.5267
= 3.132 N./mm^2
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	15.0	172.0	...	25.8	...	636.

Bending Moment [Rm]:

```
= Fl /( 2 * Bplen ) * e * rl / 2
= 0.5/( 2 * 1050.0 ) * 359.689 * 619.79/2
= 26.889 N-m
```

Compressive Allowable, KL/R < Cc (17.4685 < 138.1347) per AISC E2-1 [Sca]:

```
= (1-(Klr)^2/(2*Cc^2))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)
= ( 1-( 17.47 )^2/(2 * 138.13^2 )) * 207/
  ( 5/3+3*(17.47)/(8* 138.13)-( 17.47^3)/(8*138.13^3)
= 119.729 N./mm^2
```

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

```
= Sc/Sca + ( Rm * Distance Side/I )/Sba
= 3.13/119.73 + ( 26.89 * 86.0/6360561 )/137.9
= 0.029
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io

Rib	15.0	157.0	0.0	23.6	0.0	636.
Web	359.7	15.0	0.0	54.0	0.0	10.1
Values	...	...	...	77.5	...	646.

Compressive Allowable, KL/R < Cc (11.5546 < 138.1347) per AISC E2-1 [Sca]:
= $(1-(Klr)^2/(2*Cc^2))*Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3))$
= $(1-(11.55)^2/(2 * 138.13^2)) * 207/$
$(5/3+3*(11.55)/(8* 138.13)-(11.55^3)/(8*138.13^3)$
= 121.396 N./mm^2

AISC Unity Check of Inside Ribs (must be <= 1)
= Sc/Sca + (Rm * Distance Center/I)/Sba
= 3.91/121.4 + (28.94 * 86.0/645.75)/137.9
= 0.035

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	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	24.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	3.1275	cm^2
Saddle Load QO (Weight)	QO	91.7	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.2	kN
Maximum Transverse Force	Ft	1.0	kN
Maximum Longitudinal Force	Fl	0.5	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)
= 0.51/(172.38 * 4.0)
= 0.0073 cm^2

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
= B * Ft + Sum of X Moments
= 950.0 * 0.99 + 0.0
= 942.12 N-m

Eccentricity (e):
= Rmom / QO
= 942.12/91.67
= 10.27 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, 0.0073, 0.0]
= 0.0073 cm^2

Nozzle Calculation Summary:

Description	MAWP bars	Ext	MAPNC bars	UG-45	[tr] mm.	Weld Path	Areas or Stresses
T1	...	OK	...	OK	11.33	OK	Passed
T2	...	OK	...	OK	11.33	OK	Passed
S2	...	OK	...	OK	10.16	OK	Passed
S1	...	OK	...	OK	11.33	OK	Passed
S3	...	OK	...	OK	7.80	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	T1	425.000	270.000	598.626
20	T2	425.000	90.000	598.626
40	S2	1296.175	270.000	405.700
40	S1	5511.175	90.000	598.626
40	S3	1296.175	90.000	113.600
60	T4	6257.350	90.000	71.550
60	T3	6257.350	270.000	78.000

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: T1 From : 20

```
Pressure for Reinforcement Calculations        P      23.115  bars
Temperature for Internal Pressure           Temp         120  °C
Design External Pressure                    Pext        1.10  bars
Temperature for External Pressure         Tempex         120  °C

Shell Material   [Normalized]                       SA-516 70
Shell Allowable Stress at Temperature         Sv      137.90  N./mm^2
Shell Allowable Stress At Ambient            Sva      137.90  N./mm^2

Inside Diameter of Cylindrical Shell           D     1180.00  mm.
Design Length of Section                       L    897.3333  mm.
Shell Finished (Minimum) Thickness             t     15.0000  mm.
Shell Internal Corrosion Allowance             c      3.0000  mm.
Shell External Corrosion Allowance            co      0.0000  mm.

Distance from Bottom/Left Tangent                     425.00  mm.

User Entered Minimum Design Metal Temperature         -45.00  °C
```

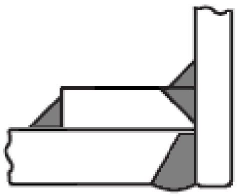
Type of Element Connected to the Shell : Nozzle

```
Material         [Impact Tested]                     SA-333 6
Material UNS Number                                   K03006
Material Specification/Type                 Smls. & wld. pipe
Allowable Stress at Temperature               Sn      117.90  N./mm^2
Allowable Stress At Ambient                  Sna      117.90  N./mm^2

Diameter Basis (for tr calc only)                         OD
Layout Angle                                          270.00  deg
Diameter                                             12.0000  in.

Size and Thickness Basis                               Minimum
Nominal Thickness                             tn       80

Flange Material                                     SA-350 LF2
Flange Type                                   Weld Neck Flange

Corrosion Allowance                          can      3.0000  mm.
Joint Efficiency of Shell Seam at Nozzle      E1        1.00
Joint Efficiency of Nozzle Neck               En        1.00

Outside Projection                            ho    200.0000  mm.
Weld leg size between Nozzle and Pad/Shell    Wo     14.0000  mm.
Groove weld depth between Nozzle and Vessel Wgnv     15.0000  mm.
Inside Projection                              h      0.0000  mm.
Weld leg size, Inside Element to Shell        Wi      0.0000  mm.

Pad Material     [Normalized]                       SA-516 70
Pad Allowable Stress at Temperature           Sp      137.90  N./mm^2
Pad Allowable Stress At Ambient              Spa      137.90  N./mm^2
Diameter of Pad along vessel surface          Dp    483.8500  mm.
Thickness of Pad                              te     15.0000  mm.
Weld leg size between Pad and Shell           Wp     10.0000  mm.
Groove weld depth between Pad and Nozzle    Wgpn     15.0000  mm.
Reinforcing Pad Width                                80.0000  mm.

Class of attached Flange                            300
Grade of attached Flange                            GR 1.1
```

The Pressure Design option was Design Pressure + static head.

```
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for CONDENSER E-PK6101-2
Nozzle Calcs.: T1                       Nozl:     8  10:31pm   Feb 6,2022
```

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           12.750  in.
 Actual Thickness Used in Calculation                   0.601  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]

```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.12*593.0)/(138*1.0-0.6*23.12)
  = 10.0415 mm.
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]

```
  = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = (23.12*161.925)/(118*1.0+0.4*23.12)
  = 3.1500 mm.
```

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

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

```
 Parallel to Vessel Wall (Diameter Limit)            Dl    598.6257   mm.
 Parallel to Vessel Wall, opening length              d    299.3128   mm.
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp     30.0000   mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 117.9/137.9 )
  = 0.855
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 117.9/137.9 )
  = 0.855
```

Weld Strength Reduction Factor [fr4]:

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

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 0.855, 1.0 )
  = 0.855
```

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	30.413	5.299	NA
Area in Shell	A1	5.792	25.141	NA
Area in Nozzle Wall	A2	4.678	5.848	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	2.676	2.676	NA
Area in Element	A5	18.000	18.000	NA
TOTAL AREA AVAILABLE	Atot	31.146	51.665	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

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

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	477.3341	15.0000	mm.
Based on given Pad Diameter:	483.8500	14.3891	mm.
Based on Shell or Nozzle Thickness:	477.3341	15.0000	mm.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (299.3128*10.0415*1.0+2*12.2686*10.0415*1.0*(1-0.86))
  = 30.413 cm^2
```

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 299.313( 1.0 * 12.0 - 1.0 * 10.042 ) - 2 * 12.269
    ( 1.0 * 12.0 - 1.0 * 10.0415 ) * ( 1 - 0.855 )
  = 5.792 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 30.0 ) * ( 12.27 - 3.15 ) * 0.855
  = 4.678 cm^2
```

Area Available in Welds [A41 + A42 + A43]:
```
  = Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
  = 14.0² * 0.86 + (0.0)² * 0.86 + 10.0² * 1.0
  = 2.676 cm^2
```

Area Available in Element, also see UG-37(h) [A5]:
```
  = (min(Dp,DL)-(Nozzle OD))(min(tp,Tlwp,te)) * fr4 * 0.75
  = ( 483.85 - 323.85 )15.0 * 1.0 * 0.75
  = 18.000 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 6.1500 mm.
 Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 13.0415 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 13.0415 mm.
 Wall Thickness, shell/head, external pressure     trb2 = 3.4733 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                     tb3 = 11.3312 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 11.331, max( 13.0415, 4.5 ) ]
  = 11.3312 mm.
```

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

```
  = max( ta, tb )
  = max( 6.15, 11.3312 )
  = 11.3312 mm.
```

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

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

```
 Sustained  :     38.5,  Allowable :    117.9 N./mm^2  Passed
 Expansion  :      0.0,  Allowable :    256.2 N./mm^2  Passed
 Occasional :     13.5,  Allowable :    156.8 N./mm^2  Passed
 Shear      :     13.9,  Allowable :     82.5 N./mm^2  Passed
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

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

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

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

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

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

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

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

Govrn. thk, tg = 15.0, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.837, Temp. Reduction = 9 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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

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

Govrn. thk, tg = 15.0, tr = 10.042, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.837, Temp. Reduction = 9 °C

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

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

Govrn. thk, tg = 15.0, tr = 10.042, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.837, Temp. Reduction = 9 °C

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

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

```
Design Pressure/Ambient Rating = 23.12/51.10 = 0.452
```

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

Weld Size Calculations, Description: T1

```
Intermediate Calc. for nozzle/shell Welds   Tmin      12.2686  mm.
Intermediate Calc. for pad/shell Welds    TminPad     12.0000  mm.
```

Results Per UW-16.1:

```
                        Required Thickness    Actual Thickness
Nozzle Weld           6.0000 = Min per Code 9.8980 = 0.7 * Wo mm.
Pad Weld              6.0000 = 0.5*TminPad  7.0700 = 0.7 * Wp mm.
```

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (30.4129 - 5.7923 + 2 * 12.2686 * 0.855 *
     (1.0 * 12.0 - 10.0415 ) )138)
  = 345.15 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.6778 + 18.0 + 2.6758 - 0.0 * 0.86 ) * 138
  = 349.60 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.6778 + 0.0 + 1.6758 + ( 2.5175 ) ) * 138
  = 122.32 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.6778 + 0.0 + 2.6758 + 18.0 + ( 2.5175 ) ) * 138
  = 384.31 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 323.85 * 14.0 * 0.49 * 118
  = 411. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 483.85 * 10.0 * 0.49 * 138
  = 514. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 155.7907) * ( 15.2686 - 3.0 ) * 0.7 * 118
  = 496. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 323.85 * 15.0 * 0.74 * 138
  = 779. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 323.85 * ( 15.0 - 3.0 ) * 0.74 * 138
  = 623. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 514 + 496 ) = 1009 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 411 + 779 + 623 + 0 ) = 1813 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 514 + 623 + 0 ) = 1136 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 1009 kN , must exceed W = 345 kN  or W1 = 349 kN
 Path 2-2 = 1812 kN , must exceed W = 345 kN  or W2 = 122 kN
 Path 3-3 = 1136 kN , must exceed W = 345 kN  or W3 = 384 kN

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

The Drop for this Nozzle is : 22.6551 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 237.6551 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    1180.000  mm.
 Vessel Thickness                                Tv      15.000  mm.

 Design Temperature                                      120.00  °C
 Vessel Material                                      SA-516 70
 Vessel Cold S.I. Allowable                     Smc      137.90  N./mm^2
 Vessel Hot  S.I. Allowable                     Smh      137.90  N./mm^2

 Attachment Type                               Type      Round

 Diameter Basis for Nozzle                   Nbasis      OD
 Corrosion Allowance for Nozzle                 Can      3.0000  mm.
 Nozzle Diameter                                 Dn     323.850  mm.
 Nozzle Thickness                                Tn      15.269  mm.
 Nozzle Material                                        SA-333 6
 Nozzle Cold S.I. Allowable                    SNmc      117.90  N./mm^2
 Nozzle Hot  S.I. Allowable                    SNmh      117.90  N./mm^2

 Thickness of Reinforcing Pad                  Tpad      15.000  mm.
 Diameter  of Reinforcing Pad                  Dpad     483.850  mm.
```

```
 Design Internal Pressure                        Dp       23.115  bars
 Include Pressure Thrust                                      No
```

External Forces and Moments in WRC 107/537 Convention:

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


 Use Interactive Control                             No
 WRC107 Version                           Version  March  1979

 Include Pressure Stress Indices per Div. 2                 No
 Compute Pressure Stress per WRC-368                        No
 Local Loads applied at end of Nozzle/Attachment            No
```

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

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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 323.85 + 2 * 1.65 * sqrt( 599.0 ( 15.0 - 3.0 ) )
  = 603.631 mm.
```

WRC 107 Stress Calculation for SUStained loads:

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

 Dimensionless Parameters used :    Gamma =    22.46
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

```
 -------------------------------------------------------------------
 Curves read for 1979               Beta  Figure     Value   Location
 -------------------------------------------------------------------
 N(PHI) / ( P/Rm )                 0.234   4C        3.260   (A,B)
 N(PHI) / ( P/Rm )                 0.234   3C        2.215   (C,D)
 M(PHI) / ( P )                    0.234   2C1       0.041   (A,B)
 M(PHI) / ( P )                    0.234   1C        0.070   (C,D)
 N(PHI) / ( MC/(Rm**2 * Beta) )    0.234   3A        0.941   (A,B,C,D)
 M(PHI) / ( MC/(Rm     * Beta) )   0.234   1A        0.083   (A,B,C,D)
 N(PHI) / ( ML/(Rm**2 * Beta) )    0.234   3B        2.410   (A,B,C,D)
 M(PHI) / ( ML/(Rm     * Beta) )   0.234   1B        0.029   (A,B,C,D)

 N(x)   / ( P/Rm )                 0.234   3C        2.215   (A,B)
 N(x)   / ( P/Rm )                 0.234   4C        3.260   (C,D)
 M(x)   / ( P )                    0.234   1C1       0.073   (A,B)
 M(x)   / ( P )                    0.234   2C        0.041   (C,D)
 N(x)   / ( MC/(Rm**2 * Beta) )    0.234   4A        1.607   (A,B,C,D)
 M(x)   / ( MC/(Rm     * Beta) )   0.234   2A        0.041   (A,B,C,D)
 N(x)   / ( ML/(Rm**2 * Beta) )    0.234   4B        0.902   (A,B,C,D)
 M(x)   / ( ML/(Rm     * Beta) )   0.234   2B        0.048   (A,B,C,D)
```

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-2.4	-2.4	-2.4	-2.4	-1.6	-1.6	-1.6	-1.6
Circ. Bend.	P	-4.0	4.0	-4.0	4.0	-6.9	6.9	-6.9	6.9
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-6.2	-6.2	6.2	6.2
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-73.7	73.7	73.7	-73.7
Circ. Memb.	ML	-15.9	-15.9	15.9	15.9	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-25.7	25.7	25.7	-25.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-48.0	11.5	35.1	-8.2	-88.5	72.8	71.4	-62.2
Long. Memb.	P	-1.6	-1.6	-1.6	-1.6	-2.4	-2.4	-2.4	-2.4
Long. Bend.	P	-7.2	7.2	-7.2	7.2	-4.0	4.0	-4.0	4.0
Long. Memb.	MC	0.0	0.0	0.0	0.0	-10.6	-10.6	10.6	10.6
Long. Bend.	MC	0.0	0.0	0.0	0.0	-36.6	36.6	36.6	-36.6
Long. Memb.	ML	-5.9	-5.9	5.9	5.9	0.0	0.0	0.0	0.0
Long. Bend.	ML	-42.6	42.6	42.6	-42.6	0.0	0.0	0.0	0.0
Tot. Long. Str.		-57.3	42.2	39.7	-31.1	-53.6	27.7	40.8	-24.4
Shear	VC	0.9	0.9	-0.9	-0.9	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Shear	MT	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Tot. Shear		5.1	5.1	3.4	3.4	3.4	3.4	5.1	5.1
Str. Int.		59.6	43.0	41.5	31.6	88.8	73.1	72.2	62.9

Stress Intensity Values at (Au through Dl)

Dimensionless Parameters used : Gamma = 49.92

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.353	4C	4.461	(A,B)
N(PHI) / (P/Rm)	0.353	3C	1.855	(C,D)
M(PHI) / (P)	0.353	2C1	0.009	(A,B)
M(PHI) / (P)	0.353	1C !	0.065	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.353	3A	1.401	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.353	1A	0.059	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.353	3B	2.663	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.353	1B	0.007	(A,B,C,D)
N(x) / (P/Rm)	0.353	3C	1.855	(A,B)
N(x) / (P/Rm)	0.353	4C	4.461	(C,D)
M(x) / (P)	0.353	1C1	0.024	(A,B)
M(x) / (P)	0.353	2C !	0.033	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.353	4A	4.827	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.353	2A	0.023	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.353	4B	1.536	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.353	2B	0.011	(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	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
Circ. Memb. P	-7.4	-7.4	-7.4	-7.4	-3.1	-3.1	-3.1	-3.1
Circ. Bend. P	-4.7	4.7	-4.7	4.7	-32.6	32.6	-32.6	32.6
Circ. Memb. MC	0.0	0.0	0.0	0.0	-14.1	-14.1	14.1	14.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	-177.6	177.6	177.6	-177.6
Circ. Memb. ML	-26.8	-26.8	26.8	26.8	0.0	0.0	0.0	0.0
Circ. Bend. ML	-21.5	21.5	21.5	-21.5	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-60.5	-8.0	36.1	2.5	-227.3	193.0	156.0	-134.0
Long. Memb. P	-3.1	-3.1	-3.1	-3.1	-7.4	-7.4	-7.4	-7.4
Long. Bend. P	-12.1	12.1	-12.1	12.1	-16.7	16.7	-16.7	16.7
Long. Memb. MC	0.0	0.0	0.0	0.0	-48.5	-48.5	48.5	48.5
Long. Bend. MC	0.0	0.0	0.0	0.0	-70.1	70.1	70.1	-70.1
Long. Memb. ML	-15.4	-15.4	15.4	15.4	0.0	0.0	0.0	0.0
Long. Bend. ML	-33.2	33.2	33.2	-33.2	0.0	0.0	0.0	0.0
Tot. Long. Str.	-63.8	26.8	33.5	-8.8	-142.7	30.8	94.4	-12.3
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	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Tot. Shear	5.6	5.6	3.0	3.0	3.0	3.0	5.6	5.6
Str. Int.	68.0	36.5	38.1	12.8	227.4	193.0	156.5	134.3

WRC 107/537 Stress Summations:

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

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
Circ. Pm (SUS)	49.6	52.0	49.6	52.0	49.6	52.0	49.6	52.0
Circ. Pl (SUS)	-18.3	-18.3	13.5	13.5	-7.8	-7.8	4.6	4.6
Circ. Q (SUS)	-29.7	29.7	21.7	-21.7	-80.6	80.6	66.8	-66.8
Long. Pm (SUS)	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8
Long. Pl (SUS)	-7.6	-7.6	4.3	4.3	-13.0	-13.0	8.2	8.2
Long. Q (SUS)	-49.8	49.8	35.4	-35.4	-40.7	40.7	32.6	-32.6
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.9	0.9	-0.9	-0.9	-0.9	-0.9	0.9	0.9
Shear Q (SUS)	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Pm (SUS)	49.6	52.0	49.6	52.0	49.6	52.0	49.6	52.0
Pm+Pl (SUS)	31.4	33.7	63.2	65.5	41.8	44.1	54.3	56.6
Pm+Pl+Q (Total)	35.6	70.6	85.3	50.5	39.9	124.9	121.5	14.8

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	51.95	137.90	Passed
Pm+Pl (SUS)	65.47	206.85	Passed
Pm+Pl+Q (TOTAL)	124.92	413.70	Passed

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at							
	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	113.1	115.4	113.1	115.4	113.1	115.4	113.1	115.4
Circ. Pl (SUS)	-34.2	-34.2	19.3	19.3	-17.2	-17.2	11.0	11.0
Circ. Q (SUS)	-26.3	26.3	16.8	-16.8	-210.1	210.1	145.0	-145.0
Long. Pm (SUS)	56.5	56.5	56.5	56.5	56.5	56.5	56.5	56.5
Long. Pl (SUS)	-18.5	-18.5	12.3	12.3	-56.0	-56.0	41.1	41.1
Long. Q (SUS)	-45.3	45.3	21.1	-21.1	-86.8	86.8	53.4	-53.4
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.3	1.3	-1.3	-1.3	-1.3	-1.3	1.3	1.3
Shear Q (SUS)	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Pm (SUS)	113.1	115.4	113.1	115.4	113.1	115.4	113.1	115.4
Pm+Pl (SUS)	78.9	81.2	132.4	134.8	95.9	98.2	124.1	126.4
Pm+Pl+Q (Total)	60.9	108.7	149.4	118.0	114.5	308.4	269.3	63.9

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	115.40	137.90	Passed
Pm+Pl (SUS)	134.75	206.85	Passed
Pm+Pl+Q (TOTAL)	308.39	413.70	Passed

INPUT VALUES, Nozzle Description: T2 From : 20

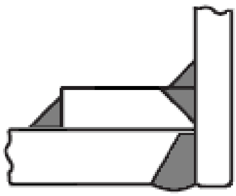
Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	120	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1180.00	mm.
Design Length of Section	L	897.3333	mm.
Shell Finished (Minimum) Thickness	t	15.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		425.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type		Smls. & wld. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		12.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	14.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	15.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
Diameter of Pad along vessel surface	Dp	483.8500	mm.
Thickness of Pad	te	15.0000	mm.
Weld leg size between Pad and Shell	Wp	10.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	15.0000	mm.
Reinforcing Pad Width		80.0000	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            12.750  in.
 Actual Thickness Used in Calculation                    0.601  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]

```
   = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
   = (23.0*593.0)/(138*1.0-0.6*23.0)
   = 9.9911 mm.
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]

```
   = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
   = (23.0*161.925)/(118*1.0+0.4*23.0)
   = 3.1344 mm.
```

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

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

```
 Parallel to Vessel Wall (Diameter Limit)             Dl    598.6257   mm.
 Parallel to Vessel Wall, opening length               d    299.3128   mm.
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp      30.0000   mm.
```

Weld Strength Reduction Factor [fr1]:

```
   = min( 1, Sn/Sv )
   = min( 1, 117.9/137.9 )
   = 0.855
```

Weld Strength Reduction Factor [fr2]:

```
   = min( 1, Sn/Sv )
   = min( 1, 117.9/137.9 )
   = 0.855
```

Weld Strength Reduction Factor [fr4]:

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

Weld Strength Reduction Factor [fr3]:

```
   = min( fr2, fr4 )
   = min( 0.855, 1.0 )
   = 0.855
```

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	30.260	5.299	NA
Area in Shell	A1	5.942	25.141	NA
Area in Nozzle Wall	A2	4.686	5.848	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	2.676	2.676	NA
Area in Element	A5	18.000	18.000	NA
TOTAL AREA AVAILABLE	Atot	31.303	51.665	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

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

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	474.5778	15.0000	mm.
Based on given Pad Diameter:	483.8500	14.1307	mm.
Based on Shell or Nozzle Thickness:	474.5778	15.0000	mm.

Area Required [A]:
```
= ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
= (299.3128*9.9911*1.0+2*12.2686*9.9911*1.0*(1-0.86))
= 30.260 cm^2
```

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
```
= d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
= 299.313( 1.0 * 12.0 - 1.0 * 9.991 ) - 2 * 12.269
  ( 1.0 * 12.0 - 1.0 * 9.9911 ) * ( 1 - 0.855 )
= 5.942 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
= ( 2 * Tlwp ) * ( tn - trn ) * fr2
= ( 2 * 30.0 ) * ( 12.27 - 3.13 ) * 0.855
= 4.686 cm^2
```

Area Available in Welds [A41 + A42 + A43]:
```
= Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
= 14.0² * 0.86 + (0.0)² * 0.86 + 10.0² * 1.0
= 2.676 cm^2
```

Area Available in Element, also see UG-37(h) [A5]:
```
= (min(Dp,DL)-(Nozzle OD))(min(tp,Tlwp,te)) * fr4 * 0.75
= ( 483.85 - 323.85 )15.0 * 1.0 * 0.75
= 18.000 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures          ta = 6.1344 mm.
Wall Thickness per UG16(b),                          tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure         trb1 = 12.9911 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 12.9911 mm.
Wall Thickness, shell/head, external pressure         trb2 = 3.4733 mm.
Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                          tb3 = 11.3312 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 11.331, max( 12.9911, 4.5 ) ]
  = 11.3312 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 6.1344, 11.3312 )
  = 11.3312 mm.
```

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

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

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

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

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

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

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

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

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

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

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

Govrn. thk, tg = 15.0, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.833, Temp. Reduction = 9 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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

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

Govrn. thk, tg = 15.0, tr = 9.991, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.833, Temp. Reduction = 9 °C

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

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

Govrn. thk, tg = 15.0, tr = 9.991, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.833, Temp. Reduction = 9 °C

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

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

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

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

Weld Size Calculations, Description: T2

```
Intermediate Calc. for nozzle/shell Welds   Tmin      12.2686  mm.
Intermediate Calc. for pad/shell Welds    TminPad     12.0000  mm.
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
Nozzle Weld          6.0000 = Min per Code 9.8980 = 0.7 * Wo mm.
Pad Weld             6.0000 = 0.5*TminPad  7.0700 = 0.7 * Wp mm.
```

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

Weld Load [W]:
```
= max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max( 0, (30.26 - 5.9415 + 2 * 12.2686 * 0.855 *
  (1.0 * 12.0 - 9.9911 ) )138)
= 341.13 kN
```

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

Weld Load [W1]:
```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 4.6858 + 18.0 + 2.6758 - 0.0 * 0.86 ) * 138
= 349.71 kN
```

Weld Load [W2]:
```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 4.6858 + 0.0 + 1.6758 + ( 2.5175 ) ) * 138
= 122.43 kN
```

Weld Load [W3]:
```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 4.6858 + 0.0 + 2.6758 + 18.0 + ( 2.5175 ) ) * 138
= 384.42 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 ) * 323.85 * 14.0 * 0.49 * 118
= 411. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 483.85 * 10.0 * 0.49 * 138
  = 514. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 155.7907) * ( 15.2686 - 3.0 ) * 0.7 * 118
  = 496. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 323.85 * 15.0 * 0.74 * 138
  = 779. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 323.85 * ( 15.0 - 3.0 ) * 0.74 * 138
  = 623. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 514 + 496 ) = 1009 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 411 + 779 + 623 + 0 ) = 1813 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 514 + 623 + 0 ) = 1136 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 1009 kN , must exceed W = 341 kN  or W1 = 349 kN
 Path 2-2 = 1812 kN , must exceed W = 341 kN  or W2 = 122 kN
 Path 3-3 = 1136 kN , must exceed W = 341 kN  or W3 = 384 kN

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

The Drop for this Nozzle is : 22.6551 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 237.6551 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    1180.000  mm.
 Vessel Thickness                               Tv      15.000  mm.

 Design Temperature                                     120.00  °C
 Vessel Material                                     SA-516 70
 Vessel Cold S.I. Allowable                    Smc      137.90  N./mm^2
 Vessel Hot  S.I. Allowable                    Smh      137.90  N./mm^2

 Attachment Type                              Type      Round

 Diameter Basis for Nozzle                  Nbasis      OD
 Corrosion Allowance for Nozzle                Can      3.0000  mm.
 Nozzle Diameter                                Dn     323.850  mm.
 Nozzle Thickness                               Tn      15.269  mm.
 Nozzle Material                                       SA-333 6
 Nozzle Cold S.I. Allowable                   SNmc      117.90  N./mm^2
 Nozzle Hot  S.I. Allowable                   SNmh      117.90  N./mm^2

 Thickness of Reinforcing Pad                 Tpad      15.000  mm.
 Diameter  of Reinforcing Pad                 Dpad     483.850  mm.
```

Design Internal Pressure	Dp	23.000	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

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

Use Interactive Control		No
WRC107 Version	Version	March 1979

Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No
Local Loads applied at end of Nozzle/Attachment	No

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

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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 323.85 + 2 * 1.65 * sqrt( 599.0 ( 15.0 - 3.0 ) )
  = 603.631 mm.
```

WRC 107 Stress Calculation for SUStained loads:

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

Dimensionless Parameters used : Gamma = 22.46

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.234	4C	3.260	(A,B)
N(PHI) / (P/Rm)	0.234	3C	2.215	(C,D)
M(PHI) / (P)	0.234	2C1	0.041	(A,B)
M(PHI) / (P)	0.234	1C	0.070	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.234	3A	0.941	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.234	1A	0.083	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.234	3B	2.410	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.234	1B	0.029	(A,B,C,D)
N(x) / (P/Rm)	0.234	3C	2.215	(A,B)
N(x) / (P/Rm)	0.234	4C	3.260	(C,D)
M(x) / (P)	0.234	1C1	0.073	(A,B)
M(x) / (P)	0.234	2C	0.041	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.234	4A	1.607	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.234	2A	0.041	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.234	4B	0.902	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.234	2B	0.048	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
Circ. Memb. P	-2.4	-2.4	-2.4	-2.4	-1.6	-1.6	-1.6	-1.6
Circ. Bend. P	-4.0	4.0	-4.0	4.0	-6.9	6.9	-6.9	6.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	-6.2	-6.2	6.2	6.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	-73.7	73.7	73.7	-73.7
Circ. Memb. ML	-15.9	-15.9	15.9	15.9	0.0	0.0	0.0	0.0
Circ. Bend. ML	-25.7	25.7	25.7	-25.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-48.0	11.5	35.1	-8.2	-88.5	72.8	71.4	-62.2
Long. Memb. P	-1.6	-1.6	-1.6	-1.6	-2.4	-2.4	-2.4	-2.4
Long. Bend. P	-7.2	7.2	-7.2	7.2	-4.0	4.0	-4.0	4.0
Long. Memb. MC	0.0	0.0	0.0	0.0	-10.6	-10.6	10.6	10.6
Long. Bend. MC	0.0	0.0	0.0	0.0	-36.6	36.6	36.6	-36.6
Long. Memb. ML	-5.9	-5.9	5.9	5.9	0.0	0.0	0.0	0.0
Long. Bend. ML	-42.6	42.6	42.6	-42.6	0.0	0.0	0.0	0.0
Tot. Long. Str.	-57.3	42.2	39.7	-31.1	-53.6	27.7	40.8	-24.4
Shear VC	0.9	0.9	-0.9	-0.9	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Shear MT	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Tot. Shear	5.1	5.1	3.4	3.4	3.4	3.4	5.1	5.1
Str. Int.	59.6	43.0	41.5	31.6	88.8	73.1	72.2	62.9

Dimensionless Parameters used : Gamma = 49.92

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.353	4C	4.461	(A,B)
N(PHI) / (P/Rm)	0.353	3C	1.855	(C,D)
M(PHI) / (P)	0.353	2C1	0.009	(A,B)
M(PHI) / (P)	0.353	1C !	0.065	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.353	3A	1.401	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.353	1A	0.059	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.353	3B	2.663	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.353	1B	0.007	(A,B,C,D)
N(x) / (P/Rm)	0.353	3C	1.855	(A,B)
N(x) / (P/Rm)	0.353	4C	4.461	(C,D)
M(x) / (P)	0.353	1C1	0.024	(A,B)
M(x) / (P)	0.353	2C !	0.033	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.353	4A	4.827	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.353	2A	0.023	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.353	4B	1.536	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.353	2B	0.011	(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	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-7.4	-7.4	-7.4	-7.4	-3.1	-3.1	-3.1	-3.1
Circ. Bend. P	-4.7	4.7	-4.7	4.7	-32.6	32.6	-32.6	32.6
Circ. Memb. MC	0.0	0.0	0.0	0.0	-14.1	-14.1	14.1	14.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	-177.6	177.6	177.6	-177.6
Circ. Memb. ML	-26.8	-26.8	26.8	26.8	0.0	0.0	0.0	0.0
Circ. Bend. ML	-21.5	21.5	21.5	-21.5	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-60.5	-8.0	36.1	2.5	-227.3	193.0	156.0	-134.0
Long. Memb. P	-3.1	-3.1	-3.1	-3.1	-7.4	-7.4	-7.4	-7.4
Long. Bend. P	-12.1	12.1	-12.1	12.1	-16.7	16.7	-16.7	16.7
Long. Memb. MC	0.0	0.0	0.0	0.0	-48.5	-48.5	48.5	48.5
Long. Bend. MC	0.0	0.0	0.0	0.0	-70.1	70.1	70.1	-70.1
Long. Memb. ML	-15.4	-15.4	15.4	15.4	0.0	0.0	0.0	0.0
Long. Bend. ML	-33.2	33.2	33.2	-33.2	0.0	0.0	0.0	0.0
Tot. Long. Str.	-63.8	26.8	33.5	-8.8	-142.7	30.8	94.4	-12.3
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	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Tot. Shear	5.6	5.6	3.0	3.0	3.0	3.0	5.6	5.6
Str. Int.	68.0	36.5	38.1	12.8	227.4	193.0	156.5	134.3

WRC 107/537 Stress Summations:

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

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	49.4	51.7	49.4	51.7	49.4	51.7	49.4	51.7
Circ. Pl (SUS)	-18.3	-18.3	13.5	13.5	-7.8	-7.8	4.6	4.6
Circ. Q (SUS)	-29.7	29.7	21.7	-21.7	-80.6	80.6	66.8	-66.8
Long. Pm (SUS)	24.7	24.7	24.7	24.7	24.7	24.7	24.7	24.7
Long. Pl (SUS)	-7.6	-7.6	4.3	4.3	-13.0	-13.0	8.2	8.2
Long. Q (SUS)	-49.8	49.8	35.4	-35.4	-40.7	40.7	32.6	-32.6
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.9	0.9	-0.9	-0.9	-0.9	-0.9	0.9	0.9
Shear Q (SUS)	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Pm (SUS)	49.4	51.7	49.4	51.7	49.4	51.7	49.4	51.7
Pm+Pl (SUS)	31.2	33.5	62.9	65.2	41.6	43.9	54.0	56.3
Pm+Pl+Q (Total)	35.5	70.5	85.1	50.4	40.1	124.7	121.2	14.9

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	51.69	137.90	Passed
Pm+Pl (SUS)	65.21	206.85	Passed
Pm+Pl+Q (TOTAL)	124.66	413.70	Passed

WRC 107/537 Stress Summations:

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

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	112.5	114.8	112.5	114.8	112.5	114.8	112.5	114.8
Circ. Pl (SUS)	-34.2	-34.2	19.3	19.3	-17.2	-17.2	11.0	11.0
Circ. Q (SUS)	-26.3	26.3	16.8	-16.8	-210.1	210.1	145.0	-145.0
Long. Pm (SUS)	56.3	56.3	56.3	56.3	56.3	56.3	56.3	56.3
Long. Pl (SUS)	-18.5	-18.5	12.3	12.3	-56.0	-56.0	41.1	41.1
Long. Q (SUS)	-45.3	45.3	21.1	-21.1	-86.8	86.8	53.4	-53.4
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.3	1.3	-1.3	-1.3	-1.3	-1.3	1.3	1.3
Shear Q (SUS)	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Pm (SUS)	112.5	114.8	112.5	114.8	112.5	114.8	112.5	114.8
Pm+Pl (SUS)	78.3	80.6	131.9	134.2	95.4	97.7	123.6	125.9
Pm+Pl+Q (Total)	60.6	108.1	148.8	117.5	115.1	307.8	268.8	64.1

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	114.83	137.90	Passed
Pm+Pl (SUS)	134.18	206.85	Passed
Pm+Pl+Q (TOTAL)	307.82	413.70	Passed

INPUT VALUES, Nozzle Description: S2 From : 40

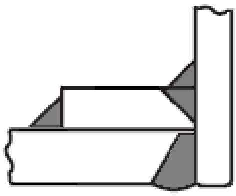
```
Pressure for Reinforcement Calculations          P      23.054  bars
Temperature for Internal Pressure             Temp        125  °C
Design External Pressure                      Pext       1.10  bars
Temperature for External Pressure           Tempex        125  °C

Shell Material  [Impact Tested]                   SA-516 70
Shell Allowable Stress at Temperature           Sv     137.90  N./mm^2
Shell Allowable Stress At Ambient              Sva     137.90  N./mm^2

Inside Diameter of Cylindrical Shell             D    1180.00  mm.
Design Length of Section                         L  4844.0005  mm.
Shell Finished (Minimum) Thickness               t    15.0000  mm.
Shell Internal Corrosion Allowance               c     3.0000  mm.
Shell External Corrosion Allowance              co     0.0000  mm.

Distance from Bottom/Left Tangent                     1296.17  mm.

User Entered Minimum Design Metal Temperature          -45.00  °C
```

Type of Element Connected to the Shell : Nozzle

```
Material        [Impact Tested]                     SA-333 6
Material UNS Number                                   K03006
Material Specification/Type                 Smls. & wld. pipe
Allowable Stress at Temperature                 Sn     117.90  N./mm^2
Allowable Stress At Ambient                    Sna     117.90  N./mm^2

Diameter Basis (for tr calc only)                          OD
Layout Angle                                           270.00  deg
Diameter                                               8.0000  in.

Size and Thickness Basis                              Minimum
Nominal Thickness                               tn      80

Flange Material                                    SA-350 LF2
Flange Type                                  Weld Neck Flange

Corrosion Allowance                            can     3.0000  mm.
Joint Efficiency of Shell Seam at Nozzle        E1       1.00
Joint Efficiency of Nozzle Neck                 En       1.00

Outside Projection                              ho   200.0000  mm.
Weld leg size between Nozzle and Pad/Shell      Wo    10.0000  mm.
Groove weld depth between Nozzle and Vessel   Wgnv    15.0000  mm.
Inside Projection                                h     0.0000  mm.
Weld leg size, Inside Element to Shell          Wi     0.0000  mm.

Pad Material     [Normalized]                       SA-516 70
Pad Allowable Stress at Temperature             Sp     137.90  N./mm^2
Pad Allowable Stress At Ambient                Spa     137.90  N./mm^2
Diameter of Pad along vessel surface            Dp   379.0750  mm.
Thickness of Pad                                te    15.0000  mm.
Weld leg size between Pad and Shell             Wp    10.0000  mm.
Groove weld depth between Pad and Nozzle      Wgpn    15.0000  mm.
Reinforcing Pad Width                                 80.0000  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: S2

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

```
Actual Outside Diameter Used in Calculation              8.625  in.
Actual Thickness Used in Calculation                     0.438  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]

```
= (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
= (23.05*593.0)/(138*1.0-0.6*23.05)
= 10.0148 mm.
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]

```
= (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
= (23.05*109.5375)/(118*1.0+0.4*23.05)
= 2.1253 mm.
```

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

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl   405.7000  mm.
Parallel to Vessel Wall, opening length              d   202.8500  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp    30.0000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
= min( 1, Sn/Sv )
= min( 1, 117.9/137.9 )
= 0.855
```

Weld Strength Reduction Factor [fr2]:

```
= min( 1, Sn/Sv )
= min( 1, 117.9/137.9 )
= 0.855
```

Weld Strength Reduction Factor [fr4]:

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

Weld Strength Reduction Factor [fr3]:

```
= min( fr2, fr4 )
= min( 0.855, 1.0 )
= 0.855
```

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	20.551	7.264	NA
Area in Shell	A1	3.980	9.866	NA
Area in Nozzle Wall	A2	3.071	3.806	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.855	1.855	NA
Area in Element	A5	18.000	18.000	NA
TOTAL AREA AVAILABLE	Atot	26.907	33.527	NA

The Internal Pressure Case Governs the Analysis.

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

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

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	322.5775	15.0000	mm.
Based on given Pad Diameter:	379.0750	9.7034	mm.
Based on Shell or Nozzle Thickness:	358.7859	11.1125	mm.

Area Required [A]:

```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (202.85*10.0148*1.0+2*8.1125*10.0148*1.0*(1-0.86))
  = 20.551 cm^2
```

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 202.85( 1.0 * 12.0 - 1.0 * 10.015 ) - 2 * 8.113
    ( 1.0 * 12.0 - 1.0 * 10.0148 ) * ( 1 - 0.855 )
  = 3.980 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 30.0 ) * ( 8.11 - 2.13 ) * 0.855
  = 3.071 cm^2
```

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

```
  = Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
  = 10.0² * 0.86 + (0.0)² * 0.86 + 10.0² * 1.0
  = 1.855 cm^2
```

Area Available in Element, also see UG-37(h) [A5]:

```
  = (min(Dp,DL)-(Nozzle OD))(min(tp,Tlwp,te)) * fr4 * 0.75
  = ( 379.075 - 219.075 )15.0 * 1.0 * 0.75
  = 18.000 cm^2
```

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

```
 Wall Thickness for Internal/External pressures        ta = 5.1253 mm.
 Wall Thickness per UG16(b),                         tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure        trb1 = 13.0148 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 13.0148 mm.
 Wall Thickness, shell/head, external pressure        trb2 = 3.4733 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                         tb3 = 10.1600 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 10.16, max( 13.0148, 4.5 ) ]
  = 10.1600 mm.
```

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

```
  = max( ta, tb )
  = max( 5.1253, 10.16 )
  = 10.1600 mm.
```

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

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

Sustained	:	50.5,	Allowable :	117.9 N./mm^2	Passed
Expansion	:	0.0,	Allowable :	244.3 N./mm^2	Passed
Occasional	:	13.9,	Allowable :	156.8 N./mm^2	Passed
Shear	:	20.4,	Allowable :	82.5 N./mm^2	Passed

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

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

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

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

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

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

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

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

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

Govrn. thk, tg = 11.113, tr = 2.125, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.262, Temp. Reduction = 78 °C

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

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

Govrn. thk, tg = 15.0, tr = 10.015, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.835, Temp. Reduction = 9 °C

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

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

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

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

Calculated Minimum Design Metal Temperature                -104 °C

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
```
Design Pressure/Ambient Rating = 23.05/51.10 = 0.451
```

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

Weld Size Calculations, Description: S2

```
Intermediate Calc. for nozzle/shell Welds   Tmin      8.1125  mm.
Intermediate Calc. for pad/shell Welds    TminPad    12.0000  mm.
```

Results Per UW-16.1:

```
                        Required Thickness     Actual Thickness
Nozzle Weld           5.6788 = 0.7 * tmin.   7.0700 = 0.7 * Wo mm.
Pad Weld              6.0000 = 0.5*TminPad   7.0700 = 0.7 * Wp mm.
```

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (20.5507 - 3.9802 + 2 * 8.1125 * 0.855 *
     (1.0 * 12.0 - 10.0148 ) )138)
  = 232.28 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.0714 + 18.0 + 1.855 - 0.0 * 0.86 ) * 138
  = 316.13 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.0714 + 0.0 + 0.855 + ( 1.6647 ) ) * 138
  = 77.09 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.0714 + 0.0 + 1.855 + 18.0 + ( 1.6647 ) ) * 138
  = 339.08 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 ) * 219.075 * 10.0 * 0.49 * 118
  = 199. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 379.075 * 10.0 * 0.49 * 138
  = 402. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 105.4813) * ( 11.1125 - 3.0 ) * 0.7 * 118
  = 222. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 219.075 * 15.0 * 0.74 * 138
  = 527. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 219.075 * ( 15.0 - 3.0 ) * 0.74 * 138
  = 421. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 402 + 222 ) = 624 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 199 + 527 + 421 + 0 ) = 1147 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 402 + 421 + 0 ) = 824 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 624 kN , must exceed W = 232 kN  or W1 = 316 kN
 Path 2-2 = 1146 kN , must exceed W = 232 kN  or W2 = 77 kN
 Path 3-3 = 823 kN , must exceed W = 232 kN  or W3 = 339 kN

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

The Drop for this Nozzle is : 10.2574 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 225.2574 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     1180.000  mm.
 Vessel Thickness                                Tv       15.000  mm.

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

 Attachment Type                               Type       Round

 Diameter Basis for Nozzle                   Nbasis       OD
 Corrosion Allowance for Nozzle                 Can       3.0000  mm.
 Nozzle Diameter                                 Dn      219.075  mm.
 Nozzle Thickness                                Tn       11.113  mm.
 Nozzle Material                                         SA-333 6
 Nozzle Cold S.I. Allowable                    SNmc       117.90  N./mm^2
 Nozzle Hot  S.I. Allowable                    SNmh       117.90  N./mm^2
```

```
Thickness of Reinforcing Pad                Tpad      15.000  mm.
Diameter  of Reinforcing Pad                Dpad     379.075  mm.

Design Internal Pressure                      Dp      23.054  bars
Include Pressure Thrust                                   No
```

External Forces and Moments in WRC 107/537 Convention:

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


Use Interactive Control                             No
WRC107 Version                           Version   March   1979

Include Pressure Stress Indices per Div. 2                No
Compute Pressure Stress per WRC-368                       No
Local Loads applied at end of Nozzle/Attachment           No
```

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

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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 219.075 + 2 * 1.65 * sqrt( 599.0 ( 15.0 - 3.0 ) )
  = 498.856 mm.
```

WRC 107 Stress Calculation for SUStained loads:

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

Dimensionless Parameters used :    Gamma =    22.46
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.158	4C	3.689	(A,B)
N(PHI) / (P/Rm)	0.158	3C	3.023	(C,D)
M(PHI) / (P)	0.158	2C1	0.072	(A,B)
M(PHI) / (P)	0.158	1C	0.104	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.158	3A	0.773	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.158	1A	0.093	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.158	3B	2.443	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.158	1B	0.041	(A,B,C,D)
N(x) / (P/Rm)	0.158	3C	3.023	(A,B)
N(x) / (P/Rm)	0.158	4C	3.689	(C,D)
M(x) / (P)	0.158	1C1	0.109	(A,B)
M(x) / (P)	0.158	2C	0.072	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.158	4A	1.177	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.158	2A	0.050	(A,B,C,D)

```
N(x)    / ( ML/(Rm**2 * Beta) )    0.158   4B        0.745    (A,B,C,D)
M(x)    / ( ML/(Rm    * Beta) )    0.158   2B        0.067    (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	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
Circ. Memb. P	-1.8	-1.8	-1.8	-1.8	-1.5	-1.5	-1.5	-1.5
Circ. Bend. P	-4.7	4.7	-4.7	4.7	-6.9	6.9	-6.9	6.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	-3.3	-3.3	3.3	3.3
Circ. Memb. MC	0.0	0.0	0.0	0.0	-54.3	54.3	54.3	-54.3
Circ. Memb. ML	-10.6	-10.6	10.6	10.6	0.0	0.0	0.0	0.0
Circ. Bend. ML	-24.1	24.1	24.1	-24.1	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-41.3	16.5	28.2	-10.6	-66.0	56.4	49.4	-45.6
Long. Memb. P	-1.5	-1.5	-1.5	-1.5	-1.8	-1.8	-1.8	-1.8
Long. Bend. P	-7.2	7.2	-7.2	7.2	-4.7	4.7	-4.7	4.7
Long. Memb. MC	0.0	0.0	0.0	0.0	-5.1	-5.1	5.1	5.1
Long. Bend. MC	0.0	0.0	0.0	0.0	-29.0	29.0	29.0	-29.0
Long. Memb. ML	-3.2	-3.2	3.2	3.2	0.0	0.0	0.0	0.0
Long. Bend. ML	-39.1	39.1	39.1	-39.1	0.0	0.0	0.0	0.0
Tot. Long. Str.	-51.0	41.6	33.7	-30.2	-40.6	26.8	27.5	-21.0
Shear VC	0.9	0.9	-0.9	-0.9	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Shear MT	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
Tot. Shear	5.0	5.0	3.3	3.3	3.3	3.3	5.0	5.0
Str. Int.	53.1	42.5	35.2	30.7	66.4	56.7	50.4	46.6

Dimensionless Parameters used : Gamma = 49.92

Dimensionless Loads for Cylindrical Shells at Pad edge:

```
-------------------------------------------------------------------
Curves read for 1979               Beta   Figure    Value   Location
-------------------------------------------------------------------
N(PHI)  / ( P/Rm )                 0.277   4C        5.562    (A,B)
N(PHI)  / ( P/Rm )                 0.277   3C        2.690    (C,D)
M(PHI)  / ( P )                    0.277   2C1       0.016    (A,B)
M(PHI)  / ( P )                    0.277   1C   !    0.065    (C,D)
N(PHI)  / ( MC/(Rm**2 * Beta) )    0.277   3A        1.715    (A,B,C,D)
M(PHI)  / ( MC/(Rm    * Beta) )    0.277   1A        0.061    (A,B,C,D)
N(PHI)  / ( ML/(Rm**2 * Beta) )    0.277   3B        3.655    (A,B,C,D)
M(PHI)  / ( ML/(Rm    * Beta) )    0.277   1B        0.012    (A,B,C,D)

N(x)    / ( P/Rm )                 0.277   3C        2.690    (A,B)
N(x)    / ( P/Rm )                 0.277   4C        5.562    (C,D)
M(x)    / ( P )                    0.277   1C1       0.038    (A,B)
M(x)    / ( P )                    0.277   2C   !    0.033    (C,D)
N(x)    / ( MC/(Rm**2 * Beta) )    0.277   4A        4.650    (A,B,C,D)
M(x)    / ( MC/(Rm    * Beta) )    0.277   2A        0.025    (A,B,C,D)
N(x)    / ( ML/(Rm**2 * Beta) )    0.277   4B        1.839    (A,B,C,D)
M(x)    / ( ML/(Rm    * Beta) )    0.277   2B        0.018    (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	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
Circ. Memb. P	-6.2	-6.2	-6.2	-6.2	-3.0	-3.0	-3.0	-3.0
Circ. Bend. P	-5.2	5.2	-5.2	5.2	-21.7	21.7	-21.7	21.7
Circ. Memb. MC	0.0	0.0	0.0	0.0	-9.8	-9.8	9.8	9.8
Circ. Memb. MC	0.0	0.0	0.0	0.0	-104.5	104.5	104.5	-104.5
Circ. Memb. ML	-20.8	-20.8	20.8	20.8	0.0	0.0	0.0	0.0
Circ. Bend. ML	-19.8	19.8	19.8	-19.8	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-52.0	-2.0	29.3	0.0	-139.0	113.4	89.6	-76.0
Long. Memb. P	-3.0	-3.0	-3.0	-3.0	-6.2	-6.2	-6.2	-6.2
Long. Bend. P	-12.6	12.6	-12.6	12.6	-11.1	11.1	-11.1	11.1
Long. Memb. MC	0.0	0.0	0.0	0.0	-26.5	-26.5	26.5	26.5
Long. Bend. MC	0.0	0.0	0.0	0.0	-43.1	43.1	43.1	-43.1
Long. Memb. ML	-10.5	-10.5	10.5	10.5	0.0	0.0	0.0	0.0
Long. Bend. ML	-29.9	29.9	29.9	-29.9	0.0	0.0	0.0	0.0
Tot. Long. Str.	-56.0	29.1	24.8	-9.8	-87.0	21.5	52.3	-11.7
Shear VC	1.1	1.1	-1.1	-1.1	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.1	-1.1	1.1	1.1
Shear MT	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Tot. Shear	4.2	4.2	2.0	2.0	2.0	2.0	4.2	4.2
Str. Int.	58.7	32.2	30.1	10.6	139.1	113.5	90.0	76.3

WRC 107/537 Stress Summations:

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

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
Circ. Pm (SUS)	49.5	51.8	49.5	51.8	49.5	51.8	49.5	51.8
Circ. Pl (SUS)	-12.4	-12.4	8.8	8.8	-4.8	-4.8	1.9	1.9
Circ. Q (SUS)	-28.9	28.9	19.4	-19.4	-61.2	61.2	47.5	-47.5
Long. Pm (SUS)	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8
Long. Pl (SUS)	-4.7	-4.7	1.7	1.7	-6.9	-6.9	3.3	3.3
Long. Q (SUS)	-46.3	46.3	32.0	-32.0	-33.7	33.7	24.2	-24.2
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.9	0.9	-0.9	-0.9	-0.9	-0.9	0.9	0.9
Shear Q (SUS)	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
Pm (SUS)	49.5	51.8	49.5	51.8	49.5	51.8	49.5	51.8
Pm+Pl (SUS)	37.2	39.5	58.3	60.6	44.7	47.0	51.4	53.7
Pm+Pl+Q (Total)	35.9	72.4	78.2	47.1	19.5	108.4	99.4	10.3

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	51.82	137.90	Passed
Pm+Pl (SUS)	60.62	206.85	Passed
Pm+Pl+Q (TOTAL)	108.38	413.70	Passed

WRC 107/537 Stress Summations:

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

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	112.8	115.1	112.8	115.1	112.8	115.1	112.8	115.1
Circ. Pl (SUS)	-27.0	-27.0	14.7	14.7	-12.8	-12.8	6.8	6.8
Circ. Q (SUS)	-25.0	25.0	14.7	-14.7	-126.2	126.2	82.8	-82.8
Long. Pm (SUS)	56.4	56.4	56.4	56.4	56.4	56.4	56.4	56.4
Long. Pl (SUS)	-13.5	-13.5	7.5	7.5	-32.7	-32.7	20.3	20.3
Long. Q (SUS)	-42.6	42.6	17.3	-17.3	-54.2	54.2	32.0	-32.0
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.1	1.1	-1.1	-1.1	-1.1	-1.1	1.1	1.1
Shear Q (SUS)	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Pm (SUS)	112.8	115.1	112.8	115.1	112.8	115.1	112.8	115.1
Pm+Pl (SUS)	85.8	88.1	127.5	129.8	100.0	102.3	119.6	121.9
Pm+Pl+Q (Total)	61.1	113.7	142.2	115.2	31.3	228.6	202.6	47.0

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	115.10	137.90	Passed
Pm+Pl (SUS)	129.77	206.85	Passed
Pm+Pl+Q (TOTAL)	228.57	413.70	Passed

INPUT VALUES, Nozzle Description: S1 From : 40

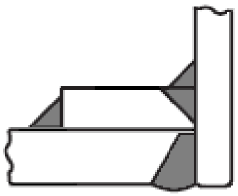
Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1180.00	mm.
Design Length of Section	L	4844.0005	mm.
Shell Finished (Minimum) Thickness	t	15.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		5511.17	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type		Smls. & wld. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		12.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	15.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
Diameter of Pad along vessel surface	Dp	523.8500	mm.
Thickness of Pad	te	12.0000	mm.
Weld leg size between Pad and Shell	Wp	10.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	12.0000	mm.
Reinforcing Pad Width		100.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: S1

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

```
 Actual Outside Diameter Used in Calculation          12.750  in.
 Actual Thickness Used in Calculation                  0.601  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]

```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.0*593.0)/(138*1.0-0.6*23.0)
  = 9.9911 mm.
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]

```
  = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = (23.0*161.925)/(118*1.0+0.4*23.0)
  = 3.1344 mm.
```

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

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

```
 Parallel to Vessel Wall (Diameter Limit)            Dl   598.6257  mm.
 Parallel to Vessel Wall, opening length              d   299.3128  mm.
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp    30.0000  mm.
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 117.9/137.9 )
  = 0.855
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 117.9/137.9 )
  = 0.855
```

Weld Strength Reduction Factor [fr4]:

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

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 0.855, 1.0 )
  = 0.855
```

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	30.260	10.721	NA
Area in Shell	A1	5.942	14.553	NA
Area in Nozzle Wall	A2	4.686	5.848	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.855	1.855	NA
Area in Element	A5	18.000	18.000	NA
TOTAL AREA AVAILABLE	Atot	30.482	40.256	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

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

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	521.3797	12.0000	mm.
Based on given Pad Diameter:	523.8500	11.8518	mm.
Based on Shell or Nozzle Thickness:	481.8738	15.0000	mm.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (299.3128*9.9911*1.0+2*12.2686*9.9911*1.0*(1-0.86))
  = 30.260 cm^2
```

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 299.313( 1.0 * 12.0 - 1.0 * 9.991 ) - 2 * 12.269
    ( 1.0 * 12.0 - 1.0 * 9.9911 ) * ( 1 - 0.855 )
  = 5.942 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 30.0 ) * ( 12.27 - 3.13 ) * 0.855
  = 4.686 cm^2
```

Area Available in Welds [A41 + A42 + A43]:
```
  = Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
  = 10.0² * 0.86 + (0.0)² * 0.86 + 10.0² * 1.0
  = 1.855 cm^2
```

Area Available in Element, also see UG-37(h) [A5]:
```
  = (min(Dp,DL)-(Nozzle OD))(min(tp,Tlwp,te)) * fr4 * 0.75
  = ( 523.85 - 323.85 )12.0 * 1.0 * 0.75
  = 18.000 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures       ta = 6.1344 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 12.9911 mm.
 Wall Thickness                 tb1 = max(trb1, tr16b) = 12.9911 mm.
 Wall Thickness, shell/head, external pressure      trb2 = 3.4733 mm.
 Wall Thickness                 tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 11.3312 mm.
```


Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 11.331, max( 12.9911, 4.5 ) ]
  = 11.3312 mm.
```

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

```
  = max( ta, tb )
  = max( 6.1344, 11.3312 )
  = 11.3312 mm.
```

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

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

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

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

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

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

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

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

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

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

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

Govrn. thk, tg = 12.0, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.833, Temp. Reduction = 9 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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

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

Govrn. thk, tg = 12.0, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.833, Temp. Reduction = 9 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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

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

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

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

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

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

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

Weld Size Calculations, Description: S1

```
Intermediate Calc. for nozzle/shell Welds   Tmin      12.0000  mm.
Intermediate Calc. for pad/shell Welds    TminPad     12.0000  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	6.0000 = Min per Code	7.0700 = 0.7 * Wo mm.
Pad Weld	6.0000 = 0.5*TminPad	7.0700 = 0.7 * Wp mm.

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

Weld Load [W]:
```
= max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max( 0, (30.26 - 5.9415 + 2 * 12.2686 * 0.855 *
  (1.0 * 12.0 - 9.9911 ) )138)
= 341.13 kN
```

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

Weld Load [W1]:
```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 4.6858 + 18.0 + 1.855 - 0.0 * 0.86 ) * 138
= 338.39 kN
```

Weld Load [W2]:
```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 4.6858 + 0.0 + 0.855 + ( 2.5175 ) ) * 138
= 111.11 kN
```

Weld Load [W3]:
```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 4.6858 + 0.0 + 1.855 + 18.0 + ( 2.5175 ) ) * 138
= 373.10 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 ) * 323.85 * 10.0 * 0.49 * 118
= 294. kN
```

Shear, Pad Element Weld [Spew]:
```
= (pi/2) * DP * WP * 0.49 * SEW
= ( 3.1416/2.0 ) * 523.85 * 10.0 * 0.49 * 138
```

```
  = 556. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 155.7907) * ( 15.2686 - 3.0 ) * 0.7 * 118
  = 496. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 323.85 * 12.0 * 0.74 * 138
  = 623. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 323.85 * ( 15.0 - 3.0 ) * 0.74 * 138
  = 623. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 556 + 496 ) = 1052 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 294 + 623 + 623 + 0 ) = 1540 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 556 + 623 + 0 ) = 1179 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 1051 kN , must exceed W = 341 kN  or W1 = 338 kN
 Path 2-2 = 1539 kN , must exceed W = 341 kN  or W2 = 111 kN
 Path 3-3 = 1178 kN , must exceed W = 341 kN  or W3 = 373 kN

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

The Drop for this Nozzle is : 22.6551 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 237.6551 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     1180.000  mm.
 Vessel Thickness                              Tv       15.000  mm.

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

 Attachment Type                             Type       Round

 Diameter Basis for Nozzle                 Nbasis       OD
 Corrosion Allowance for Nozzle               Can       3.0000  mm.
 Nozzle Diameter                               Dn      323.850  mm.
 Nozzle Thickness                              Tn       15.269  mm.
 Nozzle Material                                       SA-333 6
 Nozzle Cold S.I. Allowable                  SNmc       117.90  N./mm^2
 Nozzle Hot  S.I. Allowable                  SNmh       117.90  N./mm^2

 Thickness of Reinforcing Pad                Tpad       12.000  mm.
 Diameter  of Reinforcing Pad                Dpad      523.850  mm.

 Design Internal Pressure                      Dp       23.000  bars
```

Include Pressure Thrust No

External Forces and Moments in WRC 107/537 Convention:

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

Use Interactive Control No
WRC107 Version Version March 1979

Include Pressure Stress Indices per Div. 2 No
Compute Pressure Stress per WRC-368 No
Local Loads applied at end of Nozzle/Attachment No

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

Stress Attenuation Diameter (for Insert Plates) per WRC 297:
= NozzleOD + 2 * 1.65 * sqrt(Rmean(t - ca))
= 323.85 + 2 * 1.65 * sqrt(599.0 (15.0 - 3.0))
= 603.631 mm.

WRC 107 Stress Calculation for SUStained loads:

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

Dimensionless Parameters used : Gamma = 25.21

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.234	4C	3.562	(A,B)
N(PHI) / (P/Rm)	0.234	3C	2.326	(C,D)
M(PHI) / (P)	0.234	2C1	0.036	(A,B)
M(PHI) / (P)	0.234	1C !	0.066	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.234	3A	1.068	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.234	1A	0.081	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.234	3B	2.666	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.234	1B	0.026	(A,B,C,D)
N(x) / (P/Rm)	0.234	3C	2.326	(A,B)
N(x) / (P/Rm)	0.234	4C	3.562	(C,D)
M(x) / (P)	0.234	1C1	0.068	(A,B)
M(x) / (P)	0.234	2C !	0.036	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.234	4A	1.842	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.234	2A	0.039	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.234	4B	1.023	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.234	2B	0.045	(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 Attachment Junction (N./mm^2)

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
Circ. Memb. P	-2.9	-2.9	-2.9	-2.9	-1.9	-1.9	-1.9	-1.9
Circ. Bend. P	-4.6	4.6	-4.6	4.6	-8.2	8.2	-8.2	8.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	-7.9	-7.9	7.9	7.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	-91.1	91.1	91.1	-91.1
Circ. Memb. ML	-19.8	-19.8	19.8	19.8	0.0	0.0	0.0	0.0
Circ. Bend. ML	-29.7	29.7	29.7	-29.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-57.1	11.5	42.1	-8.3	-109.2	89.5	88.9	-76.9
Long. Memb. P	-1.9	-1.9	-1.9	-1.9	-2.9	-2.9	-2.9	-2.9
Long. Bend. P	-8.5	8.5	-8.5	8.5	-4.6	4.6	-4.6	4.6
Long. Memb. MC	0.0	0.0	0.0	0.0	-13.7	-13.7	13.7	13.7
Long. Bend. MC	0.0	0.0	0.0	0.0	-43.7	43.7	43.7	-43.7
Long. Memb. ML	-7.6	-7.6	7.6	7.6	0.0	0.0	0.0	0.0
Long. Bend. ML	-50.2	50.2	50.2	-50.2	0.0	0.0	0.0	0.0
Tot. Long. Str.	-68.2	49.2	47.4	-36.0	-64.9	31.6	49.9	-28.4
Shear VC	1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear MT	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Tot. Shear	5.8	5.8	3.8	3.8	3.8	3.8	5.8	5.8
Str. Int.	70.7	50.0	49.4	36.5	109.6	89.8	89.7	77.6

Dimensionless Parameters used : Gamma = 49.92

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.383	4C	4.119	(A,B)
N(PHI) / (P/Rm)	0.383	3C	1.626	(C,D)
M(PHI) / (P)	0.383	2C1	0.008	(A,B)
M(PHI) / (P)	0.383	1C !	0.065	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.383	3A	1.305	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.383	1A	0.058	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.383	3B	2.364	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.383	1B	0.006	(A,B,C,D)
N(x) / (P/Rm)	0.383	3C	1.626	(A,B)
N(x) / (P/Rm)	0.383	4C	4.119	(C,D)
M(x) / (P)	0.383	1C1	0.020	(A,B)
M(x) / (P)	0.383	2C !	0.033	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.383	4A	4.788	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.383	2A	0.023	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.383	4B	1.407	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.383	2B	0.010	(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	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-6.9	-6.9	-6.9	-6.9	-2.7	-2.7	-2.7	-2.7
Circ. Bend. P	-4.0	4.0	-4.0	4.0	-32.6	32.6	-32.6	32.6
Circ. Memb. MC	0.0	0.0	0.0	0.0	-12.1	-12.1	12.1	12.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	-162.1	162.1	162.1	-162.1
Circ. Memb. ML	-21.9	-21.9	21.9	21.9	0.0	0.0	0.0	0.0
Circ. Bend. ML	-17.0	17.0	17.0	-17.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-49.9	-7.8	28.1	2.0	-209.5	179.8	138.9	-120.1
Long. Memb. P	-2.7	-2.7	-2.7	-2.7	-6.9	-6.9	-6.9	-6.9
Long. Bend. P	-10.2	10.2	-10.2	10.2	-16.7	16.7	-16.7	16.7
Long. Memb. MC	0.0	0.0	0.0	0.0	-44.5	-44.5	44.5	44.5
Long. Bend. MC	0.0	0.0	0.0	0.0	-64.2	64.2	64.2	-64.2
Long. Memb. ML	-13.1	-13.1	13.1	13.1	0.0	0.0	0.0	0.0
Long. Bend. ML	-26.4	26.4	26.4	-26.4	0.0	0.0	0.0	0.0
Tot. Long. Str.	-52.4	20.8	26.6	-5.9	-132.3	29.6	85.1	-10.0
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	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
Tot. Shear	4.9	4.9	2.4	2.4	2.4	2.4	4.9	4.9
Str. Int.	56.2	30.2	29.9	9.3	209.5	179.9	139.3	120.3

WRC 107/537 Stress Summations:

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

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	55.7	58.0	55.7	58.0	55.7	58.0	55.7	58.0
Circ. Pl (SUS)	-22.8	-22.8	16.9	16.9	-9.9	-9.9	6.0	6.0
Circ. Q (SUS)	-34.3	34.3	25.2	-25.2	-99.4	99.4	82.9	-82.9
Long. Pm (SUS)	27.9	27.9	27.9	27.9	27.9	27.9	27.9	27.9
Long. Pl (SUS)	-9.5	-9.5	5.7	5.7	-16.6	-16.6	10.8	10.8
Long. Q (SUS)	-58.7	58.7	41.7	-41.7	-48.2	48.2	39.1	-39.1
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.0	1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q (SUS)	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Pm (SUS)	55.7	58.0	55.7	58.0	55.7	58.0	55.7	58.0
Pm+Pl (SUS)	33.0	35.3	72.6	74.9	45.9	48.2	61.8	64.1
Pm+Pl+Q (Total)	41.2	80.1	98.4	58.4	54.4	147.7	145.1	21.7

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	58.01	137.90	Passed
Pm+Pl (SUS)	74.91	206.85	Passed
Pm+Pl+Q (TOTAL)	147.69	413.70	Passed

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	112.5	114.8	112.5	114.8	112.5	114.8	112.5	114.8
Circ. Pl (SUS)	-28.8	-28.8	15.1	15.1	-14.8	-14.8	9.4	9.4
Circ. Q (SUS)	-21.0	21.0	13.1	-13.1	-194.6	194.6	129.5	-129.5
Long. Pm (SUS)	56.3	56.3	56.3	56.3	56.3	56.3	56.3	56.3
Long. Pl (SUS)	-15.8	-15.8	10.3	10.3	-51.3	-51.3	37.6	37.6
Long. Q (SUS)	-36.6	36.6	16.2	-16.2	-80.9	80.9	47.5	-47.5
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)	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
Pm (SUS)	112.5	114.8	112.5	114.8	112.5	114.8	112.5	114.8
Pm+Pl (SUS)	83.7	86.0	127.6	129.9	97.7	100.0	122.0	124.3
Pm+Pl+Q (Total)	63.1	107.8	140.8	116.9	97.2	294.7	251.6	52.5

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	114.83	137.90	Passed
Pm+Pl (SUS)	129.92	206.85	Passed
Pm+Pl+Q (TOTAL)	294.67	413.70	Passed

INPUT VALUES, Nozzle Description: S3 From : 40

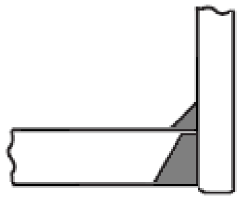
Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1180.00	mm.
Design Length of Section	L	4844.0005	mm.
Shell Finished (Minimum) Thickness	t	15.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1296.17	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm^2
Allowable Stress At Ambient	Sna	137.90	N./mm^2
Diameter Basis (for tr calc only)		ID	
Layout Angle		90.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	15.0000	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: 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)
  = (23.0*593.0)/(138*1.0-0.6*23.0)
  = 9.9911 mm.
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (23.0*28.4)/(138*1.0-0.6*23.0)
  = 0.4785 mm.
```

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

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl    113.6000  mm.
Parallel to Vessel Wall, opening length              d     56.8000  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     30.0000  mm.
```

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

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

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	5.675	2.011	NA
Area in Shell	A1	1.141	2.795	NA
Area in Nozzle Wall	A2	7.873	7.922	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	10.014	11.717	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*9.9911*1.0+2*13.6*9.9911*1.0*(1-1.0))
  = 5.675 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 * 12.0 - 1.0 * 9.991 ) - 2 * 13.6
    ( 1.0 * 12.0 - 1.0 * 9.9911 ) * ( 1 - 1.0 )
  = 1.141 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 30.0 )( 13.6 - 0.48 )1.0
  = 7.873 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 = 3.4785 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 12.9911 mm.
 Wall Thickness                 tbl = max(trb1, tr16b) = 12.9911 mm.
 Wall Thickness, shell/head, external pressure      trb2 = 3.4733 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( 12.9911, 4.5 ) ]
  = 7.8000 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.4785, 7.8 )
  = 7.8000 mm.
```

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

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

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

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

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

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

Governing MDMT of all the sub-joints of this Junction   :   -46 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

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

Weld Size Calculations, Description: S3

```
Intermediate Calc. for nozzle/shell Welds   Tmin     12.0000  mm.
```

Results Per UW-16.1:
```
                       Required Thickness    Actual Thickness
Nozzle Weld          6.0000 = Min per Code 7.0700 = 0.7 * Wo mm.
```

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (5.6749 - 1.1411 + 2 * 13.6 * 1.0 *
     (1.0 * 12.0 - 9.9911 ) )138)
  = 70.05 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 7.8729 + 0.0 + 1. - 0.0 * 1.0 ) * 138
  = 122.35 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 7.8729 + 0.0 + 1. + ( 3.264 ) ) * 138
  = 167.35 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 7.8729 + 0.0 + 1. + 0.0 + ( 3.264 ) ) * 138
  = 167.35 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 * 138
  = 89. 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 * ( 15.0 - 3.0 ) * 0.74 * 138
  = 162. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89 + 145 ) = 234 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89 + 0 + 162 + 0 ) = 251 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89 + 162 + 0 ) = 251 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 234 kN , must exceed W = 70 kN  or W1 = 122 kN
 Path 2-2 = 250 kN , must exceed W = 70 kN  or W2 = 167 kN
 Path 3-3 = 250 kN , must exceed W = 70 kN  or W3 = 167 kN

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

The Drop for this Nozzle is : 1.4968 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 216.4968 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    1180.000  mm.
 Vessel Thickness                               Tv      15.000  mm.

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

 Attachment Type                              Type      Round

 Diameter Basis for Nozzle                  Nbasis      ID
 Corrosion Allowance for Nozzle                Can      3.0000  mm.
 Nozzle Diameter                                Dn      50.800  mm.
 Nozzle Thickness                               Tn      16.600  mm.
 Nozzle Material                                    SA-350 LF2
 Nozzle Cold S.I. Allowable                   SNmc      137.90  N./mm^2
 Nozzle Hot  S.I. Allowable                   SNmh      137.90  N./mm^2

 Design Internal Pressure                       Dp      23.000  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(599.0 (15.0 - 3.0))
= 363.781 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 = 49.92

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.061	4C	9.229	(A,B)
N(PHI) / (P/Rm)	0.061	3C	8.801	(C,D)
M(PHI) / (P)	0.061	2C1	0.121	(A,B)
M(PHI) / (P)	0.061	1C	0.157	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.061	3A	0.985	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.061	1A	0.102	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.061	3B	3.840	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.061	1B	0.054	(A,B,C,D)
N(x) / (P/Rm)	0.061	3C	8.801	(A,B)
N(x) / (P/Rm)	0.061	4C	9.229	(C,D)
M(x) / (P)	0.061	1C1	0.163	(A,B)
M(x) / (P)	0.061	2C	0.121	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.061	4A	1.327	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.061	2A	0.059	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.061	4B	0.970	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.061	2B	0.088	(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	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-2.6	-2.6	-2.6	-2.6	-2.4	-2.4	-2.4	-2.4
Circ. Bend.	P	-10.1	10.1	-10.1	10.1	-13.1	13.1	-13.1	13.1

(Stress Intensity Values at: Au … Dl)

Circ. Memb. MC	0.0	0.0	0.0	0.0	-1.5	-1.5	1.5	1.5
Circ. Memb. MC	0.0	0.0	0.0	0.0	-46.3	46.3	46.3	-46.3
Circ. Memb. ML	-5.8	-5.8	5.8	5.8	0.0	0.0	0.0	0.0
Circ. Bend. ML	-24.4	24.4	24.4	-24.4	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-42.9	26.2	17.5	-11.1	-63.4	55.5	32.3	-34.2
Long. Memb. P	-2.4	-2.4	-2.4	-2.4	-2.6	-2.6	-2.6	-2.6
Long. Bend. P	-13.6	13.6	-13.6	13.6	-10.1	10.1	-10.1	10.1
Long. Memb. MC	0.0	0.0	0.0	0.0	-2.0	-2.0	2.0	2.0
Long. Bend. MC	0.0	0.0	0.0	0.0	-26.8	26.8	26.8	-26.8
Long. Memb. ML	-1.5	-1.5	1.5	1.5	0.0	0.0	0.0	0.0
Long. Bend. ML	-40.1	40.1	40.1	-40.1	0.0	0.0	0.0	0.0
Tot. Long. Str.	-57.5	49.7	25.5	-27.5	-41.5	32.4	16.2	-17.3
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	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Tot. Shear	5.0	5.0	2.5	2.5	2.5	2.5	5.0	5.0
Str. Int.	59.1	50.7	26.2	27.9	63.6	55.7	33.7	35.6

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)	112.5	114.8	112.5	114.8	112.5	114.8	112.5	114.8
Circ. Pl (SUS)	-8.4	-8.4	3.2	3.2	-3.9	-3.9	-1.0	-1.0
Circ. Q (SUS)	-34.5	34.5	14.3	-14.3	-59.4	59.4	33.2	-33.2
Long. Pm (SUS)	56.3	56.3	56.3	56.3	56.3	56.3	56.3	56.3
Long. Pl (SUS)	-3.9	-3.9	-1.0	-1.0	-4.6	-4.6	-0.6	-0.6
Long. Q (SUS)	-53.6	53.6	26.5	-26.5	-36.9	36.9	16.7	-16.7
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)	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Pm (SUS)	112.5	114.8	112.5	114.8	112.5	114.8	112.5	114.8
Pm+Pl (SUS)	104.2	106.5	115.8	118.1	108.6	110.9	111.6	113.9
Pm+Pl+Q (Total)	71.6	141.7	130.2	103.8	49.4	170.4	145.2	81.2

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	114.83	137.90	Passed
Pm+Pl (SUS)	118.10	206.85	Passed
Pm+Pl+Q (TOTAL)	170.38	413.70	Passed

INPUT VALUES, Nozzle Description: T4 From : 60

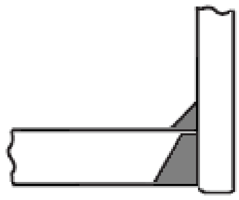
```
Pressure for Reinforcement Calculations        P        23.000  bars
Temperature for Internal Pressure           Temp           190  °C
Design External Pressure                    Pext          1.10  bars
Temperature for External Pressure         Tempex           190  °C

Shell Material  [Normalized]                          SA-516 70
Shell Allowable Stress at Temperature         Sv        137.90  N./mm^2
Shell Allowable Stress At Ambient            Sva        137.90  N./mm^2

Inside Diameter of Cylindrical Shell           D       1180.00  mm.
Design Length of Section                       L      447.3333  mm.
Shell Finished (Minimum) Thickness             t       15.0000  mm.
Shell Internal Corrosion Allowance             c        3.0000  mm.
Shell External Corrosion Allowance            co        0.0000  mm.

Distance from Bottom/Left Tangent                      6257.35  mm.

User Entered Minimum Design Metal Temperature           -45.00  °C
```

Type of Element Connected to the Shell : Nozzle

```
Material         [Impact Tested]                     SA-350 LF2
Material UNS Number                                      K03011
Material Specification/Type                            Forgings
Allowable Stress at Temperature               Sn        137.90  N./mm^2
Allowable Stress At Ambient                  Sna        137.90  N./mm^2

Diameter Basis (for tr calc only)                           ID
Layout Angle                                             90.00  deg
Diameter                                                0.7500  in.

Size and Thickness Basis                                 Actual
Actual Thickness                              tn       14.2500  mm.

Flange Material [Normalized]                         SA-350 LF2
Flange Type                                      Long Weld Neck

Corrosion Allowance                          can        3.0000  mm.
Joint Efficiency of Shell Seam at Nozzle      E1          1.00
Joint Efficiency of Nozzle Neck               En          1.00

Outside Projection                            ho      200.0000  mm.
Weld leg size between Nozzle and Pad/Shell    Wo       10.0000  mm.
Groove weld depth between Nozzle and Vessel Wgnv       15.0000  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                    0.561  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]
```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.0*593.0)/(138*1.0-0.6*23.0)
  = 9.9911 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([23.0/(137.9*1.0]-1)
  = 0.2107 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2876 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl     71.5500  mm.
Parallel to Vessel Wall                       Rn+tn+t     35.7750  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     28.1250  mm.
```

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

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

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	2.503	0.332	NA
Area in Shell	A1	0.934	4.347	NA
Area in Nozzle Wall	A2	6.210	6.166	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	8.144	11.514	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*9.9911*1.0+2*11.25*9.9911*1.0*(1-1.0))
= 2.503 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 )
= 46.5( 1.0 * 12.0 - 1.0 * 9.991 ) - 2 * 11.25
  ( 1.0 * 12.0 - 1.0 * 9.9911 ) * ( 1 - 1.0 )
= 0.934 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
= ( 2 * tlnp )( tn - trn )fr2
= ( 2 * 28.13 )( 11.25 - 0.21 )1.0
= 6.210 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 = 3.2876 mm.
Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure      trb1 = 12.9911 mm.
Wall Thickness                 tb1 = max(trb1, tr16b) = 12.9911 mm.
Wall Thickness, shell/head, external pressure      trb2 = 3.4733 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( 12.9911, 4.5 ) ]
= 6.2200 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
= max( ta, tb )
= max( 3.2876, 6.22 )
= 6.2200 mm.
```

Available Nozzle Neck Thickness = 14.2500 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 14.25, tr = 0.211, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.019, 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

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

```
 Design Pressure/Ambient Rating = 23.00/51.10 = 0.450
```

Weld Size Calculations, Description: T4

```
 Intermediate Calc. for nozzle/shell Welds   Tmin     11.2500  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,  (2.5028 - 0.9342 + 2 * 11.25 * 1.0 *
     (1.0 * 12.0 - 9.9911 ) )138)
  = 27.86 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 6.2096 + 0.0 + 1. - 0.0 * 1.0 ) * 138
  = 99.41 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 6.2096 + 0.0 + 1. + ( 2.7 ) ) * 138
  = 136.64 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 6.2096 + 0.0 + 1. + 0.0 + ( 2.7 ) ) * 138
  = 136.64 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 ) * 47.55 * 10.0 * 0.49 * 138
  = 50. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 18.15) * ( 14.25 - 3.0 ) * 0.7 * 138
  = 62. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 47.55 * ( 15.0 - 3.0 ) * 0.74 * 138
  = 91. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 50 + 62 ) = 112 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 50 + 0 + 91 + 0 ) = 142 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 50 + 91 + 0 ) = 142 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 112 kN , must exceed W = 27 kN  or W1 = 99 kN
 Path 2-2 = 141 kN , must exceed W = 27 kN  or W2 = 136 kN
 Path 3-3 = 141 kN , must exceed W = 27 kN  or W3 = 136 kN

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

The Drop for this Nozzle is : 0.4792 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 215.4792 mm.

INPUT VALUES, Nozzle Description: T3 From : 60

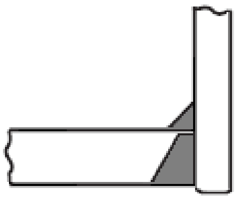
Pressure for Reinforcement Calculations	P	23.115	bars
Temperature for Internal Pressure	Temp	190	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	190	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1180.00	mm.
Design Length of Section	L	447.3333	mm.
Shell Finished (Minimum) Thickness	t	15.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		6257.35	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm^2
Allowable Stress At Ambient	Sna	137.90	N./mm^2
Diameter Basis (for tr calc only)		ID	
Layout Angle		270.00	deg
Diameter		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	14.3000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	15.0000	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)
  = (23.12*593.0)/(138*1.0-0.6*23.12)
  = 10.0415 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([23.12/(137.9*1.0]-1)
  = 0.2654 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    78.0000  mm.
Parallel to Vessel Wall                         Rn+tn+t    39.0000  mm.
Normal to Vessel Wall (Thickness Limit), no pad    Tlnp    28.2500  mm.
```

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

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

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	3.153	0.416	NA
Area in Shell	A1	0.913	4.357	NA
Area in Nozzle Wall	A2	6.235	6.210	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	8.147	11.567	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*10.0415*1.0+2*11.3*10.0415*1.0*(1-1.0))
  = 3.153 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 )
  = 46.6( 1.0 * 12.0 - 1.0 * 10.042 ) - 2 * 11.3
    ( 1.0 * 12.0 - 1.0 * 10.0415 ) * ( 1 - 1.0 )
  = 0.913 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 28.25 )( 11.3 - 0.27 )1.0
  = 6.235 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 = 3.3088 mm.
Wall Thickness per UG16(b),                        tr16b = 4.5000 mm.
Wall Thickness, shell/head, internal pressure       trb1 = 13.0415 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 13.0415 mm.
Wall Thickness, shell/head, external pressure       trb2 = 3.4733 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( 13.0415, 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)), Curve: D

Govrn. thk, tg = 14.3, tr = 0.265, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.023, 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

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

Where the Stress Reduction Ratio per UCS-66(i)(2) is :

```
Design Pressure/Ambient Rating = 23.12/51.10 = 0.452
```

Weld Size Calculations, Description: T3

```
Intermediate Calc. for nozzle/shell Welds   Tmin     11.3000  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, (3.153 - 0.9126 + 2 * 11.3 * 1.0 *
    (1.0 * 12.0 - 10.0415 ) )138)
  = 37.00 kN
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 6.2345 + 0.0 + 1. - 0.0 * 1.0 ) * 138
  = 99.76 kN
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 6.2345 + 0.0 + 1. + ( 2.712 ) ) * 138
  = 137.15 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 6.2345 + 0.0 + 1. + 0.0 + ( 2.712 ) ) * 138
  = 137.15 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 * 138
  = 57. 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 * ( 15.0 - 3.0 ) * 0.74 * 138
  = 104. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 57 + 73 ) = 130 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 57 + 0 + 104 + 0 ) = 161 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 57 + 104 + 0 ) = 161 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 130 kN , must exceed W = 36 kN  or W1 = 99 kN
 Path 2-2 = 161 kN , must exceed W = 36 kN  or W2 = 137 kN
 Path 3-3 = 161 kN , must exceed W = 36 kN  or W3 = 137 kN

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

The Drop for this Nozzle is : 0.6181 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 215.6181 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	1.872	14.250	...	...	215.48	300
T3	1.000 in	Actual	LWN	2.126	14.300	...	...	215.62	300
S3	2.000 in	Actual	LWN	3.307	16.600	...	...	216.50	300
S2	8.000 in	80	WNF	8.625	12.700	379.08	15.00	225.26	300
T1	12.000 in	80	WNF	12.750	17.450	483.85	15.00	237.66	300
T2	12.000 in	80	WNF	12.750	17.450	483.85	15.00	237.66	300
S1	12.000 in	80	WNF	12.750	17.450	523.85	12.00	237.66	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-350 LF2	15.000	10.000	...	...	...
T3	SA-350 LF2	15.000	10.000	...	...	...
S3	SA-350 LF2	15.000	10.000	...	...	...
S2	SA-333 6	15.000	10.000	10.000	15.000	...
T1	SA-333 6	15.000	14.000	10.000	15.000	...
T2	SA-333 6	15.000	14.000	10.000	15.000	...
S1	SA-333 6	15.000	10.000	10.000	12.000	...

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

Nozzle Miscellaneous Data:

Description	Elev/Distance From Datum mm.	Layout Angle deg	Proj Outside mm.	Proj Inside mm.	Installed in Component
T4	6207.350	90.0	200.00	0.00	CHANNEL 002
T3	6207.350	270.0	200.00	0.00	CHANNEL 002

S3	1246.175	90.0	200.00	0.00	SHELL
S2	1246.175	270.0	200.00	0.00	SHELL
T1	375.000	270.0	200.00	0.00	CHANNEL 01
T2	375.000	90.0	200.00	0.00	CHANNEL 01
S1	5461.175	90.0	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	23.00	bars
Shell Maximum Operating Pressure	Psox,max	23.00	bars
Shell Minimum Operating Pressure	Psox,min	0.00	bars
Shell Thickness	ts	15.0000	mm.
Shell Internal Corrosion Allowance	cas	3.0000	mm.
Shell External Corrosion Allowance	caext	0.0000	mm.
Inside Diameter of Shell	Ds	1180.000	mm.
Shell Circumferential Joint Efficiency	Esw	1.000	
Shell Temperature for Internal Pressure	Ts	190.00	°C
Shell Material		SA-516 70	

Note:
Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

Shell Material UNS Number		K02700	
Shell Allowable Stress at Temperature	Ss	137.90	N./mm^2
Shell Allowable Stress at Ambient		137.90	N./mm^2

Channel Description: CHANNEL 01

Channel Type:		Cylinder	
Channel Maximum Design Pressure	Ptd,max	23.00	bars
Channel Maximum Operating Pressure	Ptox,max	23.00	bars
Channel Minimum Operating Pressure	Ptox,min	0.00	bars
Channel Thickness	tc	15.0000	mm.
Channel Corrosion Allowance	cac	3.0000	mm.
Inside Diameter of Channel	Dc	1180.000	mm.
Channel Design Temperature	TEMPC	190.00	°C
Channel Material		SA-516 70	

Note:
Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

Channel Material UNS Number		K02700	
Channel Allowable Stress at Temperature	Sc	137.90	N./mm^2
Channel Allowable Stress at Ambient		137.90	N./mm^2

Tube Data:

Number of Tube Holes	Nt	1802	
Tube Wall Thickness	et	2.1080	mm.
Tube Outside Diameter	D	19.0500	mm.
Total Straight Tube Length	Lt	5000.00	mm.
Straight Tube Length (bet. inner tubsht faces)	L	4840.00	mm.
Design Temperature of the Tubes		190.00	°C
Tube Material		SA-334 6	
Tube Material UNS Number		K03006	
Is this a Welded Tube		No	
Tube Material Specification used		Smls. & wld. tube	
Tube Allowable Stress at Temperature		117.90	N./mm^2
Tube Allowable Stress At Ambient		117.90	N./mm^2
Tube Yield Stress At design Temperature	Syt	208.13	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	571.120	mm.
Largest Center-to-Center Tube Distance	Ul	38.1000	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-350 LF2	

Note:
Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-350 LF2

Tubesheet Material UNS Number		K03011	
Tubesheet Allowable Stress at Temperature	S	137.90	N./mm^2
Tubesheet Allowable Stress at Ambient	Tt	137.90	N./mm^2
Thickness of Tubesheet	h	80.0000	mm.
Tubesheet Corr. Allowance (Shell side)	Cats	3.0000	mm.
Tubesheet Corr. Allowance (Channel side)	Catc	3.0000	mm.
Tubesheet Outside Diameter	A	1350.000	mm.

Additional Data for Stepped Tubesheets:

Is the Tubesheet Stepped?		NO	
Area of the Untubed Lanes	AL	479.0	cm^2

Additional Data for Fixed/Floating Tubesheet Exchangers:

Unsupported Tube Span under consideration	l	1354.000	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	53.80	°C
Mean Tube Metal Temp. along Tube length	Ttm	42.50	°C
Junction Stress Reduction option		Perform Plastic Calculation	

Additional Data for Gasketed Tubesheets:

Tubesheet Gasket on which Side		Channel	
Flange Outside Diameter	A	1350.000	mm.
Flange Inside Diameter	B	1180.000	mm.
Flange Face Outside Diameter	Fod	1266.000	mm.
Flange Face Inside Diameter	Fid	1180.000	mm.
Gasket Outside Diameter	Go	1263.000	mm.

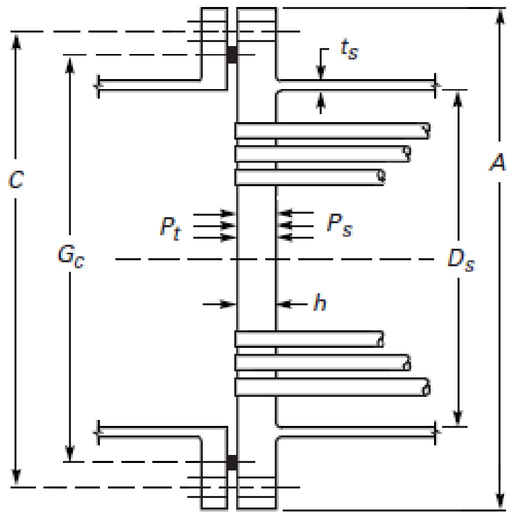
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for CONDENSER E-PK6101-2
ASME TS Calc: Case: 1 10:31p Feb 6,2022

Gasket Inside Diameter	Gi	1223.000	mm.
Small end Hub thk.	g0	15.0000	mm.
Large end Hub thk.	g1	27.0000	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	10.0000	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	1298.000	mm.
Nominal Bolt Diameter	dB	22.2250	mm.
Type of Thread Series	UNC	Thread Series	
Number of Bolts	n	76	

Tubesheet Integral With Shell and Gasketed With Channel, Extended as a Flange



Configuration b:

Bolt Material SA-320 L7

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	64.0000	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    53.8 °C    0.0000118028 /°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    53.8 °C      0.20083E+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    42.5 °C    0.0000117296 /°C
 Elastic Mod. at Design Temperature      190.0 °C      0.19308E+09 KPa.
 Elastic Mod. at Metal Temp. along Len    42.5 °C      0.20148E+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)
  = (24.03*(19.05/2-0.0)/(117.9*1.0+0.4*24.03)
  = 0.1926 + 0.0000 = 0.1926 mm.
```

Tube Required Thickness under External Pressure (Shellside pressure) :

```
 External Pressure Chart     CS-2              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    4840.00      9.04    50.0000  0.0134693        118.20
 EMAWP = (2.167/(D/T)-0.0833)*B = 184.9632 bars
```

Results for Reqd Thickness for Ext. Pressure (Tca):

```
     TCA        ODCA      SLEN        D/T        L/D    Factor A         B
   0.4881      19.05    4840.00     39.03    50.0000  0.0007221         70.35
```

EMAWP = (4*B)/(3*(D/T)) = (4 *70.3514)/(3 *39.0302) = 24.0318 bars

Summary of Tube Required Thickness Results:

Total Required Thickness including Corrosion all.	0.4881	mm.
Allowable Internal Pressure at Corroded thickness	286.26	bars
Required Internal Design Pressure	24.03	bars
Allowable External Pressure at Corroded thickness	184.96	bars
Required External Design Pressure	24.03	bars
Required Thickness due to Shell Side pressure	0.4881	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	1247.068	mm.

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:

= 2a + 6t/(m + 0.5)
= 2 * 22.225 + 6 * 64.0/(3.78 + 0.5)
= 134.170 mm.

Actual Circumferential Bolt Spacing [Bs]:

= C * sin(pi / n)
= 1298.0 * sin(3.142/76)
= 53.640 mm.

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:

= max(sqrt(Bs/(2a + t)), 1)
= max(sqrt(53.64/(2 * 22.225 + 64.0)), 1)
= 1.0000

Bolting Information for UNC Thread Series (Non Mandatory):

Distance Across Corners for Nuts		40.361	mm.
Circular Wrench End Diameter	a	60.325	mm.

	Minimum	Actual	Maximum
Bolt Area, cm^2	199.862	205.445	
Radial Distance between Hub and Bolts:	23.812	44.000	
Radial Distance between Bolts and the Ed	23.812	26.000	
Circumferential Spacing between the Bolt	52.400	53.640	134.170

Flange Design Bolt Load, Seating Condition	W :	3492.94	kN
Flange Design Bolt Load, Operating Condition	Wm1:	3444.83	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 )
  = 0.0/80.0 = 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)*
    ( 117/137 )*(0.0 ), 19.05 -2*2.108 )
  = 19.0500 mm.
```

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
```
  = 2 * ro + dt = 2 * 571.12 + 19.05 = 1161.29 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 = 1161.2899/2 = 580.645 mm.
```

Compute the Effective Tube Pitch [p*]:
```
  = p / sqrt( 1 - 4 * min( AL * CNV_factor, 4*Do*p)/(Pi * Do^2) )
  = 24.0/sqrt( 1 - 4 * min( 479.0 *100.0, 4*1161.29 *24.0 )/( 3.141 * 1161.29^2) )
  = 24.5618 mm.
```

Compute the Effective Ligament Efficiency for Bending [mu*]:
```
  = (p* - d*)/p* = (24.5618 - 19.05 )/24.5618 = 0.2244
```

Compute the Ratio [Rhos]:
```
  = as/ao = 590.0/580.645 = 1.016111
```

Compute the Ratio [Rhoc]:
```
  = ac/ao = 623.5342/580.645 = 1.073865
```

Compute Parameter [xt]:
```
  = 1 - Nt * (( dt - 2 * tt )/( 2 * ao ))^2
  = 1 - 1802 * ((19.05 - 2 * 2.108 )/(2 * 580.645 ))^2 = 0.706
```

Determine Parameter [xs]:
```
  = 1 - Nt*( dt/(2*ao) )^2
  = 1 - 1802 *( 19.05/(2*580.645 ) )^2 = 0.5151
```

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 * 15.0 ( 1180.0 + 15.0 ).19308E+09/4840.0
  = 2246438912.0000 KPa. * mm.
```

Determine the Axial Tube Stiffness [Kt]:
```
  = pi * tt( Dt - tt )Et/L
  = 3.1416 * 2.108 ( 19.05 - 2.108 ).19308E+09/4840.0
  = 4475801.0000 KPa. * mm.
```

Compute the Stiffness Factor [Ks,t]:
```
  = Ks/( Nt * Kt ) = 0.22464E+1/( 1802 * 4475801 ) = 0.27853
```

Rigidty Ratio [J]:
```
  = 1 / ( 1 + Ks/Kj )
  = 1/(1 + 0.22464E+1/0.0 ) = 1. (= 1 if No Exp. Jt.)
```

Compute Shell Coefficient [betas]:
```
  = (( 12 * (1-nus²))^0.25 )/((Ds + ts) * ts )^0.5
  = (( 12 * (1 - 0.3²) )^0.25 )/(( 1180.0 + 15.0 ) * 15.0 )^0.5
  = 0.0136 1/mm.
```

Determine Shell Coefficient [ks]:
```
  = betas * Es * ts³ / ( 6 * (1 - nus²) )
  = 0.014 * 0.19308E+09 * 15.0³/( 6 * (1 - 0.3²) )
  = 16204597.0000 bars*mm.²
```

Determine Shell Coefficient [Lambdas]:
```
  = (6*Ds*ks)/(h³) * (1 + h*betas + 0.5*(h*betas)²)
  = 6*1180.0 *16204597/(80.0³) * ( 1 + 80.0 * 0.014 + 0.59 )
  = 599669.1250 bars
```

Determine Shell Coefficient [deltaS]:
```
  = Ds²/(4 * Es * Ts) * ( 1 - nus/2 )
  = 1180.0²/( 4 * 0.19308E+09 * 15.0 ) * ( 1 - 0.3/2 )
  = 0.1021587178 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 =   3.333333 ;  mu* =   0.224406
  E*/E =   0.184708 ;  nu* =   0.425544 ;  E* = 35662968. KPa.
```

Note: As h/p (3.333) is > 2, data values for h/p = 2 were used.

Compute the Tube Bundle Stiffness Factor [Xa]:
```
  = ((24 *(1 - nu*²)*Nt * Et* tt* (dt - tt)* ao²) /
    ( E* * L * H³ ) )^0.25
  = ((24 *(1 - 0.426²)*1802 *.19308E+09*2.108 *
    (19.05 - 2.108 )*580.645²)/( 35662968 *
    4840.0 * 80.0³ ))^0.25
  = 5.5248
```

Values from Table UHX-13.1
```
  Zd =       0.008877 ;  Zv =       0.032485 ;  Zm =       0.257682
  Za =   0.455082E+02 ;  Zw =       0.032485
```

UHX-13.5.4 Step 4:

Compute the Diameter Ratio [K]:
```
  = A/Do = 1350.0/1161.2899 = 1.1625
```

Compute Coefficient [F]:
```
  = (1 - nu*) / (E*) * ( Lambdas + Lambdac + E * ln(K) )
  = (1 - 0.43 )/(35662968 ) * ( 599669 + 0.0 +
    0.19308E+09 * ln(1.16 ) )
  = 1.4342
```

Compute Parameter [Phi]:
```
  = (1 + nu*) * F = (1 + 0.4255 ) * 1.4342 = 2.0446
```

Compute Parameter [Q1]:
```
  = (Rhos - 1 - Phi * Zv)/(1 + Phi * Zm)
  = (1.0161 - 1 - 2.0446 * 0.0325 )/(1 + 2.0446 * 0.2577 )
  = -0.032947633
```

Compute Parameter [Qz1]:
$= (Zd + Q1*Zw)/2 *Xa^4$
$= (0.00888 + -0.03295 * 0.03248)/2 *5.52477^4 = 3.6367$

Compute Parameter [Qz2]:
$= (Zv + Q1*Zm)/2 *Xa^4$
$= (0.03248 + -0.03295 * 0.25768)/2 *5.52477^4 = 11.1775$

Compute Parameter [U]:
$= (Zw + (Rhos - 1)*Zm)*Xa^4 / (1 + Phi*Zm)$
$= (0.0325 + (1.0161 - 1)* 0.2577)*5.52477^4/(1 + 2.0446 * 0.2577)$
$= 22.3551$

UHX-13.5.5 Step 5:

Determine factor [gamab]:
= (Gc - C) / Do (config b)
= (1247.0685 - 1298.0)/1161.2899 = -0.04386

Compute Parameter [gamma]:
= 0.000 mm. (For Pressure only cases)

Calculate Parameter [OmegaS]:
= rhos * ks * Betas * deltaS(1 + h * Betas)
= 1.0161 * 16204597 * 0.0136 * 0.102159 (1 + 80.0 * 0.0136)
$= 4765.0288$ mm.^{2}

Calculate Parameter [Omega*S]:
$= Ao^2 * (Rhos^2 - 1) * (Rhos - 1) / 4 - OmegaS$
$= 580.645^2 * (1.016^2 - 1) * (1.016 - 1)/4 - 4765.029$
$= -4720.9180$ mm.^{2}

Calculate Parameter [OmegaC]:
= rhoc * kc * Betac * deltaC(1 + h * Betac)
= 1.0739 * 0.0 * 0.0 * 0. (1 + 80.0 * 0.0)
$= 0.0000$ mm.^{2}

Calculate Parameter [Omega*C]:
$= ao^2[(Rhoc^2+1)*(Rhoc-1)/4 -(Rhos-1)/2]- OmegaC$
$= 580.64496^2[(1.07386^2+1)*(1.07386 -1)/4 -(1.01611 -1)/2]- 0.$
$= 10689.4580$ 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]:
$= Ps * \{xs + 2(1 - xs)nut + [2/Kst(Ds/Do)^2]nus - [(rhos^2-1)/(J*Kst)]-[(1-J)/(2J*Kst)][(Dj^2-(Ds)^2)/Do^2]\}$
$= 23.0 * \{ 0.515 + 2(1 - 0.515) 0.3 + [2/0.279 (1180.0/1161.29)^2] 0.3 - [(1.016^2-1)/(1.0 * 0.279)] - [(1 - 1.0)/(2 * 1.0 * 0.279)][(0.0^2-(1180.0)^2)/1161.29^2]\}$
= 67.0121 bars

Compute the Pressure [P't]:
= [xt + 2(1 - xt)nut + 1/(J * Kst)]*Pt

```
  = [ 0.706 + 2(1 - 0.706 ) 0.3 +
    1/(1. * 0.279 ) ]* 23.0
  = 102.8719 bars
```

Compute the Pressure [Pgama]:

```
  = Nt * Kt * gama / ( pi * ao² )
  = 1802 * 4475801 * 0.0/(3.142 * 580.645²) = 0.0 bars
```

Compute the Pressure [Pw]:

```
  = -gamab * U * W* / (2 * pi * ao²)
  = --0.044 * 22.355 * 3444.83/(2 * 3.142 * 580.645²)
  = 15.9441 bars
```

Calculate the Pressure [Prim]:

```
  = -( U/ao²)(Omega*S * Ps - Omega*C * Pt )
  = -( 22.355/580.645²)(-7.317 * 23.0 - 16.569 * 23.0 )
  = 23.5015 bars
```

Calculate the Pressure [POmega]:

```
  = U/ao²(OmegaS * P*s - OmegaC * P*c )
  = 22.355/580.645²( 7.3858 * 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 * 0.279/(1 + 1.0 * 0.279 *(3.637 + (1.016 -
    1) * 11.178 )) * (67.012 - 102.872 + 0.0 + 15.944 + 23.502 )
  = 0.4841 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)
  = [( ( -4720.918 * 23.0 - 10689.458 * 23.0 ) -
    ( 4765.029 * 0.0 - 0.0 * 0.0 )) * 0. +
    3444.8 * -0.044/(2*3.141)]/(1 + 2.04457 * 0.25768 )
  = -38.961647034 kN
```

Calculate Factor [Q3]:

```
  = Q1 + 2 * Q2 / ( Pe * ao² )
  = -0.033 + 2 * -38.962/( 0.484 * 580.645² )
  = -4.807294
```

Fm Value from Table UHX-13.1 = 2.403647

The Tubesheet Bending Stress - Original Thickness [Sigma]:

```
  = (1.5 * Fm / mu* ) * (2 * ao/(H - h'g)² * Pe
  = (1.5 * 2.4036/0.2244 ) * (2 * 580.645/(80.0 - 5.0 ))² * 0.48
  = 186.4901 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 * 1.3604/0.2244 ) * (2 * 580.645/(75.699 - 5.0 ))² * 0.84
  = 206.8439 N./mm^2
```

Reqd Tubesheet Thickness, for Bending Stress (Including CA) [HReqB]:

```
  = h + Cats + Catc = 75.6992 + 0.0 + 0.0 = 75.6992 mm.
```

UHX-13.5.8 Step 8:

Shear Stress check [Tau_limit]:
```
  = 1.6 * S * MU * h / ao
  = 1.6 * 137.9 * 0.206 * 80.0/580.64
  = 6.2699 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.)= 5.1216 mm.
  Tubesheet Shear Stress           = 73.8959 N./mm^2
```

Reqd Tubesheet Thickness for Given Loadings (Including CA) [Hreqd] :
```
  = Max( HreqB, HreqS ) = Max( 75.6992, 5.1216 ) = 75.6992 mm.
```

UHX-13.5.9 Step 9:

The Ftmin and Ftmax Coefficients from Table UHX-13.2:
```
  Ftmin = -68.6108, Ftmax = 22.8356
```

First Extreme Tube Axial Stress from among all the tubes [Sigmat1]:
```
  = ( (Ps * xs - Pt * xt) - Pe * Ftmin ) / ( Xt - Xs )
  = ( (23.0 * 0.5151 - 23.0 * 0.706 ) - ( 0.484 ) * -68.611 )/
    ( 0.706 - 0.5151 ) )
  = 15.1016 N./mm^2
```

Second Extreme value of Tube Axial Stress from among all the tubes [Sigmat2]:
```
  = ( (Ps * xs - Pt * xt) - Pe * Ftmax ) / ( Xt - Xs )
  = ( (23.0 * 0.5151 - 23.0 * 0.706 ) - ( 0.484 ) * 22.836 )/
    ( 0.706 - 0.5151 ) )
  = -8.0919 N./mm^2
```

Maximum Tube Axial Stress [Sigmat,max]:
```
  = MAX( abs(Sigmat1), abs(Sigmat2) ) = 15.102 N./mm^2
```

The Allowable Tube Stress, [SigmatA]:
```
  = Sot = 117.9045 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*( 0.009 + -4.807 * 0.032 )*5.525^4), 1.25 )
  = 2.0000 (Should be <= 2 )
```

Determine the Factor [rt]:
```
  = ( ( dt² + (dt - 2*tt)² ).5 )/4
  = ( (19.05² + (19.05 - 2*2.108 )² ).5 )/4 = 6.0361 mm.
```

Determine the Factor [Ct]:
```
  = ( 2 * PI² * Et/Syt )^0.5
  = ( 2 * 3.14² * 0.19308E+09/208 )^0.5 = 135.3227
```

Determine the Factor [Ft]:
```
  = k * L/r = 0.8 * 1354.0/6.036 = 179.4539
```

The Buckling Allowable Stress [Stb]:
```
  = 1/Fs * PI²*Et/(Ft²) (Ct <= Ft)
  = 1/2.0 * 3.14²*.19308E+09/(179.4539²)
```

```
  = 29.588 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 = 15.1 * 1.122 = 1.69 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 ) * 117.9 = 13.228 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 ) * 117.9
  = 6.1280  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 ) * 117.9
  = 9.4706  kN

 Max. Allow. Tube-Tubesheet Joint load, Lmax
  = Ft = 13.2275 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, 13.23 is >= tube strength 13.23 kN
```

Note: This tube-tubesheet joint is a Full Strength joint

UHX-13.5.10 Step 10:

Shell Axial Membrane Allowable Stress:

```
  = Ss * Esw = 137.9 * 1.0 = 137.9 N./mm^2
```

Axial Membrane Stress in Shell [Sigmas,m]:

```
  = ao²/((Ds+ts)*ts)* [Pe + (Rhos²-1)(Ps-Pt)]+ as²*Pt/((Ds+ts)*ts)
  = 580.645²/((1180.0 +15.0 )*15.0 )* [ 0.48 + (1.016²-1)
    (23.0 -23.0 )] + 590.0²*23.0/((1180.0 +15.0 )
    * 15.0 )
  = 45.5787 N./mm^2
```

UHX-13.5.11 Step 11:

Note:
For a given Shell thickness of 15.0 mm., the minimum Shell
length adjacent to the tubesheet should be 239.474 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)
  = 580.645²/((1180.0 +15.0 )*15.0 )[ 0.48 + (1.016²-1)
    (23.0 -23.0 )] + 590.0²*23.0/((1180.0 +15.0 )
    * 15.0 )
  = 45.5787 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 * 16204597/15.0² { 0.014 [ 0.102 * 23.0 + 590.0²
    * 0.0/(.28962E+1 ) ] +
    6(1 - 0.43²)/(35662968 )(580.64/80.0 )³(1 + 80.0 *
    0.01/2)[ 0.5 ( 0.032 + 0.258 * -0.033 ) +
    2/580.64² * 0.258 * -38.962 ] }
  = -67.2638 N./mm^2
```

Shell Stress Summation vs. Allowable

```
  abs(Sigmasm) + abs(Sigmasb) <= 1.5 * Ss
  abs(45.6 ) + abs(-67.3 ) <= 206.85 N./mm^2
  112.84 must be < or = 206.85 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	186.5	<=	206.9 N./mm^2	Ok
Tubesheet Shear Stress	0.9	<=	110.3 N./mm^2	Ok
Maximum Tube Stress	15.1	<=	117.9 N./mm^2	Ok
Minimum Tube Stress (Buckling)	-8.1	<=	-29.6 N./mm^2	Ok
Maximum Force on any one Tube	1.7	<=	13.2 kN	Ok
Axial Membrane Stress in Shell	45.6	<=	137.9 N./mm^2	Ok
Shell Stress (jt. inter.)	112.8	<=	206.9 N./mm^2	Ok

Thickness Results for Loadcase D3 un-corr. (Psd,max + Ptd,max):

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	75.699	80.000	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	70.629	31.350	171	207	18	110	Ps+Pt-Th	D1	Ok
D2uc	36.720	...	58	207	19	110	Ps+Pt-Th	D2	Ok
D3uc	75.699	...	186	207	1	110	Ps+Pt-Th	D3	Ok
D4uc	8.285	...	5	207	...	110	Ps+Pt-Th	D4	Ok
O1uc	34.589	...	173	428	29	110	Ps+Pt+Th	O1	Ok
O2uc	31.848	...	109	428	10	110	Ps+Pt+Th	O2	Ok
O3uc	40.872	...	167	428	11	110	Ps+Pt+Th	O3	Ok
O4uc	11.727	...	73	428	8	110	Ps+Pt+Th	O4	Ok
D1c	78.222	31.350	199	207	19	110	Ps+Pt-Th-c	D1	Ok

D2c	34.078	...	48	207	20	110	Ps+Pt-Th-c D2	Ok
D3c	79.272	...	203	207	...	110	Ps+Pt-Th-c D3	Ok
D4c	10.429	...	5	207	...	110	Ps+Pt-Th-c D4	Ok
O1c	48.502	...	210	428	29	110	Ps+Pt+Th-c O1	Ok
O2c	40.611	...	125	428	12	110	Ps+Pt+Th-c O2	Ok
O3c	51.337	...	199	428	10	110	Ps+Pt+Th-c O3	Ok
O4c	31.835	...	90	428	6	110	Ps+Pt+Th-c O4	Ok
Max:	79.2725	31.350	mm.	0.982		0.261	(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	24	137	...	...	...	...	...	...	Ok
D2uc	19	137	...	...	...	...	...	...	Ok
D3uc	46	137	...	...	...	...	...	...	Ok
D4uc	2	137	-2	-102	...	...	...	...	Ok
O1uc	13	452	...	...	...	...	...	...	Ok
O2uc	12	452	...	...	...	...	...	...	Ok
O3uc	33	452	...	...	...	...	...	...	Ok
O4uc	9	452	-9	-102	...	...	...	...	Ok
D1c	30	137	...	...	...	...	...	...	Ok
D2c	24	137	...	...	...	...	...	...	Ok
D3c	57	137	...	...	...	...	...	...	Ok
D4c	2	137	-2	-98	...	...	...	...	Ok
O1c	18	452	...	...	...	...	...	...	Ok
O2c	17	452	...	...	...	...	...	...	Ok
O3c	44	452	...	...	...	...	...	...	Ok
O4c	8	452	-8	-98	...	...	...	...	Ok
Max RATIO		0.412		0.083		...		...	

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	25	117	-15	-47	3	13	284	452	...	...	Ok
D2uc	10	117	-10	-34	1	13	212	452	...	...	Ok
D3uc	15	117	-8	-29	2	13	113	206	...	...	Ok
D4uc	1	117	-1	-47	...	13	2	206	...	...	Ok
O1uc	37	235	-15	-47	4	26	322	452	...	...	Ok
O2uc	7	235	...	...	1	26	72	452	...	...	Ok
O3uc	28	235	-9	-47	3	26	158	452	...	...	Ok
O4uc	16	235	-3	-47	2	26	132	452	...	...	Ok
D1c	30	117	-15	-47	3	13	324	452	...	...	Ok
D2c	12	117	-12	-39	1	13	265	452	...	...	Ok
D3c	18	117	-9	-29	2	13	108	206	...	...	Ok
D4c	1	117	-1	-47	...	13	3	206	...	...	Ok
O1c	41	235	-16	-47	5	26	358	452	...	...	Ok
O2c	7	235	...	...	1	26	117	452	...	...	Ok
O3c	30	235	-9	-47	3	26	151	452	...	...	Ok
O4c	16	235	-3	-47	2	26	140	452	...	...	Ok
Max RATIO	0.251		0.338		0.251		0.791			...	

Summary of Thickness Comparisons for 16 Load Cases:

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	79.272	80.000	Ok
Tubesheet Thickness Flanged Extension :	31.350	64.000	Ok
Tube Thickness :	0.488	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, (15.000) adj. to tubesheet: 239.474 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 : -0.654 mm.
Due to Pressure Shell Compresses by : -0.069 mm.
Due to Pressure + Thermal Shell Compresses by : -0.722 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	23.939	1.000	78.953	1.000
Tubesheet Shear Stress	115.349	1.000	136.697	1.000
Tube Tensile Stress	93.185	1.000	244.176	1.000
Tube Compressive Stress	55.947	0.759	78.726	1.000
Tube-Tubesheet Joint load	93.185	1.000	244.176	1.000
Shell Stress (Axial, Junction)	23.939	1.000	40.431	1.000
Tube Pressure Stress	286.263	1.000	184.962	1.000
Tubesheet Extension Stress	23.641	...	No Calc	No Calc
Minimum MAWP	23.641		40.431	

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	27.750	0.998	78.953	1.000
Tubesheet Shear Stress	151.232	1.000	143.924	1.000
Tube Tensile Stress	110.058	1.000	284.315	1.000

Tube Compressive Stress	80.543	1.000	85.595	1.000
Tube-Tubesheet Joint load	110.058	1.000	284.315	1.000
Shell Stress (Axial, Junction)	27.750	0.998	58.967	1.000
Tube Pressure Stress	286.263	1.000	192.052	1.000
Tubesheet Extension Stress	23.641	...	No Calc	No Calc
Minimum MAPnc	23.641		58.967	

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( 80.0/4, min( 80.0, 15.0 ) )
  = 20.000 mm.
```

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

Impact Test Temperature provided per Specification -46 °C

Channel Side MDMT calculation:

Governing thickness for the channel side:
```
  = tubesheet thickness/4
  = 80.0/4
  = 20.000 mm.
```

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

Impact Test Temperature provided per Specification -46 °C

where the MDMT reduction ratio per UCS 66 (b)(1)(b) is:
```
  = max( pt/Tubeside MAPnc, ps/Shellside MAPnc ), must be <= 1
  = max( 23.0/23.64, 23.0/58.97 )
  = 0.973
```

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]	!	-45			0.835	15.000	1.00	No
S2	[1]	D	-47	-48	-29	0.835	15.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
S1	[1]	!	-46	-46		0.833	12.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
S3	[1]	!	-46	-46		0.833	15.000	1.00	No
Nozzle Flg	[5]	!	-46	-48					
Tubesheet: SS	[13]	!	-46	-46		0.973	20.000	1.00	No
Warmest MDMT:			-45	-46					
BODY FLANGE 0	[11]	!	-46	-46		0.978	15.000	1.00	No
BODY FLANGE 0	[11]	!	-46	-46		0.990	15.000	1.00	No
HEAD 1	[10]	D	-48	-48	-29	0.989	13.000	1.00	No
HEAD 1	[7]	D	-47	-48	-29	0.837	15.000	1.00	No
CHANNEL 01	[8]	D	-47	-48	-29	0.838	15.000	0.85	No
CHANNEL 002	[8]	D	-47	-48	-29	0.837	15.000	1.00	No
HEAD 002	[10]	D	-48	-48	-29	0.989	13.000	1.00	No
HEAD 002	[7]	D	-47	-48	-29	0.837	15.000	1.00	No
T1	[1]	!	-46	-46		0.837	15.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
T2	[1]	!	-46	-46		0.833	15.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
T4	[1]	D	-48	-104		0.019	14.250	1.00	No
Nozzle Flg	[5]	!	-46	-48					
T3	[1]	D	-48	-104		0.023	14.300	1.00	No
Nozzle Flg	[5]	!	-46	-48					
Tubesheet: CS	[14]	!	-46	-46		0.973	20.000	1.00	No
Warmest MDMT:			-46	-46					

Exchanger Side	Computed MDMT °C	Required MDMT °C	Pass/Fail
Shell	-45	-45	Pass
Channel/Tube	-46	-45	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.

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for CONDENSER E-PK6101-2
Vessel Design Summary: Step: 24 10:31pm Feb 6,2022

ASME Code, Section VIII Division 1, 2017

Diameter Spec : 1180.000 mm. ID		
Vessel Design Length, Tangent to Tangent	6456.35	mm.
Specified Datum Line Distance	50.00	mm.
Shell Material	SA-516 70	[Normalized]
Nozzle Material	SA-333 6	[Impact Tested]
Nozzle Material	SA-350 LF2	[Impact Tested]
Re-Pad Material	SA-516 70	[Normalized]
Shell Side Design Temperature	125	°C
Channel Side Design Temperature	190	°C
Shell Side Design Pressure	23.000	bars
Channel Side Design Pressure	23.000	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	23.115	1.10No Calc	70	3.0000	No
CHANNEL 01	23.115	1.10No Calc	70	3.0000	N/A
BODY FLANGE 01	23.115	1.10No Calc	70	3.0000	N/A
SHELL	23.054	1.10No Calc	70	3.0000	N/A
BODY FLANGE 002	23.115	1.10No Calc	70	3.0000	N/A
CHANNEL 002	23.115	1.10No Calc	70	3.0000	N/A
HEAD 002	23.115	1.10No Calc	70	3.0000	No

Liquid Level: 1180.00 mm. Dens.: 0.001 kg./cm^3 Sp. Gr.: 0.994

Element Types and Properties:

Element Type	"To" Elev mm.	Length mm.	Element Thk mm.	R e q d Int.	T h k Ext.	Joint Eff Long	Circ
Ellipse	0.0	50.0	15.0	12.9	6.3	1.00	0.85
Cylinder	749.0	749.0	15.0	14.8	6.5	0.85	0.85
Body Flg	895.0	146.0	110.0	108.7	69.8	1.00	1.00
Cylinder	5825.2	4844.0	15.0	13.0	10.1	1.00	1.00
Body Flg	5977.4	146.0	110.0	109.5	70.2	1.00	0.85
Cylinder	6356.3	299.0	15.0	13.0	5.7	1.00	1.00
Ellipse	6406.3	50.0	15.0	12.9	6.3	1.00	0.85

Element thicknesses are shown as Nominal if specified, otherwise are Minimum

Saddle Parameters:

Saddle Width	172.000	mm.
Saddle Bearing Angle	120.000	deg.
Centerline Dimension	950.000	mm.
Wear Pad Width	305.000	mm.
Wear Pad Thickness	15.000	mm.
Wear Pad Bearing Angle	132.000	deg.
Distance from Saddle to Tangent	992.000	mm.
Baseplate Length	1050.000	mm.

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for CONDENSER E-PK6101-2
Vessel Design Summary: Step: 24 10:31pm Feb 6,2022

Baseplate Thickness	20.000	mm.
Baseplate Width	220.000	mm.
Number of Ribs (including outside ribs)	4	
Rib Thickness	15.000	mm.
Web Thickness	15.000	mm.
Height of Center Web	331.000	mm.
Number of Bolts in Baseplate	4	

Baseplate Sketch

```
|------------------- 1050.000 mm. -------------------|
------------------------------------------------------ ---
|                                                    |
|                                                    | 220.000 mm.
|                                                    |
------------------------------------------------------ ---
```

Baseplate Plan View

```
------------------------------------------------------ ---
|                                                    | 20.000 mm.
------------------------------------------------------ ---
```

Baseplate Side View

Maximum Tensile Bolt Load	14.	kN

Summary of Maximum Saddle Loads, Operating Case :

Maximum Vertical Saddle Load	306.86	kN
Maximum Transverse Saddle Shear Load	71.71	kN
Maximum Longitudinal Saddle Shear Load	143.41	kN

Summary of Maximum Saddle Loads, Hydrotest Case :

Maximum Vertical Saddle Load	116.43	kN
Maximum Transverse Saddle Shear Load	0.99	kN
Maximum Longitudinal Saddle Shear Load	0.51	kN

Weights:

Fabricated	- Bare W/O Removable Internals	14572.5	kg.
Shop Test	- Fabricated + Water (Full)	20943.7	kg.
Shipping	- Fab. + Rem. Intls.+ Shipping App.	14572.5	kg.
Erected	- Fab. + Rem. Intls.+ Insul. (etc)	14855.3	kg.
Empty	- Fab. + Intls. + Details + Wghts.	14855.3	kg.
Operating	- Empty + Operating Liquid (No CA)	19254.7	kg.
Field Test	- Empty Weight + Water (Full)	20647.0	kg.

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2
PV Elite 2018 SP2 Licensee: SPLM Licensed User
FileName : Calculation Book for CONDENSER E-PK6101-2
Vessel Design Summary: Step: 24 10:31pm Feb 6,2022

Results were generated with the finite element program FE/Pipe®. Stress results are post-processed in accordance with the rules specified in ASME Section III and ASME Section VIII, Division 2.

Analysis Time Stamp: Tue Feb 06 22:21:30 2018.

```
Model Notes
Model Notes

  Input Echo:

  Model Type                   : Cylindrical Shell

  Parent Geometry
         Parent Outside Diam.   :    1210.000 mm.
         Thickness              :      12.000 mm.

  Parent Properties:
         Cold Allowable         :       174.4 MPa
         Hot  Allowable         :       156.5 MPa
         Material DB # 7005218.
         Ultimate Tensile (Amb) :       482.6 MPa
         Yield Strength (Amb)   :       262.0 MPa
         Yield Strength (Hot)   :       235.1 MPa
         Elastic Modulus (Amb)  :    202720.0 MPa
         Poissons Ratio         :       0.300
         Expansion Coefficient  :  0.1227E-04 mm./mm./deg.
         Weight Density         :  0.0000E+00  N /cu.mm.(NOT USED)

  Nozzle Geometry
         Nozzle Outside Diam.   :     323.800 mm.
         Thickness              :      12.290 mm.
         Length                 :     200.000 mm.
         RePad Width            :      80.000 mm.
         RePad Thickness        :      15.000 mm.
         Nozzle Tilt Angle      :       0.000 deg.
         Distance from Top      :     374.000 mm.
```

```
        Distance from Bottom   :     375.000 mm.

   Nozzle Properties
        Cold Allowable         :       160.7 MPa
        Hot  Allowable         :       144.1 MPa
        Material DB # 7002618.
        Ultimate Tensile (Amb) :       413.7 MPa
        Yield Strength (Amb)   :       241.3 MPa
        Yield Strength (Hot)   :       216.5 MPa
        Elastic Modulus (Amb)  :    202720.0 MPa
        Poissons Ratio         :       0.300
        Expansion Coefficient  :  0.1227E-04 mm./mm./deg.
        Weight Density         :  0.0000E+00  N /cu.mm. (NOT USED)

   Design Operating Cycles     :       7000.
   Ambient Temperature (Deg.)  :       21.10
```

Uniform thermal expansion produces no stress in this geometry. Any thermal loads will come through operating forces and moments applied through the nozzle.

```
   Nozzle Inside  Temperature  :      125.00 deg.
   Nozzle Outside Temperature  :      125.00 deg.
   Vessel Inside  Temperature  :      125.00 deg.
   Vessel Outside Temperature  :      125.00 deg.

   Nozzle Pressure             :       2.300 MPa
   Vessel Pressure             :       2.300 MPa

   Operating Pressure          :         2.3 MPa
```

The operating pressure is used for secondary and peak stress cases. The design pressure is used for primary cases. The ratio of the operating/design pressure = 1.000

User Defined Load Input Echo:
Loads are given at the End of Nozzle
Loads are defined in Global Coordinates

Forces(N) Moments (N-m)

Load Case	FX	FY	FZ	MX	MY	MZ
WEIGHT:	12000.0	12000.0	12000.0	15300.0	15300.0	18900.0

FEA Model Loads:
These are the actual loads applied to the FEA model.
These are the User Defined Loads translated to the end of the nozzle and reported in global coordinates.

Forces(N) Moments (N-m)

Load Case	FX	FY	FZ	MX	MY	MZ
WEIGHT:	12000.0	12000.0	12000.0	15300.0	15300.0	18900.0

The "top" or "positive" end of this model is "free" in the axial and translational directions.

Stresses ARE nodally AVERAGED.

No weld dimensions have been given for the nozzle connection to the shell. This will produce conservative results for external loads and may tend to produce more realistic inside surface pressure stresses.

No pad weld dimensions have been given for the pad connection to the shell. Few correlations have been performed to investigate the sensitivity of peak stresses to this value. Reasonable lengths have been assumed.

```
   Vessel Centerline  Vector   :  0.000   1.000   0.000
   Nozzle Orientation Vector   :  1.000   0.000   0.000
```

Table of Contents

```
Load Case Report
FE/Pipe Version 10.0          Jobname: NOZZLE              $P
Released Nov 2017             10:21pm  FEB  6,2018



Load Case Report                                     $X

Inner and outer element temperatures are the same
throughout the model.  No thermal ratcheting
calculations will be performed.

THE   9  LOAD CASES ANALYZED ARE:

  1   WEIGHT ONLY    (Wgt Only)

      Weight ONLY case run to get the stress range
      between the installed and the operating states.

      /-------- Loads in Case   1
        Loads due to Weight

  2   SUSTAINED      (Wgt+Pr)

      Sustained case run to satisfy local primary
      membrane and bending stress limits.

      /-------- Loads in Case   2
        Loads due to Weight
        Pressure Case    1

  3   OPERATING

      Case run to compute the operating stresses used in
      secondary, peak and range calculations as needed.

      /-------- Loads in Case   3
        Pressure Case    1
        Loads from (Operating)

  4   RANGE          (Fatigue Calc Performed)

      Case run to get the RANGE of stresses.
      as described in NB-3222.2, 5.5.3.2, 5.5.5.2 or 5.5.6.1.

      /-------- Combinations in Range Case   4
        Plus  Stress Results from CASE   3
        Minus Stress Results from CASE   1

  5   Program Generated -- Force Only

      Case run to compute sif's and flexibilities.
      /-------- Loads in Case   5
        Loads from (Axial)

  6   Program Generated -- Force Only

      Case run to compute sif's and flexibilities.
      /-------- Loads in Case   6
        Loads from (Inplane)

  7   Program Generated -- Force Only

      Case run to compute sif's and flexibilities.
      /-------- Loads in Case   7
        Loads from (Outplane)
```

8 Program Generated -- Force Only

Case run to compute sif's and flexibilities.
/-------- Loads in Case 8
Loads from (Torsion)

9 Program Generated -- Force Only

Case run to compute sif's and flexibilities.
/-------- Loads in Case 9
Pressure Case 1

Table of Contents

Solution Data
FE/Pipe Version 10.0 Jobname: NOZZLE $P
Released Nov 2017 10:21pm FEB 6,2018

Solution Data

Maximum Solution Row Size = 594
Number of Nodes = 1980
Number of Elements = 652
Number of Solution Cases = 8

Summation of Loads per Case

Case #	FX	FY	FZ
1	12000.	12001.	12000.
2	-1557.	2604255.	12000.
3	-13557.	2592255.	0.
4	1658537.	0.	0.
5	0.	6.	0.
6	0.	0.	-4.
7	0.	0.	0.
8	-13557.	2592255.	0.

Table of Contents

ASME Code Stress Output Plots
FE/Pipe Version 10.0 Jobname: NOZZLE $P
Released Nov 2017 10:21pm FEB 6,2018

ASME Code Stress Output Plots $X

1) Pl < SPL (SUS,Membrane) Case 2

2) Qb < SPS (SUS,Bending) Case 2

3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

8) Membrane < User (OPE,Membrane) Case 3

9) Bending < User (OPE,Bending) Case 3

10) S1+S2+S3 < 4S (OPE,S1+S2+S3) Case 3

11) Pl+Pb+Q+F < Sa (SIF,Outside) Case 5

12) Pl+Pb+Q+F < Sa (SIF,Outside) Case 6

13) Pl+Pb+Q+F < Sa (SIF,Outside) Case 7

14) Pl+Pb+Q+F < Sa (SIF,Outside) Case 8

15) Pl+Pb+Q+F < Sa (SIF,Outside) Case 9

16) Pl+Pb+Q < SPS (EXP,Inside) Case 4

17) Pl+Pb+Q < SPS (EXP,Outside) Case 4

18) Pl+Pb+Q+F < Sa (EXP,Inside) Case 4

19) Pl+Pb+Q+F < Sa (EXP,Outside) Case 4

Table of Contents

```
Stress Results - Notes
FE/Pipe Version 10.0          Jobname: NOZZLE              $P
Released Nov 2017             10:21pm  FEB  6,2018
```

Stress Results - Notes

- Results in this analysis were generated using the finite element solution method.

- Using 2013-2015 ASME Section VIII Division 2

- Use Polished Bar fatigue curve.

- Ratio between Operating and Design Pressure = 1.000000
  Assume pressure increases all other stresses.

- Assume free end displacements of attached pipe (e.g. thermal loads) are secondary within the limits of nozzle reinforcement.

- Use Equivalent Stress (Von Mises).

- Include S1+S2+S3 evaluation for operating stress.
  Include S1+S2+S3 evaluation in primary case evaluation.
  Assume bending stress not local primary for S1+S2+S3.

- Use local tensor values for averaged and not averaged stresses.

Table of Contents

```
ASME Overstressed Areas
FE/Pipe Version 10.0          Jobname: NOZZLE              $P
Released Nov 2017             10:21pm  FEB  6,2018
```

ASME Overstressed Areas $X

*** NO OVERSTRESSED NODES IN THIS MODEL ***

Table of Contents

Highest Primary Stress Ratios
FE/Pipe Version 10.0 Jobname: NOZZLE $P
Released Nov 2017 10:21pm FEB 6,2018

Highest Primary Stress Ratios $X

Pad/Header at Junction

Pl	SPL	Primary Membrane Load Case 2
165	235	Plot Reference:
MPa	MPa	1) Pl < SPL (SUS,Membrane) Case 2

70%

Branch at Junction

Pl	SPL	Primary Membrane Load Case 2
177	216	Plot Reference:
MPa	MPa	1) Pl < SPL (SUS,Membrane) Case 2

81%

Branch Transition

Pl	SPL	Primary Membrane Load Case 2
65	216	Plot Reference:
MPa	MPa	1) Pl < SPL (SUS,Membrane) Case 2

29%

Pad Outer Edge Weld

Pl	SPL	Primary Membrane Load Case 2
151	235	Plot Reference:
MPa	MPa	1) Pl < SPL (SUS,Membrane) Case 2

64%

Header Outside Pad Area

Pl	SPL	Primary Membrane Load Case 2
117	235	Plot Reference:
MPa	MPa	1) Pl < SPL (SUS,Membrane) Case 2

49%

Table of Contents

```
Highest Secondary Stress Ratios
FE/Pipe Version 10.0          Jobname: NOZZLE              $P
Released Nov 2017             10:21pm  FEB  6,2018



Highest Secondary Stress Ratios                         $X


Pad/Header at Junction

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 2
      181            497     Plot Reference:
      MPa            MPa     3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

            36%


Branch at Junction

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 4
      341            458     Plot Reference:
      MPa            MPa     17) Pl+Pb+Q < SPS (EXP,Outside) Case 4

            74%


Branch Transition

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 4
       95            458     Plot Reference:
      MPa            MPa     17) Pl+Pb+Q < SPS (EXP,Outside) Case 4

            20%


Pad Outer Edge Weld

  Pl+Pb+Q            SPS     Primary+Secondary (Outer) Load Case 2
      318            497     Plot Reference:
      MPa            MPa     4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

            63%


Header Outside Pad Area

  Pl+Pb+Q            SPS     Primary+Secondary (Inner) Load Case 4
      164            497     Plot Reference:
      MPa            MPa     16) Pl+Pb+Q < SPS (EXP,Inside) Case 4

            32%
```

Table of Contents

```
Highest Fatigue Stress Ratios
FE/Pipe Version 10.0          Jobname: NOZZLE              $P
Released Nov 2017             10:21pm  FEB  6,2018



Highest Fatigue Stress Ratios                           $X


Pad/Header at Junction
```

```
  Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
        120     0.046 Life     Stress Concentration Factor = 1.350
        MPa     0.415 Stress   Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 153,187.
  Allowable                    "B31" Fatigue Stress Allowable = 413.6
      289.9                    Markl Fatigue Stress Allowable = 287.5
        MPa                    WRC 474 Mean Cycles to Failure = 500,446.
                               WRC 474 99% Probability Cycles = 116,258.
        41%                    WRC 474 95% Probability Cycles = 161,410.
                               BS5500 Allowed Cycles(Curve F) = 104,848.
                               Membrane-to-Bending Ratio = 2.174
                               Bending-to-PL+PB+Q Ratio = 0.315
                               Plot Reference:
                               18) Pl+Pb+Q+F < Sa (EXP,Inside) Case 4


  Branch at Junction

  Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
        230     0.465 Life     Stress Concentration Factor = 1.350
        MPa     0.794 Stress   Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 15,042.
  Allowable                    "B31" Fatigue Stress Allowable = 381.0
      289.9                    Markl Fatigue Stress Allowable = 287.5
        MPa                    WRC 474 Mean Cycles to Failure = 135,017.
                               WRC 474 99% Probability Cycles = 31,366.
        79%                    WRC 474 95% Probability Cycles = 43,547.
                               BS5500 Allowed Cycles(Curve F) = 17,434.
                               Membrane-to-Bending Ratio = 0.185
                               Bending-to-PL+PB+Q Ratio = 0.844
                               Plot Reference:
                               19) Pl+Pb+Q+F < Sa (EXP,Outside) Case 4


  Branch Transition

  Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
         48     0.000 Life     Stress Concentration Factor = 1.000
        MPa     0.164 Stress   Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 9.1563E10
  Allowable                    "B31" Fatigue Stress Allowable = 381.0
      289.9                    Markl Fatigue Stress Allowable = 287.5
        MPa                    WRC 474 Mean Cycles to Failure = 6,394,337.
                               WRC 474 99% Probability Cycles = 1,485,462.
        16%                    WRC 474 95% Probability Cycles = 2,062,378.
                               BS5500 Allowed Cycles(Curve F) = 801,334.
                               Membrane-to-Bending Ratio = 0.680
                               Bending-to-PL+PB+Q Ratio = 0.595
                               Plot Reference:
                               19) Pl+Pb+Q+F < Sa (EXP,Outside) Case 4


  Pad Outer Edge Weld

  Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Outer) Load Case 4
        209     0.344 Life     Stress Concentration Factor = 1.350
        MPa     0.720 Stress   Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 20,322.
  Allowable                    "B31" Fatigue Stress Allowable = 413.6
      289.9                    Markl Fatigue Stress Allowable = 287.5
        MPa                    WRC 474 Mean Cycles to Failure = 166,978.
                               WRC 474 99% Probability Cycles = 38,790.
        71%                    WRC 474 95% Probability Cycles = 53,856.
                               BS5500 Allowed Cycles(Curve F) = 23,380.
                               Membrane-to-Bending Ratio = 0.602
                               Bending-to-PL+PB+Q Ratio = 0.624
                               Plot Reference:
                               19) Pl+Pb+Q+F < Sa (EXP,Outside) Case 4


  Header Outside Pad Area

  Pl+Pb+Q+F    Damage Ratio    Primary+Secondary+Peak (Inner) Load Case 4
         82     0.004 Life     Stress Concentration Factor = 1.000
```

```
        MPa     0.282 Stress   Strain Concentration Factor = 1.000
                               Cycles Allowed for this Stress = 1,981,531.
  Allowable                    "B31" Fatigue Stress Allowable = 413.6
      289.9                    Markl Fatigue Stress Allowable = 287.5
        MPa                    WRC 474 Mean Cycles to Failure = 1,150,980.
                               WRC 474 99% Probability Cycles = 267,383.
        28%                    WRC 474 95% Probability Cycles = 371,228.
                               BS5500 Allowed Cycles(Curve F) = 157,115.
                               Membrane-to-Bending Ratio = 1.200
                               Bending-to-PL+PB+Q Ratio = 0.454
                               Plot Reference:
                               18) Pl+Pb+Q+F < Sa (EXP,Inside) Case 4
```

Table of Contents

```
Stress Intensification Factors
FE/Pipe Version 10.0          Jobname: NOZZLE              $P
Released Nov 2017             10:21pm  FEB  6,2018



Stress Intensification Factors                         $X


Branch/Nozzle Sif Summary
```

	Peak	Primary	Secondary	SSI
Axial :	7.359	5.451	10.902	1.621
Inplane :	4.217	3.123	6.247	1.654
Outplane:	7.270	5.385	10.770	1.616
Torsion :	0.658	0.914	0.975	0.831
Pressure:	1.345	1.160	1.993	1.096

The above stress intensification factors are to be used in a beam-type analysis of the piping system. Inplane, Outplane and Torsional sif's should be used with the matching branch pipe whose diameter and thickness is given below. The axial sif should be used to intensify the axial stress in the branch pipe calculated by F/A. The pressure sif should be used to intensify the nominal pressure stress in the PARENT or HEADER, calculated from PDo/2T. B31 calculations use mean diameters and Section VIII calculations use outside diameters. SSIs are based on peak stress factors and correlated test results.

```
Pipe OD :      323.800  mm.
Pipe Thk:       12.290  mm.
Z approx:   936667.250  cu.mm.
Z exact :   902518.250  cu.mm.
```

(SSI = SIF^x)	Axial	Inpl	Outpl	Tors	Pres
SIF/SSI Exponents:	0.850	0.791	0.849	0.215	0.501

SIF/SSI exponent based on relationship between primary and peak stress factors from the finite element analysis.

```
B31.3 Branch Pressure i-factor =       10.703
      Header Pressure i-factor =        2.717
```

The B31.3 pressure i-factors should be used with with F/A, where F is the axial force due to pressure, and A is the area of the pipe wall. This is equivalent to finding the pressure stress from (ip)(PD/4T).

```
B31.3   (Branch)
Peak Stress Sif ....    0.000         Axial
                        4.429         Inplane
                        5.564         Outplane
                        1.000         Torsional
```

B31.1 (Branch)

Peak Stress Sif	0.000	Axial
	5.564	Inplane
	5.564	Outplane
	5.564	Torsional

WRC 330 (Branch)

Peak Stress Sif	0.000	Axial
	5.432	Inplane
	5.564	Outplane
	5.432	Torsional

Table of Contents

Allowable Loads
FE/Pipe Version 10.0 Jobname: NOZZLE $P
Released Nov 2017 10:21pm FEB 6,2018

Allowable Loads $X

SECONDARY Load Type (Range):	Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force (N)	473937.	104199.	156299.
Inplane Moment (mm. N)	62068228.	9649330.	20469320.
Outplane Moment (mm. N)	36000088.	5596692.	11872376.
Torsional Moment (mm. N)	397614656.	89136664.	133705000.
Pressure (MPa)	4.28	2.30	2.30

PRIMARY Load Type:	Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force (N)	477691.	71398.	107097.
Inplane Moment (mm. N)	62559776.	6611798.	14025742.
Outplane Moment (mm. N)	36285192.	3834898.	8135048.
Torsional Moment (mm. N)	213750912.	32398472.	48597708.
Pressure (MPa)	4.02	2.30	2.30

NOTES:

1) Maximum Individual Occuring Loads are the maximum allowed values of the respective loads if all other load components are zero, i.e. the listed axial force may be applied if the inplane, outplane and torsional moments, and the pressure are zero.

2) The Conservative Allowable Simultaneous loads are the maximum loads that can be applied simultaneously. A conservative stress combination equation is used that typically produces stresses within 50-70% of the allowable stress.

3) The Realistic Allowable Simultaneous loads are the maximum loads that can be applied simultaneously. A more realistic stress combination equation is used based on experience at Paulin Research. Stresses are typically produced within 80-105% of the allowable.

4) Secondary allowable loads are limits for expansion and operating piping loads.

5) Primary allowable loads are limits for weight, primary and sustained type piping loads.

Table of Contents

```
Flexibilities
FE/Pipe Version 10.0          Jobname: NOZZLE               $P
Released Nov 2017             10:21pm  FEB  6,2018



Flexibilities                                          $X


  The following stiffnesses should be used in a piping,
  "beam-type" analysis of the intersection.  The stiff-
  nesses should be inserted at the surface of the
  branch/header or nozzle/vessel junction.  The general
  characteristics used for the branch pipe should be:

  Outside Diameter =  323.800  mm.
  Wall Thickness   =   12.290  mm.

  Axial Translational Stiffness   =        584922.   N /mm.
  Inplane Rotational Stiffness    =     319725120.  mm. N /deg
  Outplane Rotational Stiffness   =     133334600.  mm. N /deg
  Torsional Rotational Stiffness  =    5327399424.  mm. N /deg


  Intersection Flexibility Factors for Branch/Nozzle
:

  Find axial stiffness: K = 3EI/(kd)^3   N /mm.
  Find bending and torsional stiffnesses: K = EI/(kd)  mm. N per radian.
  The EI product is   0.29662E+14    N mm.^2
  The value of (d) to use is: 311.510  mm..
  The resulting bending stiffness is in units of force x length per radian.

  Axial Flexibility Factor     (k) =     1.714
  Inplane Flexibility Factor   (k) =     5.198
  Outplane Flexibility Factor  (k) =    12.464
  Torsional Flexibility Factor (k) =     0.312
```

Table of Contents