	DEHDASHT PETROCHEMICAL INDUSTRY COMPANY DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT	
NARGAN	DOCUMENT TITLE: Mechanical Calculation for Economizer	POI: IFA
Contract No.: DPIC/98-12	DOCUMENT NUMBER: DPIC9812-000-VD-1002-ME-CLN-0030	Rev. No.: D0

DOCUMENT TITLE:

Mechanical Calculation for Economizer

(E-PK6101-3)

PURCHASER'S COMMENT/APPROVAL STATUS		Purchaser: NARGAN
1	AP: Approved (Released for Manufacturing)	Requisition No.: DPIC98-12-001-000-ME-MR-4150-0001-D1
2	AN: Approved With Minor Comments (Fabrication may Proceed)	
3	NF: Approved With Comments (Fabrication not Proceed)	Item No. (Tag No.): PK-6101
4	RJ: Rejected	
5	NR: Not be Returned	Vendor Doc. No.: DPIC9812-000-VD-1002-ME-CLN-030-D0
Date:	Signature:	

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

KASRAVAND Engineering & Construction

PPI / NARGAN	DEHDASHT PETROCHEMICAL INDUSTRY COMPANY DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT	PGPIC
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Page	Rev-D0	Rev-D1	Rev-D2	Rev-D3	Rev-D4
1	x				
2	x				
3	x				
4	x				
5	x				
6	x				
7	x				
8	x				
9	x				
10	x				
11	x				
12	x				
13	x				
14	x				
15	x				
16	x				
17	x				
18	x				
19	x				
20	x				
21	x				
22	x				
23	x				
24	x				
25	x				
26	x				
27	x				
28	x				
29	x				
30	x				
31	x				
32	x				
33	x				
34	x				
35	x				

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

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

Page	Rev-D0	Rev-D1	Rev-D2	Rev-D3	Rev-D4
106	x				
107	x				
108	x				
109	x				
110	x				
111	x				
112	x				
113	x				
114	x				
115	x				
116	x				
117	x				
118	x				
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135	x				
136	x				
137	x				
138	x				
139	x				
140	x				

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY

DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT

DOCUMENT TITLE: Mechanical Calculation for Economizer

POI: IFA

Contract No.: DPIC/98-12

DOCUMENT NUMBER: DPIC9812-000-VD-1002-ME-CLN-0030

Rev. No.: D0

Page	Rev-D0	Rev-D1	Rev-D2	Rev-D3	Rev-D4
141	x				
142	x				
143	x				
144	x				
145	x				
146	x				
147	x				
148	x				
149	x				
150	x				
151	x				
152	x				
153	x				
154	x				
155	x				
156	x				
157	x				
158	x				
159	x				
160	x				
161	x				
162	x				
163	x				
164	x				
165	x				
166	x				
167	x				
168	x				
169	x				
170					
171					
172					
173					
174					
175					

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

Table of Contents

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-3 ECONOMIZER

DESIGN CALCULATION

In Accordance with ASME Section VIII Division 1

```
ASME Code Version     : 2017

Analysis Performed by : SPLM Licensed User

Job File              :

Date of Analysis      : Dec 22,2021   11:46pm

PV Elite 2019 SP1, March 2019
```

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.

Warnings and Errors: Step: 0 11:46pm Dec 22,2021

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

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

There were no geometry errors or warnings.
```

PV Elite Vessel Analysis Program: Input Data

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-3 ECONOMIZER

Exchanger Design Pressures and Temperatures

Shell Side Design Pressure	23	bars
Channel Side Design Pressure	23	bars
Shell Side Design Temperature	120.0	°C
Channel Side Design Temperature	120.0	°C
Radiography, Shell Side	RT-1	
Radiography, Channel Side	RT-1	
Service Type, Shell Side	None	
Service Type, Channel Side	None	
MDMT (CET), Shell Side	-45.0	°C
MDMT (CET), Tube Side	-45.0	°C
User defined MAWP, Shell Side	0	bars
User defined MAWP, Channel Side	0	bars
User defined MAPnc, Shell Side	0	bars
User defined MAPnc, Channel Side	0	bars
User defined Test Pres., Shell Side	0	bars
User defined Test Pres., Channel Side	0	bars

Type of Hydrotest	UG-99(b) Note [36]	
Hydrotest Position	Horizontal	
Projection of Nozzle from Vessel Top	0	mm.
Projection of Nozzle from Vessel Bottom	0	mm.
Type of Construction	Welded	
Use Higher Longitudinal Stresses (Flag)	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	

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

Input Echo: Step: 1 11:46pm Dec 22,2021

```
Wind Design Code                                      ASCE-7 2010
Wind Load Reduction Scale Factor                            0.600
Basic Wind Speed                   [V]                        195  Km/hr
Surface Roughness Category                        C: Open Terrain
Importance Factor                                             1.0
Type of Surface                                Moderately Smooth
Base Elevation                                             123000  mm.
Percent Wind for Hydrotest                                   33.0
Using User defined Wind Press. Vs Elev.                         N
Height of Hill or Escarpment     H or Hh                        0  mm.
Distance Upwind of Crest              Lh                        0  mm.
Distance from Crest to the Vessel      x                        0  mm.
Type of Terrain ( Hill, Escarpment )                         Flat
Damping Factor (Beta) for Wind (Ope)                       0.0100
Damping Factor (Beta) for Wind (Empty)                     0.0000
Damping Factor (Beta) for Wind (Filled)                    0.0000

Seismic Design Code                                   ASCE 7-2010
Seismic Load Reduction Scale Factor                         0.700
Importance Factor                                           1.500
Table Value Fa                                              1.000
Table Value Fv                                              1.300
Short Period Acceleration value Ss                          1.163
Long Period Acceleration Value Sl                           0.600
Moment Reduction Factor Tau                                 1.000
Force Modification Factor R                                 2.000
Site Class                                                      C
Component Elevation Ratio          z/h                      0.000
Amplification Factor                Ap                      0.000
Force Factor                                                0.000
Consider Vertical Acceleration                                 No
Minimum Acceleration Multiplier                             0.000
User Value of Sds (used if > 0 )                            0.000
User Value of Sd1 (used if > 0 )                            0.000

Design Pressure + Static Head                                   Y
Consider MAP New and Cold in Noz. Design                        N
Consider External Loads for Nozzle Des.                         Y
Use ASME VIII-1 Appendix 1-9                                    N

Material Database Year        Current w/Addenda or Code Year
```

Configuration Directives:

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

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

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                                     581  mm.
Element Thickness                                    10  mm.
Internal Corrosion Allowance                          3  mm.
Nominal Thickness                                    12  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]
    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                           30.988  mm.
    Yield Stress, Operating                         236  N./mm^2
    UCS-66 Chart Curve Designation                    D
    External Pressure Chart Name                   CS-2
    UNS Number                                   K02700
    Product Form                                  Plate
Efficiency, Longitudinal Seam                       1.0
Efficiency, Circumferential Seam                    1.0
Elliptical Head Factor                              2.0
Weld is pre-Heated                                   No

    Element From Node                                10
    Detail Type                                  Liquid
    Detail ID                                         1
    Dist. from "FROM" Node / Offset dist              0  mm.
    Height/Length of Liquid                         581  mm.
    Liquid Density                            0.0005998  kg./cm^3

    Element From Node                                10
    Detail Type                              Insulation
    Detail ID                                   Ins: 10
    Dist. from "FROM" Node / Offset dist        -145.25  mm.
    Height/Length of Insulation                  195.25  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"                             407  mm.
Inside Diameter                                     581  mm.
Element Thickness                                    10  mm.
Internal Corrosion Allowance                          3  mm.
Nominal Thickness                                    10  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                       1.0
Efficiency, Circumferential Seam                    1.0
Weld is pre-Heated                                   No

    Element From Node                                20
    Detail Type                                  Liquid
    Detail ID                                         2
    Dist. from "FROM" Node / Offset dist              0  mm.
    Height/Length of Liquid                         581  mm.
    Liquid Density                            0.0005998  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                     407  mm.
    Thickness of Insulation                          80  mm.
    Density                                     0.00012  kg./cm^3

    Element From Node                                20
    Detail Type                                  Nozzle
    Detail ID                                        T4
    Dist. from "FROM" Node / Offset dist            203  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 )            0.05845  kN
    Grade of Attached Flange                     GR 1.1
    Nozzle Matl                             SA-350 LF2 [Impact Tested]

    Element From Node                                20
    Detail Type                                  Nozzle
    Detail ID                                        T1
    Dist. from "FROM" Node / Offset dist            203  mm.
    Nozzle Diameter                                   4  in.
    Nozzle Schedule                                 120
    Nozzle Class                                    300
    Layout Angle                                  270.0
    Blind Flange (Y/N)                                N
    Weight of Nozzle ( Used if > 0 )             0.2988  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"                              88  mm.
Flange Inside Diameter                              581  mm.
Element Thickness                                    62  mm.
Internal Corrosion Allowance                          3  mm.
Nominal Thickness                                    79  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-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                            223.57  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                               540  mm.
     Liquid Density                                  0.0006998  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                            88  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"                                  5880  mm.
 Inside Diameter                                           581  mm.
 Element Thickness                                          10  mm.
 Internal Corrosion Allowance                                3  mm.
 Nominal Thickness                                          10  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]
     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                                 30.988  mm.
     Yield Stress, Operating                               236  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                                       40
     Detail Type                                         Saddle
     Detail ID                                    Fixed Saddle
     Dist. from "FROM" Node / Offset dist                   940  mm.
     Width of Saddle                                        150  mm.
     Height of Saddle at Bottom                             600  mm.
     Saddle Contact Angle                                 120.0
     Height of Composite Ring Stiffener                       0  mm.
     Width of Wear Plate                                    225  mm.
     Thickness of Wear Plate                                 10  mm.
     Contact Angle, Wear Plate (degrees)                  132.0
     Friction coefficient                                   0.0
     Moment Factor                                          3.0
     Dimension E at base (optional)                           0  mm.
     Circumferential Eff. over Saddle                       1.0
     Circumferential Eff. at Midspan                        1.0
     Tangent to Tangent dist. (optional)                      0  mm.

     Element From Node                                       40
     Detail Type                                         Saddle
     Detail ID                                  Sliding Saddle
     Dist. from "FROM" Node / Offset dist                  4940  mm.
     Width of Saddle                                        150  mm.
     Height of Saddle at Bottom                             600  mm.
     Saddle Contact Angle                                 120.0
     Height of Composite Ring Stiffener                       0  mm.
     Width of Wear Plate                                    225  mm.
     Thickness of Wear Plate                                 10  mm.
     Contact Angle, Wear Plate (degrees)                  132.0
     Friction coefficient                            0.40000001
     Moment Factor                                          3.0
     Dimension E at base (optional)                           0  mm.
     Circumferential Eff. over Saddle                       1.0
     Circumferential Eff. at Midspan                        1.0
     Tangent to Tangent dist. (optional)                      0  mm.

     Element From Node                                       40
     Detail Type                                         Liquid
     Detail ID                                                4
     Dist. from "FROM" Node / Offset dist                     0  mm.
     Height/Length of Liquid                                581  mm.
     Liquid Density                                   0.0005998  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                           5880  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              196  mm.
     Nozzle Diameter                                     6  in.
     Nozzle Schedule                                    80
     Nozzle Class                                      300
     Layout Angle                                     90.0
     Blind Flange (Y/N)                                  N
     Weight of Nozzle ( Used if > 0 )               0.5568  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             5680  mm.
     Nozzle Diameter                                     6  in.
     Nozzle Schedule                                    80
     Nozzle Class                                      300
     Layout Angle                                     90.0
     Blind Flange (Y/N)                                  N
     Weight of Nozzle ( Used if > 0 )               0.5568  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              146  mm.
     Nozzle Diameter                                     2  in.
     Nozzle Schedule                                   160
     Nozzle Class                                      300
     Layout Angle                                    270.0
     Blind Flange (Y/N)                                  N
     Weight of Nozzle ( Used if > 0 )               0.1184  kN
     Grade of Attached Flange                       GR 1.1
     Nozzle Matl                                  SA-333 6 [Impact Tested]

     Element From Node                                  40
     Detail Type                                    Weight
     Detail ID                               WEIGHT BAFFLE
     Dist. from "FROM" Node / Offset dist             2940  mm.
     Miscellaneous Weight                           1.4709  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"                                88  mm.
 Flange Inside Diameter                                581  mm.
 Element Thickness                                      62  mm.
 Internal Corrosion Allowance                            3  mm.
 Nominal Thickness                                      79  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-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                           223.57  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                              581  mm.
    Liquid Density                                 0.0005998  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                           88  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"                                  407  mm.
Inside Diameter                                          581  mm.
Element Thickness                                         10  mm.
Internal Corrosion Allowance                               3  mm.
Nominal Thickness                                         10  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]
    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                                30.988  mm.
    Yield Stress, Operating                              236  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                               581  mm.
    Liquid Density                                  0.0005998  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                           407  mm.
    Thickness of Insulation                                80  mm.
    Density                                           0.00012  kg./cm^3

    Element From Node                                      60
    Detail Type                                        Nozzle
    Detail ID                                              T2
    Dist. from "FROM" Node / Offset dist                  200  mm.
    Nozzle Diameter                                         6  in.
    Nozzle Schedule                                        80
    Nozzle Class                                          300
    Layout Angle                                         90.0
    Blind Flange (Y/N)                                      N
    Weight of Nozzle ( Used if > 0 )                   0.5568  kN
    Grade of Attached Flange                           GR 1.1
    Nozzle Matl                                      SA-333 6 [Impact Tested]

    Element From Node                                      60
    Detail Type                                        Nozzle
    Detail ID                                              T3
    Dist. from "FROM" Node / Offset dist                  203  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                                           581  mm.
Element Thickness                                          10  mm.
Internal Corrosion Allowance                                3  mm.
Nominal Thickness                                          12  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                          1.0
 Efficiency, Circumferential Seam                       1.0
 Elliptical Head Factor                                 2.0
 Weld is pre-Heated                                      No

     Element From Node                                   70
     Detail Type                                     Liquid
     Detail ID                                            6
     Dist. from "FROM" Node / Offset dist                 0  mm.
     Height/Length of Liquid                            581  mm.
     Liquid Density                               0.0005998  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                     195.25  mm.
     Thickness of Insulation                             80  mm.
     Density                                        0.00012  kg./cm^3
```

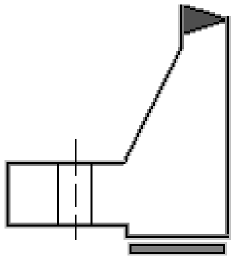
XY Coordinate Calculations:

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
HEAD 1		50	...	50	...
CHANNEL 01		457	...	407	...
BODY FLANGE 01		545	...	88	...
SHELL		6493.18	...	5880	...
BODY FLANGE 002		6587.35	...	88	...
CHANNEL 002		7056.35	...	407	...
HEAD 002		7106.35	...	50	...

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

BODY FLANGE 01

```
Description of Flange Geometry (Type)          Integral Weld Neck
Design Pressure                          P           23.04  bars
Design Temperature                                     120  °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         581.000  mm.
Flange Outside Diameter                  A         715.000  mm.
Flange Thickness                         t         62.0000  mm.
Thickness of Hub at Small End           go         10.0000  mm.
Thickness of Hub at Large End           g1         17.0000  mm.
Length of Hub                            h         26.0000  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         673.000  mm.
Nominal Bolt Diameter                    a         19.0500  mm.
Type of Threads                          UNC Thread Series
Number of Bolts                                         32

Flange Face Outside Diameter           Fod         644.000  mm.
Flange Face Inside Diameter            Fid         581.000  mm.
Flange Facing Sketch                     1, Code Sketch 1a

Gasket Outside Diameter                 Go         641.000  mm.
Gasket Inside Diameter                  Gi         611.000  mm.
Gasket Factor                            m          3.7800
Gasket Design Seating Stress             y           62.05  N./mm^2

Column for Gasket Seating                2, Code Column II
Gasket Thickness                        tg          3.0000  mm.

Length of Partition Gasket              lp       1078.0000  mm.
Width  of Partition Gasket              tp          6.0000  mm.
Partition Gasket Factor              mPart          3.7500
Partition Gasket Design Seating Stress yPart         62.05  N./mm^2
```



ASME Code, Section VIII Division 1, 2017

Hub Small End Required Thickness due to Internal Pressure:

```
  = (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
  = (23.04*(581.0/2+3.0))/(137.9*1.0-0.6*23.04)+Ca
  = 7.9530 mm.
```

Hub Small End Hub MAWP:

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9 * 1.0 * 7.0)/(293.5 + 0.6 * 7.0 )
  = 32.423 bars
```

```
 Corroded Flange Thickness, tc = T-ci                      59.000  mm.
 Corroded Flange ID,      Bcor = B+2*Fcor                 587.000  mm.
 Corroded Large Hub,     g1Cor = g1-ci                     14.000  mm.
 Corroded Small Hub,     g0Cor = go-ci                      7.000  mm.
 Code R Dimension,           R = ((C-Bcor)/2)-g1cor        29.000  mm.

 Gasket Contact Width,       N = (Go - Gi) / 2             15.000  mm.
 Basic Gasket Width,        bo = N / 2                      7.500  mm.
 Effective Gasket Width,     b = Cb sqrt(bo)                6.901  mm.
 Gasket Reaction Diameter,   G = Go - 2 * b               627.198  mm.
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:

```
  = 0.785 * G² * Peq
  = 0.785 * 627.1979² * 23.037
  = 711.728 kN
```

Contact Load on Gasket Surfaces [Hp]:

```
  = 2 * b * Pi * G * m * P + 2 * lp * bPart * mPart * P
  = 2 * 6.9011 * 3.1416 * 627.1979 * 3.78 * 23.04
    + 2.0 * 1078.0 * 3.0 * 3.75 * 23.0371
  = 292.690 kN
```

Hydrostatic End Load at Flange ID [Hd]:

```
  = Pi * Bcor² * P  / 4
  = 3.1416 * 587.0² *23.0371/4
  = 623.421 kN
```

Pressure Force on Flange Face [Ht]:

```
  = H - Hd
  = 712 - 623
  = 88.307 kN
```

Operating Bolt Load [Wm1]:

```
  = max( H + Hp + H'p, 0 )
  = max( 712 + 293 + 0, 0 )
  = 1004.418 kN
```

Gasket Seating Bolt Load [Wm2]:

```
  = y * b * Pi * G  + yPart * bPart * lp
  = 62.05*6.9011*3.141*627.198+62.05*3.0*1078.0
  = 1044.378 kN
```

Required Bolt Area [Am]:

```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 1004/172, 1044/172
  = 60.593 cm^2
```

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

```
  = 2a + 6t/(m + 0.5)
  = 2 * 19.05 + 6 * 59.0/(3.78 + 0.5)
  = 120.810 mm.
```

Actual Circumferential Bolt Spacing [Bs]:

```
  = C * sin( pi / n )
  = 673.0 * sin( 3.142/32 )
  = 65.966 mm.
```

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:

```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 65.966/( 2 * 19.05 + 59.0 )), 1 )
  = 1.0000
```

Bolting Information for UNC Thread Series (Non Mandatory):

	Minimum	Actual	Maximum
Bolt Area, cm^2	60.593	62.348	
Radial Distance between Hub and Bolts:	28.575	29.000	
Radial Distance between Bolts and Edge:	20.637	21.000	
Circ. Spacing between the Bolts:	44.450	65.966	120.810

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:

```
  = Ab * Sa/( y * Pi * (Go + Gi) )
  = 62.348 * 172.38/(62.05 * 3.14 * (641.0 + 611.0) )
  = 4.403 mm.
```

Flange Design Bolt Load, Gasket Seating [W]:

```
  = Sa * ( Am + Ab ) / 2
  = 172.38 * ( 60.5927 + 62.3483 )/2
  = 1059.51 kN
```

Gasket Load for the Operating Condition [HG]:

```
  = Wm1 - H
  = 1004 - 712
  = 292.69 kN
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
  = (C - G ) / 2
  = ( 673.0 - 627.1979 )/2
  = 22.9011 mm.
```

Distance to Face Pressure Reaction [ht]:

```
  = ( R + g1 + hg ) / 2
  = ( 29.0 + 14.0 + 22.9011 )/2
  = 32.9505 mm.
```

Distance to End Pressure Reaction [hd]:

```
  = R + ( g1 / 2 )
  = 29.0 + ( 14.0/2.0 )
  = 36.0000 mm.
```

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

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	623.	36.0000	1.0000	22452.
Face Pressure,	Mt	88.	32.9505	1.0000	2911.
Gasket Load,	Mg	293.	22.9011	1.0000	6706.
Gasket Seating,	Matm	1060.	22.9011	1.0000	24274.

```
Total Moment for Operation,      Mop                             32069. N-m
Total Moment for Gasket seating, Matm                            24274. N-m

Effective Hub Length, ho = sqrt(Bcor*goCor)           64.101  mm.
Hub Ratio,          h/h0 = HL / H0                     0.406
```

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

Flange Factors for Integral Flange:

```
 Factor F                                              0.847
 Factor V                                              0.257
 Factor f                                              1.586
 Factors from Figure 2-7.1                   K =       1.218
                    T =      1.832           U =      10.940
                    Y =      9.955           Z =       5.135
                    d = 0.13358E+06 mm.³       e =     0.0132 mm.^-1
 Stress Factors                          ALPHA =       1.779
                 BETA =      2.039       GAMMA =       0.972
                DELTA =      1.537       Lamda =       2.509
```

Longitudinal Hub Stress, Operating [SHo]:

```
  = ( f * Mop / Bcor ) / ( L * g1² )
  = (1.5858*32069/587.0)/(2.5089*14.0²)
  = 176.12 N./mm^2
```

Longitudinal Hub Stress, Seating [SHa]:

```
  = ( f * Matm / Bcor ) / ( L * g1² )
  = (1.5858*24274/587.0)/(2.5089*14.0²)
  = 133.31 N./mm^2
```

Radial Flange Stress, Operating [SRo]:

```
  = ( Beta * Mop / Bcor ) / ( L * t² )
  = (2.0393*32069/587.0)/(2.5089*59.0²)
  = 12.75 N./mm^2
```

Radial Flange Stress, Seating [SRa]:

```
  = ( Beta * Matm/Bcor ) / ( L * t² )
  = (2.0393*24274/587.0)/(2.5089*59.0²)
  = 9.65 N./mm^2
```

Tangential Flange Stress, Operating [STo]:

```
  = ( Y * Mo / (t² * Bcor) ) - Z * SRo
  = (9.9551*32069/(59.0²*587.0))-5.1351*13
  = 90.71 N./mm^2
```

Tangential Flange Stress, Seating [STa]:

```
  = ( y * Matm / (t² * Bcor) ) - Z * SRa
  = (9.9551*24274/(59.0²*587.0))-5.1351*10
  = 68.66 N./mm^2
```

Average Flange Stress, Operating [SAo]:

```
  = ( SHo + max( SRo, STo ) ) / 2
  = (176+max(13,91))/2
  = 133.41 N./mm^2
```

Average Flange Stress, Seating [SAa]:

```
  = ( SHa + max( SRa, STa ) ) / 2
  = (133+max(10,69))/2
  = 100.98 N./mm^2
```

Bolt Stress, Operating [BSo]:

```
  = Wm1 / Ab
  = 1004/62.3483
  = 161.11 N./mm^2
```

Bolt Stress, Seating [BSa]:

```
  = ( Wm2 / Ab )
  = (1044/62.3483)
  = 167.52 N./mm^2
```

Flange Stress Analysis Results: N./mm^2

	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Longitudinal Hub	176.	207.	133.	207.
Radial Flange	13.	138.	10.	138.
Tangential Flange	91.	138.	69.	138.
Maximum Average	133.	138.	101.	138.
Bolting	161.	172.	168.	172.

Minimum Required Flange Thickness	60.833	mm.
Estimated M.A.W.P. (Operating)	23.812	bars
Estimated Finished Weight of Flange at given Thk.	70.6	kg.
Estimated Unfinished Weight of Forging at given Thk	93.0	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 * 24273.7/1.0 * 999.68 * 0.257/(2.409 * 202713 *
7.0² * 64.101 * 0.3)
= 0.707 (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 * 32068.8/1.0 * 999.68 * 0.257/(2.409 * 196922
* 7.0² * 64.101 * 0.3)
= 0.962 (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 * 24273.7/1.0 * 999.68 * 0.257/(2.509 * 202713 *
7.0² * 64.101 * 0.3)
= 0.679 (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 * 32068.8/1.0 * 999.68 * 0.257/(2.509 * 196922
* 7.0² * 64.101 * 0.3)
= 0.924 (should be <= 1)

Minimum Design Metal Temperature Results:

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

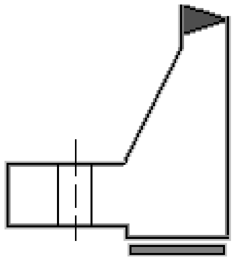
Impact Test Temperature provided per Specification -46 °C

Note: UCS-66(b)(-c) was considered in the flange MDMT calculation.

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

BODY FLANGE 002

```
Description of Flange Geometry (Type)          Integral Weld Neck
Design Pressure                          P            23.03  bars
Design Temperature                                      120  °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          581.000  mm.
Flange Outside Diameter                  A          715.000  mm.
Flange Thickness                         t          62.0000  mm.
Thickness of Hub at Small End           go          10.0000  mm.
Thickness of Hub at Large End           g1          17.0000  mm.
Length of Hub                            h          26.0000  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          673.000  mm.
Nominal Bolt Diameter                    a          19.0500  mm.
Type of Threads                           UNC Thread Series
Number of Bolts                                          32

Flange Face Outside Diameter           Fod          644.000  mm.
Flange Face Inside Diameter            Fid          581.000  mm.
Flange Facing Sketch                      1, Code Sketch 1a

Gasket Outside Diameter                 Go          641.000  mm.
Gasket Inside Diameter                  Gi          611.000  mm.
Gasket Factor                            m           3.7800
Gasket Design Seating Stress             y            62.05  N./mm^2

Column for Gasket Seating                 2, Code Column II
Gasket Thickness                        tg           3.0000  mm.

Length of Partition Gasket              lp        1078.0000  mm.
Width  of Partition Gasket              tp           6.0000  mm.
Partition Gasket Factor              mPart           3.7500
Partition Gasket Design Seating Stress yPart          62.05  N./mm^2
```



ASME Code, Section VIII Division 1, 2017

Hub Small End Required Thickness due to Internal Pressure:
```
  = (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
  = (23.03*(581.0/2+3.0))/(137.9*1.0-0.6*23.03)+Ca
  = 7.9524 mm.
```

Hub Small End Hub MAWP:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9 * 1.0 * 7.0)/(293.5 + 0.6 * 7.0 )
  = 32.423 bars
```

```
 Corroded Flange Thickness, tc = T-ci                    59.000  mm.
 Corroded Flange ID,      Bcor = B+2*Fcor               587.000  mm.
 Corroded Large Hub,     g1Cor = g1-ci                   14.000  mm.
 Corroded Small Hub,     g0Cor = go-ci                    7.000  mm.
 Code R Dimension,           R = ((C-Bcor)/2)-g1cor      29.000  mm.

 Gasket Contact Width,       N = (Go - Gi) / 2           15.000  mm.
 Basic Gasket Width,        bo = N / 2                    7.500  mm.
 Effective Gasket Width,     b = Cb sqrt(bo)              6.901  mm.
 Gasket Reaction Diameter,   G = Go - 2 * b             627.198  mm.
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.785 * 627.1979² * 23.034
  = 711.639 kN
```
Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * Pi * G * m * P + 2 * lp * bPart * mPart * P
  = 2 * 6.9011 * 3.1416 * 627.1979 * 3.78 * 23.03
    + 2.0 * 1078.0 * 3.0 * 3.75 * 23.0342
  = 292.653 kN
```
Hydrostatic End Load at Flange ID [Hd]:
```
  = Pi * Bcor² * P  / 4
  = 3.1416 * 587.0² *23.0342/4
  = 623.343 kN
```
Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 712 - 623
  = 88.296 kN
```
Operating Bolt Load [Wm1]:
```
  = max( H + Hp + H'p, 0 )
  = max( 712 + 293 + 0, 0 )
  = 1004.292 kN
```
Gasket Seating Bolt Load [Wm2]:
```
  = y * b * Pi * G  + yPart * bPart * lp
  = 62.05*6.9011*3.141*627.198+62.05*3.0*1078.0
  = 1044.378 kN
```
Required Bolt Area [Am]:
```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 1004/172, 1044/172
  = 60.593 cm^2
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
```
  = 2a + 6t/(m + 0.5)
  = 2 * 19.05 + 6 * 59.0/(3.78 + 0.5)
  = 120.810 mm.
```

Actual Circumferential Bolt Spacing [Bs]:

```
  = C * sin( pi / n )
  = 673.0 * sin( 3.142/32 )
  = 65.966 mm.
```

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:

```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 65.966/( 2 * 19.05 + 59.0 )), 1 )
  = 1.0000
```

Bolting Information for UNC Thread Series (Non Mandatory):

	Minimum	Actual	Maximum
Bolt Area, cm^2	60.593	62.348	
Radial Distance between Hub and Bolts:	28.575	29.000	
Radial Distance between Bolts and Edge:	20.637	21.000	
Circ. Spacing between the Bolts:	44.450	65.966	120.810

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:

```
  = Ab * Sa/( y * Pi * (Go + Gi) )
  = 62.348 * 172.38/(62.05 * 3.14 * (641.0 + 611.0) )
  = 4.403 mm.
```

Flange Design Bolt Load, Gasket Seating [W]:

```
  = Sa * ( Am + Ab ) / 2
  = 172.38 * ( 60.5927 + 62.3483 )/2
  = 1059.51 kN
```

Gasket Load for the Operating Condition [HG]:

```
  = Wm1 - H
  = 1004 - 712
  = 292.65 kN
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
  = (C - G ) / 2
  = ( 673.0 - 627.1979 )/2
  = 22.9011 mm.
```

Distance to Face Pressure Reaction [ht]:

```
  = ( R + g1 + hg ) / 2
  = ( 29.0 + 14.0 + 22.9011 )/2
  = 32.9505 mm.
```

Distance to End Pressure Reaction [hd]:

```
  = R + ( g1 / 2 )
  = 29.0 + ( 14.0/2.0 )
  = 36.0000 mm.
```

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

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	623.	36.0000	1.0000	22449.
Face Pressure,	Mt	88.	32.9505	1.0000	2911.
Gasket Load,	Mg	293.	22.9011	1.0000	6705.
Gasket Seating,	Matm	1060.	22.9011	1.0000	24274.

```
Total Moment for Operation,      Mop                          32065. N-m
Total Moment for Gasket seating, Matm                         24274. N-m

Effective Hub Length, ho = sqrt(Bcor*goCor)          64.101  mm.
Hub Ratio,          h/h0 = HL / H0                    0.406
```

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

Flange Factors for Integral Flange:

```
 Factor F                                              0.847
 Factor V                                              0.257
 Factor f                                              1.586
 Factors from Figure 2-7.1                   K =       1.218
                    T =      1.832           U =      10.940
                    Y =      9.955           Z =       5.135
                    d = 0.13358E+06 mm.³       e =     0.0132 mm.^-1
 Stress Factors                          ALPHA =       1.779
                 BETA =      2.039       GAMMA =       0.972
                DELTA =      1.537       Lamda =       2.509
```

Longitudinal Hub Stress, Operating [SHo]:

```
  = ( f * Mop / Bcor ) / ( L * g1² )
  = (1.5858*32065/587.0)/(2.5089*14.0²)
  = 176.10 N./mm^2
```

Longitudinal Hub Stress, Seating [SHa]:

```
  = ( f * Matm / Bcor ) / ( L * g1² )
  = (1.5858*24274/587.0)/(2.5089*14.0²)
  = 133.31 N./mm^2
```

Radial Flange Stress, Operating [SRo]:

```
  = ( Beta * Mop / Bcor ) / ( L * t² )
  = (2.0393*32065/587.0)/(2.5089*59.0²)
  = 12.75 N./mm^2
```

Radial Flange Stress, Seating [SRa]:

```
  = ( Beta * Matm/Bcor ) / ( L * t² )
  = (2.0393*24274/587.0)/(2.5089*59.0²)
  = 9.65 N./mm^2
```

Tangential Flange Stress, Operating [STo]:

```
  = ( Y * Mo / (t² * Bcor) ) - Z * SRo
  = (9.9551*32065/(59.0²*587.0))-5.1351*13
  = 90.69 N./mm^2
```

Tangential Flange Stress, Seating [STa]:

```
  = ( y * Matm / (t² * Bcor) ) - Z * SRa
  = (9.9551*24274/(59.0²*587.0))-5.1351*10
  = 68.66 N./mm^2
```

Average Flange Stress, Operating [SAo]:

```
  = ( SHo + max( SRo, STo ) ) / 2
  = (176+max(13,91))/2
  = 133.40 N./mm^2
```

Average Flange Stress, Seating [SAa]:

```
  = ( SHa + max( SRa, STa ) ) / 2
  = (133+max(10,69))/2
  = 100.98 N./mm^2
```

Bolt Stress, Operating [BSo]:

```
  = Wm1 / Ab
  = 1004/62.3483
  = 161.09 N./mm^2
```

Bolt Stress, Seating [BSa]:

```
  = ( Wm2 / Ab )
  = (1044/62.3483)
  = 167.52 N./mm^2
```

Flange Stress Analysis Results: N./mm^2

	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Longitudinal Hub	176.	207.	133.	207.
Radial Flange	13.	138.	10.	138.
Tangential Flange	91.	138.	69.	138.
Maximum Average	133.	138.	101.	138.
Bolting	161.	172.	168.	172.

Minimum Required Flange Thickness	60.808	mm.
Estimated M.A.W.P. (Operating)	23.812	bars
Estimated Finished Weight of Flange at given Thk.	70.6	kg.
Estimated Unfinished Weight of Forging at given Thk	93.0	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 * 24273.7/1.0 * 999.68 * 0.257/(2.409 * 202713 *
7.0² * 64.101 * 0.3)
= 0.707 (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 * 32064.8/1.0 * 999.68 * 0.257/(2.409 * 196922
* 7.0² * 64.101 * 0.3)
= 0.962 (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 * 24273.7/1.0 * 999.68 * 0.257/(2.509 * 202713 *
7.0² * 64.101 * 0.3)
= 0.679 (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 * 32064.8/1.0 * 999.68 * 0.257/(2.509 * 196922
* 7.0² * 64.101 * 0.3)
= 0.923 (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

Note: UCS-66(b)(-c) was considered in the flange MDMT calculation.

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-3 ECONOMIZER
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for ECONOMIZER E-PK6101-3 ----
Internal Pressure Calculations: Step: 5 11:46pm Dec 22,2021

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		23.034	12	3	581	137.9
CHANNEL 01		23.034	10	3	581	137.9
BODY FLANGE 01		23.037	79	3	581	137.9
SHELL		23.034	10	3	581	137.9
BODY FLANGE 002		23.034	79	3	581	137.9
CHANNEL 002		23.034	10	3	581	137.9
HEAD 002		23.034	12	3	581	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	10	7.8451
CHANNEL 01		23	No Calc	No Calc	10	7.95245
BODY FLANGE 01		23	No Calc	No Calc	62	60.833
SHELL		23	No Calc	No Calc	10	7.95245
BODY FLANGE 002		23	No Calc	No Calc	62	60.8076
CHANNEL 002		23	No Calc	No Calc	10	7.95245
HEAD 002		23	No Calc	No Calc	10	7.8451

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 120 °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)
  = (23.034*587.0*0.987)/(2*137.9*1.0-0.2*23.034)
  = 4.8451 + 3.0000 = 7.8451 mm.
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(Kcor*D+0.2*t))/(2*E*t)
  = (23.034*(0.987*587.0+0.2*7.0))/(2*1.0*7.0)
  = 95.519 N./mm^2
```

Straight Flange Required Thickness:
```
  = (P*R)/(S*E-0.6*P) + c    per UG-27 (c)(1)
  = (23.034*293.5)/(137.9*1.0-0.6*23.034)+3.0
  = 7.952 mm.
```

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.034 bars
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9 * 1.0 * 9.0)/(293.5 + 0.6 * 9.0 )
```

= 41.520 - 0.034 = 41.485 bars

Factor K, corroded condition [Kcor]:
= (2 + (Inside Diameter/(2 * Inside Head Depth))²)/6
= (2 + (587.0/(2 * 148.25))²)/6
= 0.986578

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 8.590 %
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 10.0, tr = 4.845, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.692, Temp. Reduction = 17 °C

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

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 12.0, tr = 4.952, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.55, Temp. Reduction = 27 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -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)
= (23.034*293.5)/(137.9*1.0-0.6*23.034)
= 4.9524 + 3.0000 = 7.9524 mm.

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(R+0.6*t))/(E*t)
= (23.034*(293.5+0.6*7.0))/(1.0*7.0)
= 97.967 N./mm^2

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.692 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 10.0, tr = 4.952, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.707, Temp. Reduction = 16 °C

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

Cylindrical Shell From 40 To 50 SA-516 70 , UCS-66 Crv. D at 120 °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)
= (23.034*293.5)/(137.9*1.0-0.6*23.034)

```
  = 4.9524 + 3.0000 = 7.9524 mm.
```

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

```
  = (P*(R+0.6*t))/(E*t)
  = (23.034*(293.5+0.6*7.0))/(1.0*7.0)
  = 97.967 N./mm^2
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.692 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 10.0, tr = 4.952, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.707, Temp. Reduction = 16 °C

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

Cylindrical Shell From 60 To 70 SA-516 70 , UCS-66 Crv. D at 120 °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)
  = (23.034*293.5)/(137.9*1.0-0.6*23.034)
  = 4.9524 + 3.0000 = 7.9524 mm.
```

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

```
  = (P*(R+0.6*t))/(E*t)
  = (23.034*(293.5+0.6*7.0))/(1.0*7.0)
  = 97.967 N./mm^2
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.692 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 10.0, tr = 4.952, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.707, Temp. Reduction = 16 °C

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

Elliptical Head From 70 To 80 SA-516 70 , UCS-66 Crv. D at 120 °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)
  = (23.034*587.0*0.987)/(2*137.9*1.0-0.2*23.034)
  = 4.8451 + 3.0000 = 7.8451 mm.
```

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

```
  = (P*(Kcor*D+0.2*t))/(2*E*t)
  = (23.034*(0.987*587.0+0.2*7.0))/(2*1.0*7.0)
  = 95.519 N./mm^2
```

Straight Flange Required Thickness:


```
  = (P*R)/(S*E-0.6*P) + c    per UG-27 (c)(1)
  = (23.034*293.5)/(137.9*1.0-0.6*23.034)+3.0
  = 7.952 mm.
```

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.034 bars

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9 * 1.0 * 9.0)/(293.5 + 0.6 * 9.0 )
  = 41.520 - 0.034 = 41.485  bars
```

Factor K, corroded condition [Kcor]:

```
  = ( 2 + ( Inside Diameter/( 2 * Inside Head Depth ))²)/6
  = ( 2 + ( 587.0/( 2 * 148.25 ))²)/6
  = 0.986578
```

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 8.590 %
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 10.0, tr = 4.845, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.692, Temp. Reduction = 17 °C

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

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 12.0, tr = 4.952, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.55, Temp. Reduction = 27 °C

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

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

Hydrostatic Test Pressure Results:

Exchanger Shell Side Hydrostatic Test Pressures:

```
 Pressure per UG99b[36] = 1.30 * Design Pres * Sa/S       29.900  bars
 Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)     32.890  bars
 Pressure per App 27-4  = M.A.W.P.                        43.964  bars
```

Exchanger Channel Side Hydrostatic Test Pressures:

```
 Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S          32.043  bars
 Pressure per UG99b[36] = 1.30 * Design Pres * Sa/S       29.900  bars
 Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)       31.986  bars
 Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S          27.113  bars
 Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)     32.890  bars
 Pressure per App 27-4  = M.A.W.P.                        24.648  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	124.2	235.8	0.527	29.96
CHANNEL 01	127.4	235.8	0.540	29.96
SHELL	127.4	235.8	0.540	29.96
CHANNEL 002	127.4	235.8	0.540	29.96
HEAD 002	124.2	235.8	0.527	29.96

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

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

Internal Pressure Calculations: Step: 5 11:46pm Dec 22,2021

Description	Ambient	Operating	Ratio
T4	5.13	223.40	0.023
T1	24.22	217.19	0.112
S2	36.99	217.19	0.170
S1	36.99	217.19	0.170
S3	18.25	217.19	0.084
T2	36.99	217.19	0.170
T3	5.96	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	601	7	0.0016177	98.7135
20	30	505.417	601	7	0.0020537	104.349
30	40	No Calc	...	59	No Calc	No Calc
40	50	5880	601	7	0.00016747	16.7432
50	60	No Calc	...	59	No Calc	No Calc
60	70	505.417	601	7	0.0020537	104.349
70	80	No Calc	601	7	0.0016177	98.7135

External Pressure Calculations:

From	To	External Actual T. mm.	External Required T. mm.	External Design Pressure bars	External M.A.W.P. bars
10	20	10	4.60484	1.1	12.7742
20	30	10	4.83369	1.1	16.2041
30	40	62	50.8	1.1	No Calc
40	50	10	8.13291	1.1	2.60002
50	60	62	50.8	1.1	No Calc
60	70	10	4.83369	1.1	16.2041
70	80	10	4.60484	1.1	12.7742
Minimum					2.600

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	505.417	12031.9	No Calc	No Calc
30	40	No Calc	No Calc	No Calc	No Calc
40	50	5880	131539	No Calc	No Calc
50	60	No Calc	No Calc	No Calc	No Calc
60	70	505.417	12031.9	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 120 °C

HEAD 1

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

Results for Maximum Allowable External Pressure (MAEP):

```
     Tca          OD          D/t     Factor A            B
```

```
   7.000      601.00        85.86   0.0016177        98.71
 EMAP = B/(K0*D/t) = 98.7135/( 0.9 *85.8571 ) = 12.7742 bars
```

Results for Required Thickness (Tca):

```
     Tca          OD          D/t     Factor A           B
   1.605      601.00       374.49   0.0003709        37.08
 EMAP = B/(K0*D/t) = 37.0789/( 0.9 *374.4927 ) = 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*587.0*0.987)/(2*137.9*1.0-0.2*1.837)
  = 0.3858 + 3.0000 = 3.3858 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*7.0)/(0.987*587.0+0.2*7.0))/1.67
  = 19.913 bars
```

Maximum Allowable External Pressure [MAEP]:

```
  = min( MAEP, MAWP )
  = min( 12.77, 19.9128 )
  = 12.774 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
   7.000      601.00       505.42       85.86      0.8410   0.0020537    104.35
 EMAP = (4*B)/(3*(D/t)) = (4*104.3486)/(3*85.8571) = 16.2041 bars
```

Results for Required Thickness (Tca):

```
     Tca          OD         SLEN         D/t         L/D    Factor A         B
   1.834      601.00       505.42      327.75      0.8410   0.0002705     27.04
 EMAP = (4*B)/(3*(D/t)) = (4*27.043)/(3*327.7541) = 1.1001 bars
```

Results for Maximum Stiffened Length (Slen):

```
     Tca          OD         SLEN         D/t         L/D    Factor A         B
   7.000      601.00     12031.87       85.86     20.0198   0.0001535     15.35
 EMAP = (4*B)/(3*(D/t)) = (4*15.3457)/(3*85.8571) = 2.383 bars
```

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

SHELL

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

Results for Maximum Allowable External Pressure (MAEP):

```
     Tca          OD         SLEN         D/t         L/D    Factor A         B
```



```
   7.000      601.00      5880.00      85.86     9.7837  0.0001675    16.74
 EMAP = (4*B)/(3*(D/t)) = (4*16.7432)/(3*85.8571) = 2.6 bars
```

Results for Required Thickness (Tca):

```
     Tca         OD         SLEN        D/t         L/D    Factor A        B
   5.133      601.00      5880.00     117.09     9.7837  0.0000966     9.66
 EMAP = (4*B)/(3*(D/t)) = (4*9.6607)/(3*117.0875) = 1.1 bars
```

Results for Maximum Stiffened Length (Slen):

```
     Tca         OD         SLEN        D/t         L/D    Factor A        B
   7.000      601.00    131538.89      85.86    50.0000  0.0001516    15.15
 EMAP = (4*B)/(3*(D/t)) = (4*15.1537)/(3*85.8571) = 2.3532 bars
```

<u>Cylindrical Shell From 60 to 70 Ext. Chart: CS-2 at 120 °C</u>

CHANNEL 002

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
   7.000      601.00       505.42      85.86     0.8410  0.0020537   104.35
 EMAP = (4*B)/(3*(D/t)) = (4*104.3486)/(3*85.8571) = 16.2041 bars
```

Results for Required Thickness (Tca):

```
     Tca         OD         SLEN        D/t         L/D    Factor A        B
   1.834      601.00       505.42     327.75     0.8410  0.0002705    27.04
 EMAP = (4*B)/(3*(D/t)) = (4*27.043)/(3*327.7541) = 1.1001 bars
```

Results for Maximum Stiffened Length (Slen):

```
     Tca         OD         SLEN        D/t         L/D    Factor A        B
   7.000      601.00     12031.87      85.86    20.0198  0.0001535    15.35
 EMAP = (4*B)/(3*(D/t)) = (4*15.3457)/(3*85.8571) = 2.383 bars
```

<u>Elliptical Head From 70 to 80 Ext. Chart: CS-2 at 120 °C</u>

HEAD 002

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

Results for Maximum Allowable External Pressure (MAEP):

```
     Tca         OD          D/t     Factor A           B
   7.000      601.00        85.86   0.0016177        98.71
 EMAP = B/(K0*D/t) = 98.7135/( 0.9 *85.8571 ) = 12.7742 bars
```

Results for Required Thickness (Tca):

```
     Tca         OD          D/t     Factor A           B
   1.605      601.00       374.49   0.0003709        37.08
 EMAP = B/(K0*D/t) = 37.0789/( 0.9 *374.4927 ) = 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*587.0*0.987)/(2*137.9*1.0-0.2*1.837)
  = 0.3858 + 3.0000 = 3.3858 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*7.0)/(0.987*587.0+0.2*7.0))/1.67
  = 19.913 bars
```

Maximum Allowable External Pressure [MAEP]:

```
  = min( MAEP, MAWP )
  = min( 12.77, 19.9128 )
  = 12.774 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	47.807	38935.4	35.8552	40014.4	2.39035
20	30	58.5682	107923	41.2058	110164	2.92841
30	40	88.5944	28277.5	84.1151	28420.6	4.42972
40	50	846.145	841010	595.307	873380	42.3073
50	60	88.5944	28277.5	84.1151	28420.6	4.42972
60	70	58.5682	107923	41.2058	110164	2.92841
70	80	47.807	38935.4	35.8552	40014.4	2.39035
Total		1236	1191281.88	917	1230577.00	61

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	23.347	-48.4167	0.18167E-04	1
10	Insl	6.82273	-47.625	...	Ins: 10
20	Liqd	64.7144	203.5	...	2
20	Insl	8.3585	203.5	...	Ins: 20
20	Nozl	6.25877	203	300.025	T4
20	Nozl	31.9986	203	347.65	T1
30	Liqd	19.1661	44	20.5	3
30	Insl	2.26866	44	...	Ins: 30
40	Sadl	60.6827	940	435.25	Fixed Saddle
40	Sadl	60.6827	4940	435.25	Sliding Saddle
40	Liqd	504.298	2940	...	4
40	Insl	120.757	2940	...	Ins: 40
40	Nozl	59.6222	196	374.637	S2
40	Nozl	59.6222	5680	374.637	S1
40	Nozl	12.683	146	320.663	S3
40	Wght	150	2940	...	WEIGHT BAFFLE
50	Liqd	16.9561	44	...	5
50	Insl	2.26866	44	...	Ins: 50
60	Liqd	64.7144	203.5	...	5
60	Insl	8.3585	203.5	...	Ins: 60
60	Nozl	59.6222	200	374.637	T2
60	Nozl	6.25877	203	303.2	T3
70	Liqd	23.347	98.4167	0.18167E-04	6
70	Insl	6.82273	97.625	...	Ins: 70
30	FTsh	140.973	125	...	TUBE SHEET
30	Tube	1815.16	3094	...	
30	RTsh	140.973	6063	...	

Total Weight of Each Detail Type:

Saddles	121.4
Liquid	716.5
Insulation	155.7
Nozzles	236.1

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FileName : Calculation Book for ECONOMIZER E-PK6101-3 ----
Element and Detail Weights: Step: 7 11:46pm Dec 22,2021

Weights	150.0
Exchanger Components	2097.1
Liquid in Tubes	356.6
Sum of the Detail Weights	3833.3 kg.

Weight Summation Results: (kg.)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	1297.9	1297.9	1297.9	1297.9	1297.9	1297.9
Saddles	121.4	121.4	121.4	121.4	121.4	121.4
Nozzles	236.1	236.1	236.1	236.1	236.1	236.1
Wld Weights	150.0	150.0	150.0	150.0	150.0	150.0
Exchanger	2097.1	2097.1	2097.1	2097.1	2097.1	2097.1
Insulation	...	...	...	...	155.7	155.7 *
Ope. Liquid	...	...	...	...	...	716.5
Tube Ope Lqd	...	...	...	...	...	356.6
Test Liquid	...	1190.6	...	...	...	...
Tube Tst Lqd	...	509.4	...	...	...	...
Totals	3902.4	5602.4	3902.4	3902.4	4058.1	5131.2

Field Installation Options:
* Insulation installed after lifting.

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 without Removable Internals	3902.4 kg.
Shop Test Wt.	- Fabricated Weight + Water (Full)	5602.4 kg.
Shipping Wt.	- Fab. Weight + removable Intls.+ Shipping App.	3902.4 kg.
Erected Wt.	- Fab. Wt + or - loose items (trays,platforms etc.)	3902.4 kg.
Ope. Wt. no Liq	- Fab. Weight + Internals. + Details + Weights	4058.1 kg.
Operating Wt.	- Empty Weight + Operating Liq. Uncorroded	5131.2 kg.
Oper. Wt. + CA	- Corr Wt. + Operating Liquid	4796.9 kg.
Field Test Wt.	- Empty Weight + Water (Full)	5463.0 kg.

Exchanger Tube Data

Volume of Exchanger tubes :	509743.7 Cm3
Weight of Ope Liq in tubes :	356.6 kg.
Weight of Water in tubes :	509.4 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	4917.99

20	30	7684.56
30	40	3640.82
40	50	111020
50	60	3640.82
60	70	7684.56
70	80	4917.99
Total		143506.844 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
T4	46.00	51.10	120	300	GR 1.1	...	...	...	...
T1	46.00	51.10	120	300	GR 1.1	...	...	...	...
S2	46.00	51.10	120	300	GR 1.1	...	...	...	...
S1	46.00	51.10	120	300	GR 1.1	...	...	...	...
S3	46.00	51.10	120	300	GR 1.1	...	...	...	...
T2	46.00	51.10	120	300	GR 1.1	...	...	...	...
T3	46.00	51.10	120	300	GR 1.1	...	...	...	...

Shellside Flange Rating

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

Channelside Flange Rating

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

Selected Method for Derating ANSI B16.5 Flange MAWP: None Selected

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

Input Values:

Wind Design Code		ASCE-7 2010	
Wind Load Reduction Scale Factor		0.600	
Basic Wind Speed	[V]	195	Km/hr
Surface Roughness Category		C: Open Terrain	
Importance Factor		1.0	
Type of Surface		Moderately Smooth	
Base Elevation		123000	mm.
Percent Wind for Hydrotest		33.0	
Using User defined Wind Press. Vs Elev.		N	
Height of Hill or Escarpment	H or Hh	0	mm.
Distance Upwind of Crest	Lh	0	mm.
Distance from Crest to the Vessel	x	0	mm.
Type of Terrain (Hill, Escarpment)		Flat	
Damping Factor (Beta) for Wind (Ope)		0.0100	
Damping Factor (Beta) for Wind (Empty)		0.0000	
Damping Factor (Beta) for Wind (Filled)		0.0000	

Wind Analysis Results

Static Gust-Effect Factor, Operating Case [G]:
= min(0.85, 0.925((1 + 1.7 * gQ * Izbar * Q)/(1 + 1.7 * gV * Izbar)))
= min(0.85,0.925((1+1.7*3.4*0.143*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]	0.616
Structure Height to Diameter ratio		9.906

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
= 600.0 + 123000. = 123600.008 mm.
= 405.512 ft. Imperial Units

Velocity Pressure coefficient evaluated at height z [Kz]:
Because z (405.512 ft.) > 15 ft.
$= 2.01 * (z / Zg)^{2 / Alpha}$
$= 2.01 * (405.512/900.0)^{2/9.5}$
= 1.699

Type of Hill: No Hill

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

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Tag no:E-PK6101-3 ECONOMIZER
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FileName : Calculation Book for ECONOMIZER E-PK6101-3 ----
Wind Load Calculation: Step: 9 11:46pm Dec 22,2021

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

Topographical Factor [Kzt]:
= (1 + K1 * K2 * K3)²
= (1 + 0.0* 0.0* 0.0)²
= 1.0

Velocity Pressure evaluated at height z, Imperial Units [qz]:
= max(16, 0.00256 * Kz * Kzt * Kd * V(mph)²)
= max(16, 0.00256 * 1.699 * 1.0 * 0.95 * 121.171²)
= 60.7 psf [296.282] Kgs/m^2

Force on the first element [F]:
= qz * G * Cf * WindArea
= 60.682 * 0.85 * 0.616 * 2.005
= 63.7 lbs. [0.3] kN

Element	Hgt (z) mm.	K1	K2	K3	Kz	Kzt	qz Kgs/m^2
HEAD 1	*******	0.000	0.000	0.000	1.699	1.000	296.282
CHANNEL 01	*******	0.000	0.000	0.000	1.699	1.000	296.282
BODY FLANGE 01	*******	0.000	0.000	0.000	1.699	1.000	296.282
SHELL	*******	0.000	0.000	0.000	1.699	1.000	296.282
BODY FLANGE 002	*******	0.000	0.000	0.000	1.699	1.000	296.282
CHANNEL 002	*******	0.000	0.000	0.000	1.699	1.000	296.282
HEAD 002	*******	0.000	0.000	0.000	1.699	1.000	296.282

Wind Loads on Masses/Equipment/Piping

ID	Wind Area cm^2	Elevation mm.	Pressure Kgs/m^2	Force kN
WEIGHT BAFFLE	0.00	123600.01	296.28	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	123600	913.2	1862.66	296.282	0.17005
20	30	123600	913.2	3716.72	296.282	0.33932
30	40	123600	889.2	782.496	296.282	0.071438
40	50	123600	913.2	53696.2	296.282	4.90221
50	60	123600	889.2	782.496	296.282	0.071438
60	70	123600	913.2	3716.72	296.282	0.33932
70	80	123600	913.2	1862.66	296.282	0.17005

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

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

Earthquake Load Calculation:

Input Values:

Seismic Design Code		ASCE 7-2010
Seismic Load Reduction Scale Factor		0.700
Importance Factor		1.500
Table Value Fa		1.000
Table Value Fv		1.300
Short Period Acceleration value Ss		1.163
Long Period Acceleration Value Sl		0.600
Moment Reduction Factor Tau		1.000
Force Modification Factor R		2.000
Site Class		C
Component Elevation Ratio	z/h	0.000
Amplification Factor	Ap	0.000
Force Factor		0.000
Consider Vertical Acceleration		No
Minimum Acceleration Multiplier		0.000
User Value of Sds (used if > 0)		0.000
User Value of Sd1 (used if > 0)		0.000

Seismic Analysis Results:

Sms = Fa * Ss = 1.0 * 1.163 = 1.163
Sm1 = Fv * S1 = 1.3 * 0.6 = 0.78
Sds = 2/3 * Sms = 2/3 * 1.163 = 0.775
Sd1 = 2/3 * Sm1 = 2/3 * 0.78 = 0.52

Check Approximate Fundamental Period from 12.8-7 [Ta]:
= Ct * hn^x where Ct = 0.020, x = 0.75 and hn = Structural Height (ft.)
= 0.020 * ($2.9216^{0.75}$)
= 0.045 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 * 0.045, 0.03) per 12.8.2
= 0.030

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

Compute the Base Shear per equation 15.4-5, [V]:
= 0.3 * Sds * W * I
= 0.3 * 0.775 * 47 * 1.5
= 16.412 kN

Final Base Shear,   V = 11.49 kN

Earthquake Load Calculation:

From	To	Earthquake Height mm.	Earthquake Weight kN	Element Ope Load kN
10	20	290.5	5.22647	1.27646

20	30	290.5	5.22647	1.27646
30	40	290.5	5.22647	1.27646
40	Sadl	290.5	5.22647	1.27646
Sadl	50	290.5	5.22647	1.27646
40	50	290.5	5.22647	1.27646
50	60	290.5	5.22647	1.27646
60	70	290.5	5.22647	1.27646
70	80	290.5	5.22647	1.27646

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 after being lifted.

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

Center of Gravity of Saddles	3553.176 mm.
Center of Gravity of Liquid	3542.295 mm.
Center of Gravity of Insulation	3552.272 mm.
Center of Gravity of Nozzles	3787.192 mm.
Center of Gravity of Added Weights (Operating)	3553.176 mm.
Center of Gravity of Added Weights (Empty)	3553.176 mm.
Center of Gravity of Tubesheet(s)	3551.000 mm.
Center of Gravity of Tubes	3551.000 mm.
Center of Gravity of Bare Shell New and Cold	3548.732 mm.
Center of Gravity of Bare Shell Corroded	3547.492 mm.
Vessel CG in the Operating Condition	3560.783 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition	3564.685 mm.
Vessel CG in the Test Condition	3560.682 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      297.00  mm.
Stiffened Vessel Length per 4.15.6               L     5880.00  mm.
Distance from Saddle to Vessel tangent           a      992.00  mm.

Saddle Width                                     b      150.00  mm.
Saddle Bearing Angle                         theta      120.00  degrees

Wear Plate Width                                b1      225.00  mm.
Wear Plate Bearing Angle                    theta1      132.00  degrees
Wear Plate Thickness                            tr        10.0  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                           42.06  kN
```

Horizontal Vessel Analysis Results:	Actual N./mm^2	Allowable N./mm^2
Long. Stress at Top of Midspan	38.30	137.90
Long. Stress at Bottom of Midspan	59.36	137.90
Long. Stress at Top of Saddles	81.35	137.90
Long. Stress at Bottom of Saddles	30.81	137.90
Tangential Shear in Shell	15.69	110.32
Circ. Stress at Horn of Saddle	14.34	172.37
Circ. Compressive Stress in Shell	2.07	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 * ( 6.1/2 + 0 ) * 600.0/537.8018
  = 10.1 kN
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 0.59, 0.0, 0 ) * 600.0/4000.0
  = 0.1 kN
```

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:
```
  = max( Fl, Friction Force, Sum of X Forces ) * B / Ls
  = max( 11.49, 0.0, 0 ) * 600.0/4000.0
  = 1.7 kN
```

Saddle Reaction Force due to Earthquake Ft [Fst]:
```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0 * ( 11/2 + 0 ) * 600.0/537.8018
  = 19.2 kN
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 23 + Max( 0.1, 10, 2, 19 )
  = 42.1 kN
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		42.65	kN
Transverse Shear Load Saddle	Ft	5.74	kN
Longitudinal Shear Load Saddle		11.49	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)]
  = -42*992.0[1-(1-992.0/5880.0+(297.0²-0.0²)/
    (2*992.0*5880.0))/(1+(4*0.0)/(3*5880.0))]
  = -6726.3 N-m
```

Moment per Equation 4.15.4 [M2]:
```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 42*5880/4(1+2(297²-0²)/(5880²))/(1+(4*0)/
    (3*5880))-4*992/5880
  = 20428.3 N-m
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 23.017 * 297.0/(2*7.0) - 20428.3/(pi*297.0²*7.0)
  = 38.30 N./mm^2
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 23.017 * 297.0/(2 * 7.0) + 20428.3/(pi * 297.0² * 7.0 )
  = 59.36 N./mm^2
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 23.017*297.0/(2*7.0)--6726.3/(0.1066*pi*297.0²*7.0)
  = 81.35 N./mm^2
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 23.017*297.0/(2*7.0)+-6726.3/(0.1923*pi*297.0²*7.0)
  = 30.81 N./mm^2
```

Maximum Shear Force in the Saddle (4.15.5) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 42( 5880.0 - 2 * 992.0)/(5880.0 + ( 4 * 0.0/3))
  = 27.9 kN
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 27.87/( 297.0 * 7.0 )
  = 15.69 N./mm^2
```

Decay Length (4.15.22) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 297.0 * 7.0 )
  = 35.565 mm.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 42 * 0.1/( 7.0 * ( 150.0 + 35.56 + 35.56 ) )
  = -2.07 N./mm^2
```

Effective reinforcing plate width (4.15.1) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 150.0 + 1.56 * sqrt( 297.0 * 7.0 ), 2 * 992.0 )
  = 221.13 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 * 42 * 0.1/( 221.13( 7.0 + 1.0 * 10.0 ) )
  = -0.85 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)
  = -42/(4(7.0 + 1.0 * 10.0)221.13) -
     3 * 0.053 * 42/(2(7.0 + 1.0 * 10.0)^2)
  = -14.34 N./mm^2
```

Free Un-Restrained Thermal Expansion between the Saddles [Exp]:
```
  = Alpha * Ls * ( Design Temperature - Ambient Temperature )
  = 0.000012 * 4000.0 * ( 120.0 - 21.1 )
  = 4.838 mm.
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	545.0000	mm.
Baseplate Thickness	Bpthk	16.0000	mm.
Baseplate Width	Bpwid	180.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	206.9	N./
Height of Web at Center	Hw,c	273.0	mm.
Friction Coefficient	mu	0.000	

Note: In the tables below Io is I for the rectangle + Area * Centroid Distance^2

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

	B	D	Y	A	AY	Io
Shell	295.7	7.0	3.5	20.7	7244.9	0.343E+04

Wearplate	225.0	10.0	12.0	22.5	27000.0	0.326E+04
Web	10.0	273.5	153.7	27.3	420506.1	0.183E+04
BasePlate	180.0	16.0	298.5	28.8	859679.9	0.796E+04
Totals	...	...	...	99.3	1314430.9	0.165E+05

Distance to Centroid [C1]:
 = AY / A
 = 517.493/99.35
 = 132.304 mm.

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

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

Saddle Splitting Force [Fh]:
 = K1 * Q
 = 0.204 * 42.06
 = 8.5601 kN

Tension Stress, St = (Fh/As) = 1.0885 N./mm^2
Allowed Stress, Sa = 0.6 * Yield Str = 124.1100 N./mm^2

Saddle Splitting Dimension [d]:
 = B - R * sin(theta)/ theta
 = 600.0 - 293.5 * sin(1.0472)/1.0472
 = 357.277 mm.

Bending Moment, M = Fh * d = 3059.5596 N-m

Bending Stress, Sb = (M * C1 / I) = 2.4547 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(42 + 0.6)180.0/(4 * 545.0 * 137.9))½
 = 8.754 mm.

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:
 = 2 * cos(90 - Saddle Angle/2)(Inside Radius + Shell Thk + Wear Plate Thk)
 = 2 * cos(90 - 120.0/2)(290.5 + 10.0 + 10.0)
 = 537.802 mm.

Distance between Ribs [e]:
 = Web Length / (Nribs - 1)
 = 537.8018/(4 - 1)
 = 179.267 mm.

Baseplate Pressure Area [Ap]:
 = e * Bpwid / 2
 = 179.2673 * 180.0/2
 = 161.341 cm^2

Axial Load [P]:

```
  = Ap * Bp
  = 161.3 * 0.04
  = 6.917 kN
```

Area of the Rib and Web [Ar]:
```
  = Rib Area + Web Area
  = 14.0 + 8.963
  = 22.963 cm^2
```

Compressive Stress [Sc]:
```
  = P/Ar
  = 6.9/22.9634
  = 3.013 N./mm^2
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	10.0	150.0	...	15.0	...	281.

Rib dimension [D]:
```
  = Saddle Width - Web Thickness
  = 150.0 - 10.0
  = 140.000 mm.
```

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 0.0/22.963
  = 0.000 mm.
```

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

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 281.2/22.963 )
  = 34.997 mm.
```

Length of Outer Rib [L]:
```
  = Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
  = 600.0 - cos( 120.0/2 )( 290.5 + 10.0 + 10.0 ) - 16.0
  = 428.750 mm.
```

Intermediate Term [Cc]:
```
  = sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
  = sqrt( 2 * pi² * 0.19994E+09/206.9 )
  = 138.135
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 428.75/34.997
  = 12.251
```

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 11.5/( 2 * 545.0 ) * 179.267 * 428.75/2
  = 405.204 N-m
```

Compressive Allowable, KL/r < Cc (12.2511 < 138.1347) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.25 )²/(2 * 138.13² ))207/
    ( 5/3+3*(12.25)/(8* 138.13)-( 12.25³)/(8*138.13³)
  = 121.2 N./mm^2
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 3.01/121.21 + ( 405.2 * 75.0/2812500 )/137.9
  = 0.103
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	0.0	14.0	0.0	281.
Web	179.3	10.0	0.0	17.9	0.0	1.49
Totals	...	...	...	31.9	...	283.

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 0.0/31.927
  = 0.000 mm.
```

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

Length of Inner Rib [L]:
```
  = Saddle Height - sqrt( (Ro + Wpdthk)^2 - (Pitch/2)^2 ) - Bpthk
  = 600.0 - sqrt( (310.5 + 10.0)^2 - (179.267/2)^2 ) - 16.0
  = 286.719 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 282.7/31.927 )
  = 29.755 mm.
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 286.719/29.755
  = 9.636
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 11.488/( 2 * 545.0 )
  = 0.011 kN/mm.
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 0.011 * 179.267 * 286.719
  = 541.946 N-m
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 541.946/37688.074
  = 14.375 N./mm^2
```

Compressive Allowable, KL/r < Cc (9.6361 < 138.1347) per AISC E2-1 [Sca]:

$$= (1-(Klr)^2/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)$$
$$= (1-(9.64)^2/(2 * 138.13^2))207/$$
$$(5/3+3*(9.64)/(8* 138.13)-(9.64^3)/(8*138.13^3)$$

= 121.9 N./mm^2

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

```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 4.27/121.9 + ( 541.95 * 75.0/282.66 )/137.9
  = 0.139
```

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	72.0	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	23.4	kN
Saddle Load QL (Wind/Seismic contribution)	QL	1.7	kN
Maximum Transverse Force	Ft	5.7	kN
Maximum Longitudinal Force	Fl	11.5	kN
Saddle Bolted to Steel Foundation		Yes	

Shear Stress in a Single Bolt [taub]:

```
  = Shear Force / ( 2 * Bolt Area * Number of Bolts )
  = 11/( 2 * 3.13 * 4 )
  = 4.6 N./mm^2.  Must be less than 103.4 N./mm^2.
```

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)
  = 11.49/(172.38 * 4.0)
  = 0.1666 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
  = B * Ft + Sum of X Moments
  = 600.0 * 5.74 + 0.0
  = 3447.84 N-m
```

Eccentricity (e):

```
  = Rmom / QO
  = 3447.84/23.43
  = 147.10 mm. > Bplen/6 --> Uplift in Transverse direction

 f = Bplen / 2 - Edgedis
   = 545.0/2 - 72.0
   = 200.50 mm.

 K1 = 3 (e - 0.5 * Bplen)
```

```
    = 3 (147.1 - 0.5*545.0)
    = -376.21 mm.

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 1.0 * 6.25/180.0 * (200.5 + 147.1)
    = 7247.36 mm.²

 K3 = -K2 * (0.5 * Bplen + f)
    = -7247.36 * (0.5 * 545.0 + 200.5)
    = -3427999.84 mm.³
```

Iteratively Solving for the Effective Bearing Length:

```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + -376.21 * Y² + 7247.36 * Y + -0.3E+07 = 0
 Y  = 380.81 mm.

 Num = (Bplen / 2 - Y / 3 - e)
     = (545.0/2 - 380.81/3 - 147.1)
     = -1.54

 Denom = (Bplen / 2 - Y / 3 + f)
       = (545.0/2 - 380.81/3 + 200.5)
       = 346.06
```

Total Bolt Tension Force [Tforce]:

```
  = - QO * Num / Denom
  = - 23.43 * -1.54/346.06
  = 0.10 kN
```

Bolt Area Required due to Transverse Load [Bltareart]:

```
  = Tforce / (Stba * Nbt)
  = 0.1/( 172.38 * 2.0 )
  = 0.0030 cm^2
```

Required Area of a Single Bolt [Bltarear]:

```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0.0, 0.1666, 0.003]
  = 0.1666 cm^2
```

<u>Baseplate Thickness Calculation per D. Moss:</u>

Bearing Pressure (fc)

```
  = 2(QO + Tforce) / (Y * Bpwid)
  = 2(23.43 + 0.1)/(380.81 * 180.0)
  = 6.87 bars
```

Distance from Baseplate Edge to the Web [ADIST]:

```
  = (Bplen - Weblngth) / 2
  = (545.0 - 494.2)/2
  = 25.4000 mm.
```

Overturning Moment due To Bolt Tension [Mt]:

```
  = Tforce * Adist
  = 0.1 * 25.4
  = 2.64 N-m
```

Equivalent Bearing Pressure (f1):

```
  = fc * (Y - Adist) / Y
  = 6.87 * (380.81 - 25.4)/380.81
  = 6.41 bars
```

Overturning Moment due to Bearing Pressure [Mc]:
```
  = (Adist² * Bpwid / 6) * (f1 + 2 * fc)
  = (25.4² * 180.0/6) * (6.41 + 2 * 6.87)
  = 39.00 N-m
```

Baseplate Required Thickness [Treq]:
```
  = (6 * max(Mt,Mc) / (Bpwid * Sba))½
  = (6 *max(2.64,39.0/(180.0 * 162.38))½
  = 2.8290 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	297.00	mm.
Stiffened Vessel Length per 4.15.6	L	5880.00	mm.
Distance from Saddle to Vessel tangent	a	992.00	mm.
Saddle Width	b	150.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	225.00	mm.
Wear Plate Bearing Angle	theta1	132.00	degrees
Wear Plate Thickness	tr	10.0	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		42.24	kN

Horizontal Vessel Analysis Results:	Actual N./mm^2	Allowable N./mm^2
Long. Stress at Top of Midspan	38.26	137.90
Long. Stress at Bottom of Midspan	59.40	137.90
Long. Stress at Top of Saddles	81.48	137.90
Long. Stress at Bottom of Saddles	30.73	137.90
Tangential Shear in Shell	15.76	110.32
Circ. Stress at Horn of Saddle	14.40	172.37
Circ. Compressive Stress in Shell	2.07	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 * ( 6.1/2 + 0 ) * 600.0/537.8018
  = 10.1 kN
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 0.59, 9.44, 0 ) * 600.0/4000.0
  = 1.4 kN
```

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:
```
  = max( Fl, Friction Force, Sum of X Forces ) * B / Ls
  = max( 11.49, 9.44, 0 ) * 600.0/4000.0
  = 1.7 kN
```

Saddle Reaction Force due to Earthquake Ft [Fst]:
```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0 * ( 11/2 + 0 ) * 600.0/537.8018
  = 19.2 kN
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 23 + Max( 1, 10, 2, 19 )
  = 42.2 kN
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		42.83	kN
Transverse Shear Load Saddle	Ft	5.74	kN
Longitudinal Shear Load Saddle		11.49	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)]
  = -42*992.0[1-(1-992.0/5880.0+(297.0²-0.0²)/
    (2*992.0*5880.0))/(1+(4*0.0)/(3*5880.0))]
  = -6754.9 N-m
```

Moment per Equation 4.15.4 [M2]:
```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 42*5880/4(1+2(297²-0²)/(5880²))/(1+(4*0)/
    (3*5880))-4*992/5880
  = 20515.2 N-m
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 23.017 * 297.0/(2*7.0) - 20515.2/(pi*297.0²*7.0)
  = 38.26 N./mm^2
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 23.017 * 297.0/(2 * 7.0) + 20515.2/(pi * 297.0² * 7.0 )
  = 59.40 N./mm^2
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 23.017*297.0/(2*7.0)--6754.9/(0.1066*pi*297.0²*7.0)
  = 81.48 N./mm^2
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 23.017*297.0/(2*7.0)+-6754.9/(0.1923*pi*297.0²*7.0)
  = 30.73 N./mm^2
```

Maximum Shear Force in the Saddle (4.15.5) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 42( 5880.0 - 2 * 992.0)/(5880.0 + ( 4 * 0.0/3))
  = 28.0 kN
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 27.99/( 297.0 * 7.0 )
  = 15.76 N./mm^2
```

Decay Length (4.15.22) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 297.0 * 7.0 )
  = 35.565 mm.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 42 * 0.1/( 7.0 * ( 150.0 + 35.56 + 35.56 ) )
  = -2.07 N./mm^2
```

Effective reinforcing plate width (4.15.1) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 150.0 + 1.56 * sqrt( 297.0 * 7.0 ), 2 * 992.0 )
  = 221.13 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 * 42 * 0.1/( 221.13( 7.0 + 1.0 * 10.0 ) )
  = -0.85 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)
  = -42/(4(7.0 + 1.0 * 10.0)221.13) -
     3 * 0.053 * 42/(2(7.0 + 1.0 * 10.0)²)
  = -14.40 N./mm^2
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	545.0000	mm.
Baseplate Thickness	Bpthk	16.0000	mm.
Baseplate Width	Bpwid	180.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	206.9	N./
Height of Web at Center	Hw,c	273.0	mm.
Friction Coefficient	mu	0.400	

Note: In the tables below Io is I for the rectangle + Area * Centroid Distance^2

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

	B	D	Y	A	AY	Io
Shell	295.7	7.0	3.5	20.7	7244.9	0.343E+04
Wearplate	225.0	10.0	12.0	22.5	27000.0	0.326E+04
Web	10.0	273.5	153.7	27.3	420506.1	0.183E+04
BasePlate	180.0	16.0	298.5	28.8	859679.9	0.796E+04
Totals	...	...	...	99.3	1314430.9	0.165E+05

Distance to Centroid [C1]:
```
  = AY / A
  = 517.493/99.35
  = 132.304 mm.
```

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

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

Saddle Splitting Force [Fh]:
```
  = K1 * Q
  = 0.204 * 42.239
  = 8.5965 kN

 Tension Stress, St = ( Fh/As )       =         1.0931  N./mm^2
 Allowed Stress, Sa = 0.6 * Yield Str =       124.1100  N./mm^2
```

Saddle Splitting Dimension [d]:
```
  = B - R * sin( theta )/ theta
  = 600.0 - 293.5 * sin( 1.0472 )/1.0472
  = 357.277 mm.

 Bending Moment, M  = Fh * d          =      3072.5747  N-m

 Bending Stress, Sb = ( M * C1 / I  ) =         2.4652  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(42 + 0.6)180.0/( 4 * 545.0 * 137.9 ))½
  = 8.772 mm.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:
```
  = 2 * cos( 90 - Saddle Angle/2 )( Inside Radius + Shell Thk + Wear Plate Thk )
  = 2 * cos( 90 - 120.0/2 )( 290.5 + 10.0 + 10.0 )
  = 537.802 mm.
```

Distance between Ribs [e]:
```
  = Web Length / ( Nribs - 1 )
  = 537.8018/( 4 - 1 )
  = 179.267 mm.
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 179.2673 * 180.0/2
  = 161.341 cm^2
```

Axial Load [P]:
```
  = Ap * Bp
  = 161.3 * 0.04
  = 6.947 kN
```

Area of the Rib and Web [Ar]:
```
  = Rib Area + Web Area
  = 14.0 + 8.963
  = 22.963 cm^2
```

Compressive Stress [Sc]:
```
  = P/Ar
  = 6.9/22.9634
  = 3.025 N./mm^2
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	10.0	150.0	...	15.0	...	281.

Rib dimension [D]:
```
  = Saddle Width - Web Thickness
  = 150.0 - 10.0
  = 140.000 mm.
```

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 0.0/22.963
  = 0.000 mm.
```

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

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 281.2/22.963 )
  = 34.997 mm.
```

Length of Outer Rib [L]:
```
  = Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
  = 600.0 - cos( 120.0/2 )( 290.5 + 10.0 + 10.0 ) - 16.0
  = 428.750 mm.
```

Intermediate Term [Cc]:
```
  = sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
  = sqrt( 2 * pi² * 0.19994E+09/206.9 )
  = 138.135
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 428.75/34.997
  = 12.251
```

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 11.5/( 2 * 545.0 ) * 179.267 * 428.75/2
  = 405.204 N-m
```

Compressive Allowable, KL/r < Cc (12.2511 < 138.1347) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.25 )²/(2 * 138.13² ))207/
    ( 5/3+3*(12.25)/(8* 138.13)-( 12.25³)/(8*138.13³)
  = 121.2 N./mm^2
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 3.03/121.21 + ( 405.2 * 75.0/2812500 )/137.9
  = 0.103
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	0.0	14.0	0.0	281.
Web	179.3	10.0	0.0	17.9	0.0	1.49
Totals	...	...	...	31.9	...	283.

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 0.0/31.927
  = 0.000 mm.
```

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

Length of Inner Rib [L]:
```
  = Saddle Height - sqrt( (Ro + Wpdthk)^2 - (Pitch/2)^2 ) - Bpthk
  = 600.0 - sqrt( (310.5 + 10.0)^2 - (179.267/2)^2 ) - 16.0
  = 286.719 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 282.7/31.927 )
  = 29.755 mm.
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 286.719/29.755
  = 9.636
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 11.488/( 2 * 545.0 )
  = 0.011 kN/mm.
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 0.011 * 179.267 * 286.719
  = 541.946 N-m
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 541.946/37688.074
  = 14.375 N./mm^2
```

Compressive Allowable, KL/r < Cc (9.6361 < 138.1347) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 9.64 )²/(2 * 138.13² ))207/
    ( 5/3+3*(9.64)/(8* 138.13)-( 9.64³)/(8*138.13³)
  = 121.9 N./mm^2
```

AISC Unity Check of Inside Ribs (must be <= 1)
```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 4.29/121.9 + ( 541.95 * 75.0/282.66 )/137.9
  = 0.139
```

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	72.0	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	23.6	kN
Saddle Load QL (Wind/Seismic contribution)	QL	1.7	kN
Maximum Transverse Force	Ft	5.7	kN
Maximum Longitudinal Force	Fl	11.5	kN
Saddle Bolted to Steel Foundation		Yes	

Shear Stress in a Single Bolt [taub]:
```
  = Shear Force / ( 2 * Bolt Area * Number of Bolts )
  = 11/( 2 * 3.13 * 4 )
  = 4.6 N./mm^2.  Must be less than 103.4 N./mm^2.
```

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)
  = 11.49/(172.38 * 4.0)
  = 0.1666 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 600.0 * 5.74 + 0.0
  = 3447.84 N-m
```

Eccentricity (e):
```
  = Rmom / QO
  = 3447.84/23.61
  = 145.98 mm. > Bplen/6 --> Uplift in Transverse direction
```

```
 f = Bplen / 2 - Edgedis
   = 545.0/2 - 72.0
   = 200.50 mm.

 K1 = 3 (e - 0.5 * Bplen)
    = 3 (145.98 - 0.5*545.0)
    = -379.55 mm.

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 1.0 * 6.25/180.0 * (200.5 + 145.98)
    = 7224.12 mm.²

 K3 = -K2 * (0.5 * Bplen + f)
    = -7224.12 * (0.5 * 545.0 + 200.5)
    = -3417006.12 mm.³
```

Iteratively Solving for the Effective Bearing Length:

```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + -379.55 * Y² + 7224.12 * Y + -0.3E+07 = 0
 Y  = 383.92 mm.

 Num = (Bplen / 2 - Y / 3 - e)
     = (545.0/2 - 383.92/3 - 145.98)
     = -1.46

 Denom = (Bplen / 2 - Y / 3 + f)
       = (545.0/2 - 383.92/3 + 200.5)
       = 345.03
```

Total Bolt Tension Force [Tforce]:

```
  = - QO * Num / Denom
  = - 23.61 * -1.46/345.03
  = 0.10 kN
```

Bolt Area Required due to Transverse Load [Bltareart]:

```
  = Tforce / (Stba * Nbt)
  = 0.1/( 172.38 * 2.0 )
  = 0.0029 cm^2
```

Required Area of a Single Bolt [Bltarear]:

```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0.0, 0.1666, 0.0029]
  = 0.1666 cm^2
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)

```
  = 2(QO + Tforce) / (Y * Bpwid)
  = 2(23.61 + 0.1)/(383.92 * 180.0)
  = 6.86 bars
```

Distance from Baseplate Edge to the Web [ADIST]:

```
  = (Bplen - Weblngth) / 2
  = (545.0 - 494.2)/2
  = 25.4000 mm.
```

Overturning Moment due To Bolt Tension [Mt]:

```
  = Tforce * Adist
  = 0.1 * 25.4
  = 2.53 N-m
```

Equivalent Bearing Pressure (f1):
```
  = fc * (Y - Adist) / Y
  = 6.86 * (383.92 - 25.4)/383.92
  = 6.41 bars
```

Overturning Moment due to Bearing Pressure [Mc]:
```
  = (Adist² * Bpwid / 6) * (f1 + 2 * fc)
  = (25.4² * 180.0/6) * (6.41 + 2 * 6.86)
  = 38.98 N-m
```

Baseplate Required Thickness [Treq]:
```
  = (6 * max(Mt,Mc) / (Bpwid * Sba))½
  = (6 *max(2.53,38.98/(180.0 * 162.38))½
  = 2.8282 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	297.00	mm.
Stiffened Vessel Length per 4.15.6	L	5880.00	mm.
Distance from Saddle to Vessel tangent	a	992.00	mm.
Saddle Width	b	150.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	225.00	mm.
Wear Plate Bearing Angle	theta1	132.00	degrees
Wear Plate Thickness	tr	10.0	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		30.12	kN

Horizontal Vessel Analysis Results:	Actual N./mm^2	Allowable N./mm^2
Long. Stress at Top of Midspan	55.96	235.81
Long. Stress at Bottom of Midspan	71.04	235.81
Long. Stress at Top of Saddles	86.78	235.81
Long. Stress at Bottom of Saddles	50.59	235.81
Tangential Shear in Shell	11.24	188.65
Circ. Stress at Horn of Saddle	10.27	353.71
Circ. Compressive Stress in Shell	1.48	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) * 600.0/537.8018
= 3.3 kN

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
= max(Fl, Friction Load, Sum of X Forces) * B / Ls
= max(0.2, 0.0, 0) * 600.0/4000.0
= 0.0 kN

Load Combination Results for Q + Wind or Seismic [Q]:
= Saddle Load + Max(Fwl, Fwt, Fsl, Fst)
= 27 + Max(0.0, 3, 0, 0)
= 30.1 kN

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		30.71	kN
Transverse Shear Load Saddle	Ft	1.00	kN
Longitudinal Shear Load Saddle		0.20	kN

Hydrostatic Test Pressure at center of Vessel: 29.929 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)]
= -30*992.0[1-(1-992.0/5880.0+(297.0²-0.0²)/
  (2*992.0*5880.0))/(1+(4*0.0)/(3*5880.0))]
= -4816.7 N-m
```

Moment per Equation 4.15.4 [M2]:

```
= Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
= 30*5880/4(1+2(297²-0²)/(5880²))/(1+(4*0)/
  (3*5880))-4*992/5880
= 14628.8 N-m
```

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

```
= P * Rm/(2t) - M2/(pi*Rm²t)
= 29.929 * 297.0/(2*7.0) - 14628.8/(pi*297.0²*7.0)
= 55.96 N./mm^2
```

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

```
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 29.929 * 297.0/(2 * 7.0) + 14628.8/(pi * 297.0² * 7.0 )
= 71.04 N./mm^2
```

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

```
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 29.929*297.0/(2*7.0)--4816.7/(0.1066*pi*297.0²*7.0)
= 86.78 N./mm^2
```

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

```
= P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
= 29.929*297.0/(2*7.0)+-4816.7/(0.1923*pi*297.0²*7.0)
= 50.59 N./mm^2
```

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

```
= Q(L-2a)/(L+(4*h2/3))
= 30( 5880.0 - 2 * 992.0)/(5880.0 + ( 4 * 0.0/3))
= 20.0 kN
```

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

```
= K2 * T / ( Rm * t )
= 1.1707 * 19.96/( 297.0 * 7.0 )
= 11.24 N./mm^2
```

Decay Length (4.15.22) [x1,x2]:

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

```
  = 0.78 * sqrt( 297.0 * 7.0 )
  = 35.565 mm.
```

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

```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 30 * 0.1/( 7.0 * ( 150.0 + 35.56 + 35.56 ) )
  = -1.48 N./mm^2
```

Effective reinforcing plate width (4.15.1) [B1]:

```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 150.0 + 1.56 * sqrt( 297.0 * 7.0 ), 2 * 992.0 )
  = 221.13 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 * 30 * 0.1/( 221.13( 7.0 + 1.0 * 10.0 ) )
  = -0.61 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)
  = -30/(4(7.0 + 1.0 * 10.0)221.13) -
     3 * 0.053 * 30/(2(7.0 + 1.0 * 10.0)²)
  = -10.27 N./mm^2
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	545.0000	mm.
Baseplate Thickness	Bpthk	16.0000	mm.
Baseplate Width	Bpwid	180.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	206.9	N./
Height of Web at Center	Hw,c	273.0	mm.
Friction Coefficient	mu	0.000	

Note: In the tables below Io is I for the rectangle + Area * Centroid Distance^2

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

	B	D	Y	A	AY	Io
Shell	295.7	7.0	3.5	20.7	7244.9	0.343E+04
Wearplate	225.0	10.0	12.0	22.5	27000.0	0.326E+04
Web	10.0	273.5	153.7	27.3	420506.1	0.183E+04
BasePlate	180.0	16.0	298.5	28.8	859679.9	0.796E+04
Totals	...	...	...	99.3	1314430.9	0.165E+05

Distance to Centroid [C1]:

```
  = AY / A
  = 517.493/99.35
  = 132.304 mm.
```

Angle [beta]:

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

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

Saddle Splitting Force [Fh]:
```
  = K1 * Q
  = 0.204 * 30.119
  = 6.1299 kN

 Tension Stress, St = ( Fh/As )       =         0.7795  N./mm^2
 Allowed Stress, Sa = 0.6 * Yield Str =       124.1100  N./mm^2
```

Saddle Splitting Dimension [d]:
```
  = B - R * sin( theta )/ theta
  = 600.0 - 293.5 * sin( 1.0472 )/1.0472
  = 357.277 mm.

 Bending Moment, M  = Fh * d          =      2190.9668  N-m

 Bending Stress, Sb = ( M * C1 / I  ) =         1.7578  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(30 + 0.6)180.0/( 4 * 545.0 * 137.9 ))½
  = 7.428 mm.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:
```
  = 2 * cos( 90 - Saddle Angle/2 )( Inside Radius + Shell Thk + Wear Plate Thk )
  = 2 * cos( 90 - 120.0/2 )( 290.5 + 10.0 + 10.0 )
  = 537.802 mm.
```

Distance between Ribs [e]:
```
  = Web Length / ( Nribs - 1 )
  = 537.8018/( 4 - 1 )
  = 179.267 mm.
```

Baseplate Pressure Area [Ap]:
```
  = e * Bpwid / 2
  = 179.2673 * 180.0/2
  = 161.341 cm^2
```

Axial Load [P]:
```
  = Ap * Bp
  = 161.3 * 0.03
  = 4.954 kN
```

Area of the Rib and Web [Ar]:
```
  = Rib Area + Web Area
  = 14.0 + 8.963
  = 22.963 cm^2
```

Compressive Stress [Sc]:
```
  = P/Ar
  = 5.0/22.9634
  = 2.157 N./mm^2
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	10.0	150.0	...	15.0	...	281.

Rib dimension [D]:
```
  = Saddle Width - Web Thickness
  = 150.0 - 10.0
  = 140.000 mm.
```

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 0.0/22.963
  = 0.000 mm.
```

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

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 281.2/22.963 )
  = 34.997 mm.
```

Length of Outer Rib [L]:
```
  = Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
  = 600.0 - cos( 120.0/2 )( 290.5 + 10.0 + 10.0 ) - 16.0
  = 428.750 mm.
```

Intermediate Term [Cc]:
```
  = sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
  = sqrt( 2 * pi² * 0.19994E+09/206.9 )
  = 138.135
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 428.75/34.997
  = 12.251
```

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 0.2/( 2 * 545.0 ) * 179.267 * 428.75/2
  = 6.907 N-m
```

Compressive Allowable, KL/r < Cc (12.2511 < 138.1347) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.25 )²/(2 * 138.13² ))207/
    ( 5/3+3*(12.25)/(8* 138.13)-( 12.25³)/(8*138.13³)
  = 121.2 N./mm^2
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 2.16/121.21 + ( 6.91 * 75.0/2812500 )/137.9
  = 0.019
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	0.0	14.0	0.0	281.
Web	179.3	10.0	0.0	17.9	0.0	1.49
Totals	...	...	...	31.9	...	283.

Distance to Centroid from Datum [ytot]:
= AY / A
= 0.0/31.927
= 0.000 mm.

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

Length of Inner Rib [L]:
= Saddle Height - sqrt((Ro + Wpdthk)^2 - (Pitch/2)^2) - Bpthk
= 600.0 - sqrt((310.5 + 10.0)^2 - (179.267/2)^2) - 16.0
= 286.719 mm.

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(282.7/31.927)
= 29.755 mm.

Slenderness ratio [KL/r]:
= KL/r
= 1 * 286.719/29.755
= 9.636

Unit Force [Force,u]:
= Fl / (2 * Baseplate Length)
= 0.196/(2 * 545.0)
= 0.000 kN/mm.

Moment at base of inner Rib [Mbase,c]:
= Unit Force * e * L
= 0. * 179.267 * 286.719
= 9.238 N-m

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
= Bending Moment / Section Modulus
= 9.238/37688.074
= 0.245 N./mm^2

Compressive Allowable, KL/r < Cc (9.6361 < 138.1347) per AISC E2-1 [Sca]:
= $(1-(Klr)^2/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)$
= $(1-(9.64)^2/(2 * 138.13^2))207/$
$(5/3+3*(9.64)/(8* 138.13)-(9.64^3)/(8*138.13^3)$
= 121.9 N./mm^2

AISC Unity Check of Inside Ribs (must be <= 1)
= Sc/Sca + (Mbase,c * C1/I)/Sba
= 3.06/121.9 + (9.24 * 75.0/282.66)/137.9
= 0.027

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	72.0	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	27.4	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.0	kN
Maximum Transverse Force	Ft	1.0	kN
Maximum Longitudinal Force	Fl	0.2	kN
Saddle Bolted to Steel Foundation		Yes	

Shear Stress in a Single Bolt [taub]:
```
  = Shear Force / ( 2 * Bolt Area * Number of Bolts )
  = 1/( 2 * 3.13 * 4 )
  = 0.4 N./mm^2.  Must be less than 103.4 N./mm^2.
```

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)
  = 0.2/(172.38 * 4.0)
  = 0.0028 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 600.0 * 1.0 + 0.0
  = 600.56 N-m
```

Eccentricity (e):
```
  = Rmom / QO
  = 600.56/27.37
  = 21.94 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, 0.0028, 0.0]
  = 0.0028 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	297.00	mm.
Stiffened Vessel Length per 4.15.6	L	5880.00	mm.
Distance from Saddle to Vessel tangent	a	992.00	mm.
Saddle Width	b	150.00	mm.
Saddle Bearing Angle	theta	120.00	degrees

Wear Plate Width	b1	225.00	mm.
Wear Plate Bearing Angle	theta1	132.00	degrees
Wear Plate Thickness	tr	10.0	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 30.33 kN

Horizontal Vessel Analysis Results:	Actual N./mm^2	Allowable N./mm^2
Long. Stress at Top of Midspan	55.91	235.81
Long. Stress at Bottom of Midspan	71.09	235.81
Long. Stress at Top of Saddles	86.94	235.81
Long. Stress at Bottom of Saddles	50.50	235.81
Tangential Shear in Shell	11.32	188.65
Circ. Stress at Horn of Saddle	10.34	353.71
Circ. Compressive Stress in Shell	1.49	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) * 600.0/537.8018
= 3.3 kN

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
= max(Fl, Friction Load, Sum of X Forces) * B / Ls
= max(0.2, 0.0, 0) * 600.0/4000.0
= 0.0 kN

Load Combination Results for Q + Wind or Seismic [Q]:
= Saddle Load + Max(Fwl, Fwt, Fsl, Fst)
= 27 + Max(0.0, 3, 0, 0)
= 30.3 kN

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		30.92	kN
Transverse Shear Load Saddle	Ft	1.00	kN
Longitudinal Shear Load Saddle		0.20	kN

Hydrostatic Test Pressure at center of Vessel: 29.929 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)]
  = -30*992.0[1-(1-992.0/5880.0+(297.0²-0.0²)/
    (2*992.0*5880.0))/(1+(4*0.0)/(3*5880.0))]
  = -4849.7 N-m
```

Moment per Equation 4.15.4 [M2]:
```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 30*5880/4(1+2(297²-0²)/(5880²))/(1+(4*0)/
    (3*5880))-4*992/5880
  = 14729.0 N-m
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 29.929 * 297.0/(2*7.0) - 14729.0/(pi*297.0²*7.0)
  = 55.91 N./mm^2
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 29.929 * 297.0/(2 * 7.0) + 14729.0/(pi * 297.0² * 7.0 )
  = 71.09 N./mm^2
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 29.929*297.0/(2*7.0)--4849.7/(0.1066*pi*297.0²*7.0)
  = 86.94 N./mm^2
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 29.929*297.0/(2*7.0)+-4849.7/(0.1923*pi*297.0²*7.0)
  = 50.50 N./mm^2
```

Maximum Shear Force in the Saddle (4.15.5) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 30( 5880.0 - 2 * 992.0)/(5880.0 + ( 4 * 0.0/3))
  = 20.1 kN
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 20.09/( 297.0 * 7.0 )
  = 11.32 N./mm^2
```

Decay Length (4.15.22) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 297.0 * 7.0 )
  = 35.565 mm.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 30 * 0.1/( 7.0 * ( 150.0 + 35.56 + 35.56 ) )
  = -1.49 N./mm^2
```

Effective reinforcing plate width (4.15.1) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a )
  = min( 150.0 + 1.56 * sqrt( 297.0 * 7.0 ), 2 * 992.0 )
  = 221.13 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 * 30 * 0.1/(221.13(7.0 + 1.0 * 10.0))
= -0.61 N./mm^2

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.27) [sigma7,r]:
= $-Q/(4(t+eta*tr)b1) - 3*K7*Q/(2(t+eta*tr)^2)$
= -30/(4(7.0 + 1.0 * 10.0)221.13) -
3 * 0.053 * $30/(2(7.0 + 1.0 * 10.0)^2)$
= -10.34 N./mm^2

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	545.0000	mm.
Baseplate Thickness	Bpthk	16.0000	mm.
Baseplate Width	Bpwid	180.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	206.9	N./
Height of Web at Center	Hw,c	273.0	mm.
Friction Coefficient	mu	0.400	

Note: In the tables below Io is I for the rectangle + Area * Centroid Distance^2

Moment of Inertia of Saddle - Transverse Direction (90 degrees to long axis)

	B	D	Y	A	AY	Io
Shell	295.7	7.0	3.5	20.7	7244.9	0.343E+04
Wearplate	225.0	10.0	12.0	22.5	27000.0	0.326E+04
Web	10.0	273.5	153.7	27.3	420506.1	0.183E+04
BasePlate	180.0	16.0	298.5	28.8	859679.9	0.796E+04
Totals	...	...	...	99.3	1314430.9	0.165E+05

Distance to Centroid [C1]:
= AY / A
= 517.493/99.35
= 132.304 mm.

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

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

Saddle Splitting Force [Fh]:
= K1 * Q
= 0.204 * 30.325
= 6.1719 kN

Tension Stress, St = (Fh/As) = 0.7848 N./mm^2
Allowed Stress, Sa = 0.6 * Yield Str = 124.1100 N./mm^2

Saddle Splitting Dimension [d]:
```
  = B - R * sin( theta )/ theta
  = 600.0 - 293.5 * sin( 1.0472 )/1.0472
  = 357.277 mm.

 Bending Moment, M  = Fh * d          =       2205.9661  N-m

 Bending Stress, Sb = ( M * C1 / I  ) =          1.7699  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(30 + 0.6)180.0/( 4 * 545.0 * 137.9 ))½
  = 7.453 mm.
```

Calculation of Axial Load, Intermediate Values and Compressive Stress:

Web Length Dimension [Web Length]:
```
  = 2 * cos( 90 - Saddle Angle/2 )( Inside Radius + Shell Thk + Wear Plate Thk )
  = 2 * cos( 90 - 120.0/2 )( 290.5 + 10.0 + 10.0 )
  = 537.802 mm.
```

Distance between Ribs [e]:
```
  = Web Length / ( Nribs - 1 )
  = 537.8018/( 4 - 1 )
  = 179.267 mm.
```

Baseplate Pressure Area [Ap]:
```
  = e * Bpwid / 2
  = 179.2673 * 180.0/2
  = 161.341 cm^2
```

Axial Load [P]:
```
  = Ap * Bp
  = 161.3 * 0.03
  = 4.987 kN
```

Area of the Rib and Web [Ar]:
```
  = Rib Area + Web Area
  = 14.0 + 8.963
  = 22.963 cm^2
```

Compressive Stress [Sc]:
```
  = P/Ar
  = 5.0/22.9634
  = 2.172 N./mm^2
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	10.0	150.0	...	15.0	...	281.

Rib dimension [D]:
```
  = Saddle Width - Web Thickness
  = 150.0 - 10.0
  = 140.000 mm.
```

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 0.0/22.963
  = 0.000 mm.
```

Distance to Centroid [C1]:

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

Radius of Gyration [r]:

```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 281.2/22.963 )
  = 34.997 mm.
```

Length of Outer Rib [L]:

```
  = Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
  = 600.0 - cos( 120.0/2 )( 290.5 + 10.0 + 10.0 ) - 16.0
  = 428.750 mm.
```

Intermediate Term [Cc]:

```
  = sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
  = sqrt( 2 * pi² * 0.19994E+09/206.9 )
  = 138.135
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 428.75/34.997
  = 12.251
```

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 0.2/( 2 * 545.0 ) * 179.267 * 428.75/2
  = 6.907 N-m
```

Compressive Allowable, KL/r < Cc (12.2511 < 138.1347) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.25 )²/(2 * 138.13² ))207/
    ( 5/3+3*(12.25)/(8* 138.13)-( 12.25³)/(8*138.13³)
  = 121.2 N./mm^2
```

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

```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 2.17/121.21 + ( 6.91 * 75.0/2812500 )/137.9
  = 0.019
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	10.0	140.0	0.0	14.0	0.0	281.
Web	179.3	10.0	0.0	17.9	0.0	1.49
Totals	...	...	...	31.9	...	283.

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 0.0/31.927
  = 0.000 mm.
```

Distance to Centroid [C1]:

```
  = Saddle Width / 2
```

= 150.0/2
= 75.000 mm.

Length of Inner Rib [L]:
= Saddle Height - sqrt((Ro + Wpdthk)^2 - (Pitch/2)^2) - Bpthk
= 600.0 - sqrt((310.5 + 10.0)^2 - (179.267/2)^2) - 16.0
= 286.719 mm.

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(282.7/31.927)
= 29.755 mm.

Slenderness ratio [KL/r]:
= KL/r
= 1 * 286.719/29.755
= 9.636

Unit Force [Force,u]:
= Fl / (2 * Baseplate Length)
= 0.196/(2 * 545.0)
= 0.000 kN/mm.

Moment at base of inner Rib [Mbase,c]:
= Unit Force * e * L
= 0. * 179.267 * 286.719
= 9.238 N-m

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
= Bending Moment / Section Modulus
= 9.238/37688.074
= 0.245 N./mm^2

Compressive Allowable, KL/r < Cc (9.6361 < 138.1347) per AISC E2-1 [Sca]:
$= (1-(Klr)^2/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)$
$= (1-(9.64)^2/(2 * 138.13^2))207/$
$(5/3+3*(9.64)/(8* 138.13)-(9.64^3)/(8*138.13^3)$
= 121.9 N./mm^2

AISC Unity Check of Inside Ribs (must be <= 1)
= Sc/Sca + (Mbase,c * C1/I)/Sba
= 3.08/121.9 + (9.24 * 75.0/282.66)/137.9
= 0.027

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	72.0	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	27.6	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.0	kN
Maximum Transverse Force	Ft	1.0	kN
Maximum Longitudinal Force	Fl	0.2	kN
Saddle Bolted to Steel Foundation		Yes	

Shear Stress in a Single Bolt [taub]:
```
  = Shear Force / ( 2 * Bolt Area * Number of Bolts )
  = 1/( 2 * 3.13 * 4 )
  = 0.4 N./mm^2.  Must be less than 103.4 N./mm^2.
```

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)
  = 0.2/(172.38 * 4.0)
  = 0.0028 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 600.0 * 1.0 + 0.0
  = 600.56 N-m
```

Eccentricity (e):
```
  = Rmom / QO
  = 600.56/27.57
  = 21.77 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, 0.0028, 0.0]
  = 0.0028 cm^2
```

Nozzle Calculation Summary:

Description	MAWP bars	Ext	MAPNC bars	UG-45	[tr] mm.	Weld Path	Areas or Stresses
T4	...	OK	...	OK	6.22	OK	Passed
T1	...	OK	...	OK	7.95	OK	Passed
S2	...	OK	...	OK	7.94	OK	Passed
S1	...	OK	...	OK	7.94	OK	Passed
S3	...	OK	...	OK	6.42	OK	Passed
T2	...	OK	...	OK	7.94	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	T4	253.000	90.000	61.550
20	T1	253.000	270.000	201.662
40	S2	809.175	90.000	310.145
40	S1	6293.175	90.000	310.145
40	S3	759.175	270.000	102.068
60	T2	6849.351	90.000	310.145
60	T3	6852.351	270.000	68.000

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, Nozzle Desc: T4 From: 20

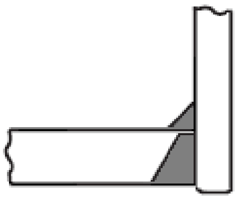
Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	120	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	581.00	mm.
Design Length of Section	L	505.4167	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		253.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm^2
Allowable Stress At Ambient	Sna	137.90	N./mm^2
Diameter Basis (for tr calc only)		ID	
Layout Angle		90.00	deg
Diameter		0.7500	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	14.2500	mm.
Flange Material		SA-350 LF2	
Flange Type		Slip on	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: T4

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

```
Actual Inside Diameter Used in Calculation          0.750  in.
Actual Thickness Used in Calculation                0.561  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*293.5)/(138*1.0-0.6*23.0)
  = 4.9450 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 : 0.2845 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl    61.5500  mm.
Parallel to Vessel Wall                      Rn+tn+t    30.7750  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    17.5000  mm.
```

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

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

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.239	0.230	NA
Area in Shell	A1	0.750	1.886	NA

Area in Nozzle Wall	A2	3.864	3.838	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.630	0.630	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	5.244	6.354	NA

The Internal Pressure Case Governs the Analysis.

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

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (25.05*4.945*1.0+2*11.25*4.945*1.0*(1-1.0))
  = 1.239 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 )
  = 36.5( 1.0 * 7.0 - 1.0 * 4.945 ) - 2 * 11.25
    ( 1.0 * 7.0 - 1.0 * 4.945 ) * ( 1 - 1.0 )
  = 0.750 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 17.5 )( 11.25 - 0.21 )1.0
  = 3.864 cm^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = ( Wo² - Area Lost )*fr2 + ( (Wi-can/0.707)² - Area Lost)*fr2
  = ( 8.0² - 0.01 ) * 1.0 + ( 0.0² -0.0 ) * 1.0
  = 0.630 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 3.2845 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 7.9450 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 7.9450 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 6.2200 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 6.22, max( 7.945, 4.5 ) ]
  = 6.2200 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.2845, 6.22 )
  = 6.2200 mm.
```

Available Nozzle Neck Thickness = 14.2500 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

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

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

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

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

Govrn. thk, tg = 10.0, tr = 4.945, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.706, Temp. Reduction = 16 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D             -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)           -86 °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: T4

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      7.0000  mm.
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
 Nozzle Weld          4.9000 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
```

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (1.2387 - 0.7501 + 2 * 11.25 * 1.0 *
    (1.0 * 7.0 - 4.945 ) )138)
  = 13.11 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.8638 + 0.0 + 0.63 - 0.0 * 1.0 ) * 138
  = 61.96 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.8638 + 0.0 + 0.63 + ( 1.575 ) ) * 138
  = 83.68 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.8638 + 0.0 + 0.63 + 0.0 + ( 1.575 ) ) * 138
  = 83.68 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 * 8.0 * 0.49 * 138
  = 40. 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 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 53. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 40 + 62 ) = 102 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 40 + 0 + 53 + 0 ) = 94 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 40 + 53 + 0 ) = 94 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 102 kN , must exceed W = 13 kN  or W1 = 61 kN
 Path 2-2 = 93 kN , must exceed W = 13 kN  or W2 = 83 kN
 Path 3-3 = 93 kN , must exceed W = 13 kN  or W3 = 83 kN

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

The Drop for this Nozzle is : 0.9745 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 210.9745 mm.

Input, Nozzle Desc: T1 From: 20

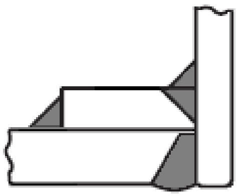
Pressure for Reinforcement Calculations	P	23.034	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	120	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	581.00	mm.
Design Length of Section	L	505.4167	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		253.00	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		4.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	120	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
Diameter of Pad along vessel surface	Dp	230.0000	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	8.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		57.8500	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: T1

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

```
 Actual Outside Diameter Used in Calculation            4.500  in.
 Actual Thickness Used in Calculation                   0.383  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.03*293.5)/(138*1.0-0.6*23.03)
  = 4.9524 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)
  = (23.03*57.15)/(118*1.0+0.4*23.03)
  = 1.1079 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.4740 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl   201.6618  mm.
 Parallel to Vessel Wall, opening length              d   100.8309  mm.
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp    17.5000  mm.
```

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

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

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

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

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(0.855, 1.0)
= 0.855

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	5.090	0.942	NA
Area in Shell	A1	2.025	5.108	NA
Area in Nozzle Wall	A2	1.684	1.873	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.545	0.545	NA
Area in Element	A5	6.552	6.552	NA
TOTAL AREA AVAILABLE	Atot	10.806	14.079	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:	125.4577	10.0000	mm.
Based on given Pad Diameter:	230.0000	1.2772	mm.
Based on Shell or Nozzle Thickness:	125.7620	9.7345	mm.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (100.8309*4.9524*1.0+2*6.7345*4.9524*1.0*(1-0.86))
= 5.090 cm^2

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 100.831(1.0 * 7.0 - 1.0 * 4.952) - 2 * 6.735
(1.0 * 7.0 - 1.0 * 4.9524) * (1 - 0.855)
= 2.025 cm^2

Area Available in Nozzle Wall Projecting Outward [A2]:
= (2 * Tlwp) * (tn - trn) * fr2
= (2 * 17.5) * (6.73 - 1.11) * 0.855
= 1.684 cm^2

Area Available in Welds [A41 + A42 + A43]:
= $(Wo^2$ - Ar Lost)*Fr3+((Wi-can/0.707)^2 - Ar Lost)*fr2 + Wp^2*fr4
= (0.6375) * 0.86 + (0.0) * 0.86 + 0.0^2 * 1.0
= 0.545 cm^2

Area Available in Element, also see UG-37(h) [A5]:
= (min(Dp,DL)-(Nozzle OD))(min(tp,Tlwp,te)) * fr4 * 0.75
= (201.6618 - 114.3)10.0 * 1.0 * 0.75
= 6.552 cm^2

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

Wall Thickness for Internal/External pressures ta = 4.1079 mm.
Wall Thickness per UG16(b), tr16b = 4.5000 mm.

```
Wall Thickness, shell/head, internal pressure     trb1 = 7.9524 mm.
Wall Thickness                  tb1 = max(trb1, tr16b) = 7.9524 mm.
Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                     tb3 = 8.2578 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 8.258, max( 7.9524, 4.5 ) ]
  = 7.9524 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 4.1079, 7.9524 )
  = 7.9524 mm.
```

Available Nozzle Neck Thickness = 9.7345 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):
```
Sustained  :     51.4, Allowable :    117.9 N./mm^2  Passed
Expansion  :      0.0, Allowable :    243.4 N./mm^2  Passed
Occasional :      8.1, Allowable :    156.8 N./mm^2  Passed
Shear      :     24.8, 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: B

Govrn. thk, tg = 9.735, tr = 1.108, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.165, Temp. Reduction = 78 °C

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

Shell to Pad Weld Junction at Pad OD, min(Curve:B, Curve:D)

Govrn. thk, tg = 10.0, tr = 4.952, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.707, Temp. Reduction = 16 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B             -29 °C
```

```
 Min Metal Temp. at Required thickness (UCS 66.1)           -45 °C
```

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

Govrn. thk, tg = 9.735, tr = 1.108, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.165, 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 the Nozzle                          :   -104 °C
 Governing MDMT of the Reinforcement Pad               :    -45 °C
 Governing MDMT of all the sub-joints of this Junction :    -45 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
 MDMT of ANSI B16.5/47 flange per Matl. Specification       -46 °C
 Flange MDMT with Temp reduction per UCS-66(i)(2)           -85 °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 = 23.03/51.10 = 0.451

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

Weld Size Calculations, Description: T1

```
 Intermediate Calc. for nozzle/shell Welds   Tmin       6.7345  mm.
 Intermediate Calc. for pad/shell Welds   TminPad       7.0000  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.7142 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.
Pad Weld	3.5000 = 0.5*TminPad	5.6560 = 0.7 * Wp mm.

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (5.0903 - 2.0246 + 2 * 6.7345 * 0.855 *
    (1.0 * 7.0 - 4.9524 ) )138)
  = 45.52 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.6838 + 6.5521 + 0.5451 - 0.0 * 0.86 ) * 138
  = 121.08 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.6838 + 0.0 + 0.5472 + ( 0.8061 ) ) * 138
  = 41.88 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.6838 + 0.0 + 0.5451 + 6.5521 + ( 0.8061 ) ) * 138
  = 132.19 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 114.3 * 8.0 * 0.49 * 118
  = 83. kN
```

Shear, Pad Element Weld [Spew]:
```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 230.0 * 8.0 * 0.49 * 138
  = 195. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 53.7827) * ( 9.7345 - 3.0 ) * 0.7 * 118
  = 94. kN
```

Tension, Pad Groove Weld [Tpgw]:
```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 114.3 * 10.0 * 0.74 * 138
  = 183. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 114.3 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 128. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 195 + 94 ) = 289 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 83 + 183 + 128 + 0 ) = 394 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 195 + 128 + 0 ) = 324 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 289 kN , must exceed W = 45 kN  or W1 = 121 kN
 Path 2-2 = 394 kN , must exceed W = 45 kN  or W2 = 41 kN
 Path 3-3 = 323 kN , must exceed W = 45 kN  or W3 = 132 kN

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

The Drop for this Nozzle is : 5.6770 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 215.6770 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	581.000	mm.
Vessel Thickness	Tv	10.000	mm.
Design Temperature	T1	120.0	°C
Vessel Material		SA-516 70	
Vessel UNS Number		K02700	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	137.90	N./mm^2

Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-3 ECONOMIZER
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for ECONOMIZER E-PK6101-3 ----
Nozzle Calcs.: T1 Nozl: 9 11:46pm Dec 22,2021

Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

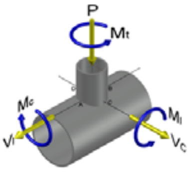
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	114.300	mm.
Nozzle Thickness	Tn	9.735	mm.
Nozzle Material		SA-333 6	
Nozzle UNS Number		K03006	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm^2
Thickness of Reinforcing Pad	Tpad	10.000	mm.
Diameter of Reinforcing Pad	Dpad	230.000	mm.
Design Internal Pressure	Dp	23.034	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	4.0	kN
Longitudinal Shear	(SUS)	Vl	4.0	kN
Circumferential Shear	(SUS)	Vc	4.0	kN
Circumferential Moment	(SUS)	Mc	1700.0	N-m
Longitudinal Moment	(SUS)	Ml	1700.0	N-m
Torsional Moment	(SUS)	Mt	2100.0	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))
= 114.3 + 2 * 1.65 * sqrt(297.0 (10.0 - 3.0))
= 264.767 mm.

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	4.0	kN
Circumferential Shear	VC	4.0	kN
Longitudinal Shear	VL	4.0	kN
Circumferential Moment	MC	1700.0	N-m
Longitudinal Moment	ML	1700.0	N-m

Torsional Moment MT 2100.0 N-m

Dimensionless Parameters used : Gamma = 17.76

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.166	4C	3.000	(A,B)
N(PHI) / (P/Rm)	0.166	3C	2.539	(C,D)
M(PHI) / (P)	0.166	2C1	0.077	(A,B)
M(PHI) / (P)	0.166	1C	0.107	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.166	3A	0.597	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.166	1A	0.095	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.166	3B	1.885	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.166	1B	0.044	(A,B,C,D)
N(x) / (P/Rm)	0.166	3C	2.539	(A,B)
N(x) / (P/Rm)	0.166	4C	3.000	(C,D)
M(x) / (P)	0.166	1C1	0.112	(A,B)
M(x) / (P)	0.166	2C	0.077	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.166	4A	0.893	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.166	2A	0.052	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.166	4B	0.568	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.166	2B	0.069	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-2.3	-2.3	-2.3	-2.3	-2.0	-2.0	-2.0	-2.0
Circ. Bend. P	-6.4	6.4	-6.4	6.4	-8.9	8.9	-8.9	8.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	-4.0	-4.0	4.0	4.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	-67.0	67.0	67.0	-67.0
Circ. Memb. ML	-12.5	-12.5	12.5	12.5	0.0	0.0	0.0	0.0
Circ. Bend. ML	-31.1	31.1	31.1	-31.1	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-52.3	22.7	34.9	-14.6	-81.8	69.9	60.0	-56.1
Long. Memb. P	-2.0	-2.0	-2.0	-2.0	-2.3	-2.3	-2.3	-2.3
Long. Bend. P	-9.3	9.3	-9.3	9.3	-6.4	6.4	-6.4	6.4
Long. Memb. MC	0.0	0.0	0.0	0.0	-5.9	-5.9	5.9	5.9
Long. Bend. MC	0.0	0.0	0.0	0.0	-36.6	36.6	36.6	-36.6
Long. Memb. ML	-3.8	-3.8	3.8	3.8	0.0	0.0	0.0	0.0
Long. Bend. ML	-48.7	48.7	48.7	-48.7	0.0	0.0	0.0	0.0
Tot. Long. Str.	-63.7	52.3	41.2	-37.7	-51.2	34.7	33.8	-26.7
Shear VC	1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.3	-1.3	1.3	1.3
Shear MT	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Tot. Shear	7.3	7.3	4.7	4.7	4.7	4.7	7.3	7.3
Str. Int.	67.3	54.0	43.7	38.6	82.5	70.6	61.9	57.8

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-3 ECONOMIZER
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for ECONOMIZER E-PK6101-3 ----
Nozzle Calcs.: T1 Nozl: 9 11:46pm Dec 22,2021

Dimensionless Parameters used : Gamma = 42.43

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.339	4C	4.173	(A,B)
N(PHI) / (P/Rm)	0.339	3C	1.862	(C,D)
M(PHI) / (P)	0.339	2C1	0.012	(A,B)
M(PHI) / (P)	0.339	1C !	0.063	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.339	3A	1.336	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.339	1A	0.064	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.339	3B	2.607	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.339	1B	0.010	(A,B,C,D)
N(x) / (P/Rm)	0.339	3C	1.862	(A,B)
N(x) / (P/Rm)	0.339	4C	4.173	(C,D)
M(x) / (P)	0.339	1C1	0.030	(A,B)
M(x) / (P)	0.339	2C !	0.032	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.339	4A	4.079	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.339	2A	0.025	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.339	4B	1.423	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.339	2B	0.016	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
Circ. Memb. P	-8.0	-8.0	-8.0	-8.0	-3.6	-3.6	-3.6	-3.6
Circ. Bend. P	-5.9	5.9	-5.9	5.9	-30.9	30.9	-30.9	30.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	-10.9	-10.9	10.9	10.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	-131.6	131.6	131.6	-131.6
Circ. Memb. ML	-21.2	-21.2	21.2	21.2	0.0	0.0	0.0	0.0
Circ. Bend. ML	-20.1	20.1	20.1	-20.1	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-55.3	-3.2	27.3	-1.0	-177.0	148.1	107.9	-93.4
Long. Memb. P	-3.6	-3.6	-3.6	-3.6	-8.0	-8.0	-8.0	-8.0
Long. Bend. P	-14.7	14.7	-14.7	14.7	-15.9	15.9	-15.9	15.9
Long. Memb. MC	0.0	0.0	0.0	0.0	-33.1	-33.1	33.1	33.1
Long. Bend. MC	0.0	0.0	0.0	0.0	-52.3	52.3	52.3	-52.3
Long. Memb. ML	-11.6	-11.6	11.6	11.6	0.0	0.0	0.0	0.0
Long. Bend. ML	-32.6	32.6	32.6	-32.6	0.0	0.0	0.0	0.0
Tot. Long. Str.	-62.4	32.1	25.8	-9.9	-109.4	27.1	61.5	-11.3
Shear VC	1.6	1.6	-1.6	-1.6	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.6	-1.6	1.6	1.6
Shear MT	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Tot. Shear	5.2	5.2	2.0	2.0	2.0	2.0	5.2	5.2
Str. Int.	65.1	36.8	28.7	10.3	177.0	148.1	108.5	93.7

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)	38.7	41.0	38.7	41.0	38.7	41.0	38.7	41.0
Circ. Pl	(SUS)	-14.8	-14.8	10.1	10.1	-5.9	-5.9	2.0	2.0
Circ. Q	(SUS)	-37.5	37.5	24.7	-24.7	-75.9	75.9	58.0	-58.0
Long. Pm	(SUS)	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3
Long. Pl	(SUS)	-5.7	-5.7	1.8	1.8	-8.2	-8.2	3.6	3.6
Long. Q	(SUS)	-58.0	58.0	39.4	-39.4	-43.0	43.0	30.2	-30.2
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)	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Pm (SUS)		38.7	41.0	38.7	41.0	38.7	41.0	38.7	41.0
Pm+Pl (SUS)		24.0	26.3	48.9	51.2	32.8	35.1	40.7	43.0
Pm+Pl+Q (Total)		46.1	75.9	75.0	45.7	44.9	111.3	99.8	19.5

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	40.95	137.90	Passed
Pm+Pl (SUS)	51.15	206.85	Passed
Pm+Pl+Q (TOTAL)	111.29	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

WRC 107/537 Stress Summations:

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

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm	(SUS)	95.4	97.8	95.4	97.8	95.4	97.8	95.4	97.8
Circ. Pl	(SUS)	-29.2	-29.2	13.1	13.1	-14.4	-14.4	7.3	7.3
Circ. Q	(SUS)	-26.0	26.0	14.1	-14.1	-162.5	162.5	100.6	-100.6
Long. Pm	(SUS)	47.7	47.7	47.7	47.7	47.7	47.7	47.7	47.7
Long. Pl	(SUS)	-15.1	-15.1	8.0	8.0	-41.2	-41.2	25.1	25.1
Long. Q	(SUS)	-47.2	47.2	17.9	-17.9	-68.2	68.2	36.4	-36.4
Shear Pm	(SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl	(SUS)	1.6	1.6	-1.6	-1.6	-1.6	-1.6	1.6	1.6
Shear Q	(SUS)	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Pm (SUS)		95.4	97.8	95.4	97.8	95.4	97.8	95.4	97.8

Pm+Pl (SUS)	66.3	68.6	108.6	110.9	81.0	83.3	102.8	105.1
Pm+Pl+Q (Total)	55.8	96.2	122.8	96.8	81.7	245.9	203.6	37.2

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	97.75	137.90	Passed
Pm+Pl (SUS)	110.94	206.85	Passed
Pm+Pl+Q (TOTAL)	245.86	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

Input, Nozzle Desc: S2 From: 40

```
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      581.00  mm.
Design Length of Section                       L   5880.0005  mm.
Shell Finished (Minimum) Thickness             t     10.0000  mm.
Shell Internal Corrosion Allowance             c      3.0000  mm.
Shell External Corrosion Allowance            co      0.0000  mm.

Distance from Bottom/Left Tangent                     809.18  mm.

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

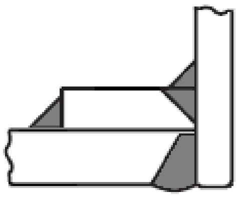
Type of Element Connected to the Shell : Nozzle

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

Diameter Basis (for tr calc only)                        OD
Layout Angle                                           90.00  deg
Diameter                                              6.0000  in.

Size and Thickness Basis                                Minimum
Nominal Thickness                             tn        80

Flange Material                                     SA-350 LF2
Flange Type                                   Weld Neck Flange

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

Outside Projection                            ho    200.0000  mm.
Weld leg size between Nozzle and Pad/Shell    Wo      8.0000  mm.
Groove weld depth between Nozzle and Vessel Wgnv     10.0000  mm.
Inside Projection                              h      0.0000  mm.
Weld leg size, Inside Element to Shell        Wi      0.0000  mm.

Pad Material                                         SA-516 70
Pad Allowable Stress at Temperature           Sp      137.90  N./mm^2
Pad Allowable Stress At Ambient              Spa      137.90  N./mm^2
Diameter of Pad along vessel surface          Dp    290.0000  mm.
Thickness of Pad                              te     10.0000  mm.
Weld leg size between Pad and Shell           Wp      8.0000  mm.
Groove weld depth between Pad and Nozzle    Wgpn     10.0000  mm.
Reinforcing Pad Width                                60.8625  mm.

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

```
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-3    ECONOMIZER
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for ECONOMIZER E-PK6101-3    ----
Nozzle Calcs.: S2                          Nozl:    10   11:46pm  Dec 22,2021
```

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              6.625  in.
 Actual Thickness Used in Calculation                     0.378  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.0*293.5)/(138*1.0-0.6*23.0)
  = 4.9450 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*84.1375)/(118*1.0+0.4*23.0)
  = 1.6287 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.5944 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl   310.1452  mm.
 Parallel to Vessel Wall, opening length              d   155.0726  mm.
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp    17.5000  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	7.763	4.029	NA
Area in Shell	A1	3.147	2.860	NA
Area in Nozzle Wall	A2	1.488	1.798	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.185	1.185	NA
Area in Element	A5	12.172	12.172	NA
TOTAL AREA AVAILABLE	Atot	17.993	18.015	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:	187.6997	10.0000	mm.
Based on given Pad Diameter:	290.0000	1.5958	mm.
Based on Shell or Nozzle Thickness:	188.5066	9.6012	mm.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (155.0726*4.945*1.0+2*6.6012*4.945*1.0*(1-0.86))
  = 7.763 cm^2
```

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 155.073( 1.0 * 7.0 - 1.0 * 4.945 ) - 2 * 6.601
    ( 1.0 * 7.0 - 1.0 * 4.945 ) * ( 1 - 0.855 )
  = 3.147 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 17.5 ) * ( 6.6 - 1.63 ) * 0.855
  = 1.488 cm^2
```

Area Available in Welds [A41 + A42 + A43]:
```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
  = ( 0.6375 ) * 0.86 + (0.0 ) * 0.86 + 203.2² * 1.0
  = 1.185 cm^2
```

Area Available in Element [A5]:
```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 290.0 - 168.275 ) * 10.0 * 1.0
  = 12.172 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 4.6287 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 7.9450 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 7.9450 mm.
```

```
 Wall Thickness                    tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 9.2200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 9.22, max( 7.945, 4.5 ) ]
  = 7.9450 mm.
```

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

```
  = max( ta, tb )
  = max( 4.6287, 7.945 )
  = 7.9450 mm.
```

Available Nozzle Neck Thickness = 9.6012 mm. --> OK

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

```
 Sustained  :    55.9,  Allowable :    117.9 N./mm^2  Passed
 Expansion  :     0.0,  Allowable :    238.8 N./mm^2  Passed
 Occasional :    13.0,  Allowable :    156.8 N./mm^2  Passed
 Shear      :    24.1,  Allowable :     82.5 N./mm^2  Passed
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

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

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

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

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

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

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

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

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

Govrn. thk, tg = 9.601, tr = 1.629, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.247, Temp. Reduction = 78 °C

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

Shell to Pad Weld Junction at Pad OD, min(Curve:B, Curve:D)

Govrn. thk, tg = 10.0, tr = 4.945, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.706, Temp. Reduction = 16 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B             -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)           -45 °C
```

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

Govrn. thk, tg = 9.601, tr = 1.629, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.247, Temp. Reduction = 78 °C

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

Governing MDMT of the Nozzle                          :  -104 °C
Governing MDMT of the Reinforcement Pad               :   -45 °C
Governing MDMT of all the sub-joints of this Junction :   -45 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ANSI B16.5/47 flange per Matl. Specification      -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)          -86 °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: S2

```
Intermediate Calc. for nozzle/shell Welds   Tmin      6.6012  mm.
Intermediate Calc. for pad/shell Welds   TminPad      7.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          4.6208 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
Pad Weld             3.5000 = 0.5*TminPad  5.6560 = 0.7 * Wp mm.
```

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (7.763 - 3.1474 + 2 * 6.6012 * 0.855 *
    (1.0 * 7.0 - 4.945 ) )138)
  = 66.84 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.488 + 12.1725 + 1.1851 - 0.0 * 0.86 ) * 138
  = 204.70 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.488 + 0.0 + 0.5472 + ( 0.7902 ) ) * 138
  = 38.96 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.488 + 0.0 + 1.1851 + 12.1725 + ( 0.7902 ) ) * 138
  = 215.60 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 ) * 168.275 * 8.0 * 0.49 * 118
  = 122. kN
```

Shear, Pad Element Weld [Spew]:
```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 290.0 * 8.0 * 0.49 * 138
  = 246. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 80.8369) * ( 9.6012 - 3.0 ) * 0.7 * 118
  = 138. kN
```

Tension, Pad Groove Weld [Tpgw]:
```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 168.275 * 10.0 * 0.74 * 138
  = 270. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 168.275 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 189. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 246 + 138 ) = 385 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 122 + 270 + 189 + 0 ) = 581 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 246 + 189 + 0 ) = 435 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 384 kN , must exceed W = 66 kN  or W1 = 204 kN
 Path 2-2 = 580 kN , must exceed W = 66 kN  or W2 = 38 kN
 Path 3-3 = 435 kN , must exceed W = 66 kN  or W3 = 215 kN

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

The Drop for this Nozzle is : 12.4512 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.4512 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    581.000  mm.
 Vessel Thickness                               Tv      10.000  mm.

 Design Temperature                             T1       120.0  °C
 Vessel Material                                      SA-516 70
 Vessel UNS Number                                      K02700
 Vessel Cold S.I. Allowable                    Smc      137.90  N./mm^2
 Vessel Hot  S.I. Allowable                    Smh      137.90  N./mm^2
```

Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

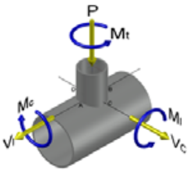
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	168.275	mm.
Nozzle Thickness	Tn	9.601	mm.
Nozzle Material		SA-333 6	
Nozzle UNS Number		K03006	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm^2
Thickness of Reinforcing Pad	Tpad	10.000	mm.
Diameter of Reinforcing Pad	Dpad	290.000	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	6.0	kN
Longitudinal Shear	(SUS)	Vl	6.0	kN
Circumferential Shear	(SUS)	Vc	6.0	kN
Circumferential Moment	(SUS)	Mc	3800.0	N-m
Longitudinal Moment	(SUS)	Ml	3800.0	N-m
Torsional Moment	(SUS)	Mt	4700.0	N-m

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

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



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

```
= NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
= 168.275 + 2 * 1.65 * sqrt( 297.0 ( 10.0 - 3.0 ) )
= 318.742 mm.
```

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	6.0	kN
Circumferential Shear	VC	6.0	kN
Longitudinal Shear	VL	6.0	kN
Circumferential Moment	MC	3800.0	N-m
Longitudinal Moment	ML	3800.0	N-m
Torsional Moment	MT	4700.0	N-m

Dimensionless Parameters used : Gamma = 17.76

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.244	4C	2.697	(A,B)
N(PHI) / (P/Rm)	0.244	3C	1.952	(C,D)
M(PHI) / (P)	0.244	2C1	0.045	(A,B)
M(PHI) / (P)	0.244	1C	0.074	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.244	3A	0.734	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.244	1A	0.085	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.244	3B	1.941	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.244	1B	0.032	(A,B,C,D)
N(x) / (P/Rm)	0.244	3C	1.952	(A,B)
N(x) / (P/Rm)	0.244	4C	2.697	(C,D)
M(x) / (P)	0.244	1C1	0.077	(A,B)
M(x) / (P)	0.244	2C	0.045	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.244	4A	1.267	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.244	2A	0.044	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.244	4B	0.709	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.244	2B	0.051	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-3.2	-3.2	-3.2	-3.2	-2.3	-2.3	-2.3	-2.3
Circ. Bend. P	-5.6	5.6	-5.6	5.6	-9.2	9.2	-9.2	9.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	-7.4	-7.4	7.4	7.4
Circ. Memb. MC	0.0	0.0	0.0	0.0	-91.0	91.0	91.0	-91.0
Circ. Memb. ML	-19.5	-19.5	19.5	19.5	0.0	0.0	0.0	0.0
Circ. Bend. ML	-33.9	33.9	33.9	-33.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-62.2	16.8	44.6	-11.9	-109.9	90.5	86.9	-76.7
Long. Memb. P	-2.3	-2.3	-2.3	-2.3	-3.2	-3.2	-3.2	-3.2
Long. Bend. P	-9.6	9.6	-9.6	9.6	-5.6	5.6	-5.6	5.6
Long. Memb. MC	0.0	0.0	0.0	0.0	-12.7	-12.7	12.7	12.7
Long. Bend. MC	0.0	0.0	0.0	0.0	-47.2	47.2	47.2	-47.2
Long. Memb. ML	-7.1	-7.1	7.1	7.1	0.0	0.0	0.0	0.0
Long. Bend. ML	-55.1	55.1	55.1	-55.1	0.0	0.0	0.0	0.0
Tot. Long. Str.	-74.1	55.2	50.4	-40.7	-68.7	37.0	51.2	-32.1
Shear VC	1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.3	-1.3	1.3	1.3
Shear MT	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Tot. Shear	7.5	7.5	4.9	4.9	4.9	4.9	7.5	7.5
Str. Int.	77.7	56.7	53.2	41.5	110.4	91.0	88.4	77.9

Dimensionless Parameters used : Gamma = 42.43

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.427	4C	3.340	(A,B)
N(PHI) / (P/Rm)	0.427	3C	1.296	(C,D)
M(PHI) / (P)	0.427	2C1	0.008	(A,B)
M(PHI) / (P)	0.427	1C !	0.063	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.427	3A	1.071	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.427	1A	0.061	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.427	3B	1.851	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.427	1B	0.006	(A,B,C,D)
N(x) / (P/Rm)	0.427	3C	1.296	(A,B)
N(x) / (P/Rm)	0.427	4C	3.340	(C,D)
M(x) / (P)	0.427	1C1	0.019	(A,B)
M(x) / (P)	0.427	2C !	0.032	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.427	4A	4.057	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.427	2A	0.024	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.427	4B	1.123	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.427	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	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-9.6	-9.6	-9.6	-9.6	-3.7	-3.7	-3.7	-3.7
Circ. Bend. P	-5.6	5.6	-5.6	5.6	-46.4	46.4	-46.4	46.4
Circ. Memb. MC	0.0	0.0	0.0	0.0	-15.4	-15.4	15.4	15.4
Circ. Memb. MC	0.0	0.0	0.0	0.0	-222.1	222.1	222.1	-222.1
Circ. Memb. ML	-26.7	-26.7	26.7	26.7	0.0	0.0	0.0	0.0
Circ. Bend. ML	-22.7	22.7	22.7	-22.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-64.6	-8.0	34.1	-0.1	-287.6	249.3	187.3	-164.0
Long. Memb. P	-3.7	-3.7	-3.7	-3.7	-9.6	-9.6	-9.6	-9.6
Long. Bend. P	-13.7	13.7	-13.7	13.7	-23.9	23.9	-23.9	23.9
Long. Memb. MC	0.0	0.0	0.0	0.0	-58.4	-58.4	58.4	58.4
Long. Bend. MC	0.0	0.0	0.0	0.0	-89.1	89.1	89.1	-89.1
Long. Memb. ML	-16.2	-16.2	16.2	16.2	0.0	0.0	0.0	0.0
Long. Bend. ML	-38.1	38.1	38.1	-38.1	0.0	0.0	0.0	0.0
Tot. Long. Str.	-71.7	31.9	36.8	-11.9	-181.1	44.9	114.1	-16.5
Shear VC	1.9	1.9	-1.9	-1.9	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.9	-1.9	1.9	1.9
Shear MT	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Tot. Shear	7.0	7.0	3.2	3.2	3.2	3.2	7.0	7.0
Str. Int.	76.0	42.3	38.9	13.4	287.7	249.4	188.0	164.3

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-3 ECONOMIZER
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for ECONOMIZER E-PK6101-3 ----
Nozzle Calcs.: S2 Nozl: 10 11:46pm Dec 22,2021

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)	38.6	40.9	38.6	40.9	38.6	40.9	38.6	40.9
Circ. Pl (SUS)	-22.7	-22.7	16.4	16.4	-9.7	-9.7	5.1	5.1
Circ. Q (SUS)	-39.5	39.5	28.2	-28.2	-100.2	100.2	81.8	-81.8
Long. Pm (SUS)	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3
Long. Pl (SUS)	-9.4	-9.4	4.8	4.8	-15.9	-15.9	9.6	9.6
Long. Q (SUS)	-64.6	64.6	45.5	-45.5	-52.8	52.8	41.6	-41.6
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)	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Pm (SUS)	38.6	40.9	38.6	40.9	38.6	40.9	38.6	40.9
Pm+Pl (SUS)	16.2	18.4	55.0	57.3	29.0	31.3	43.8	46.1
Pm+Pl+Q (Total)	56.5	77.4	84.8	51.3	72.3	131.8	126.5	38.0

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	40.89	137.90	Passed
Pm+Pl (SUS)	57.30	206.85	Passed
Pm+Pl+Q (TOTAL)	131.75	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	95.3	97.6	95.3	97.6	95.3	97.6	95.3	97.6
Circ. Pl (SUS)	-36.3	-36.3	17.0	17.0	-19.2	-19.2	11.7	11.7
Circ. Q (SUS)	-28.3	28.3	17.1	-17.1	-268.5	268.5	175.7	-175.7
Long. Pm (SUS)	47.7	47.7	47.7	47.7	47.7	47.7	47.7	47.7
Long. Pl (SUS)	-19.9	-19.9	12.4	12.4	-68.1	-68.1	48.8	48.8
Long. Q (SUS)	-51.8	51.8	24.4	-24.4	-113.0	113.0	65.3	-65.3
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.9	1.9	-1.9	-1.9	-1.9	-1.9	1.9	1.9
Shear Q (SUS)	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Pm (SUS)	95.3	97.6	95.3	97.6	95.3	97.6	95.3	97.6
Pm+Pl (SUS)	59.1	61.4	112.4	114.7	96.6	98.9	107.3	109.6

Pm+Pl+Q (Total)	56.5	93.2	129.7	97.7	192.5	347.0	283.0	98.5

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	97.61	137.90	Passed
Pm+Pl (SUS)	114.68	206.85	Passed
Pm+Pl+Q (TOTAL)	346.96	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

Input, Nozzle Desc: S1 From: 40

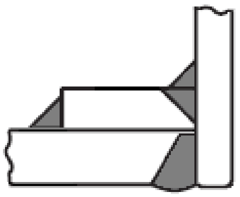
```
Pressure for Reinforcement Calculations        P      23.000  bars
Temperature for Internal Pressure           Temp         120  °C
Design External Pressure                    Pext        1.10  bars
Temperature for External Pressure         Tempex         120  °C

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      581.00  mm.
Design Length of Section                       L   5880.0005  mm.
Shell Finished (Minimum) Thickness             t     10.0000  mm.
Shell Internal Corrosion Allowance             c      3.0000  mm.
Shell External Corrosion Allowance            co      0.0000  mm.

Distance from Bottom/Left Tangent                    6293.18  mm.

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

Type of Element Connected to the Shell : Nozzle

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

Diameter Basis (for tr calc only)                         OD
Layout Angle                                           90.00  deg
Diameter                                              6.0000  in.

Size and Thickness Basis                               Minimum
Nominal Thickness                             tn       80

Flange Material                                      SA-350 LF2
Flange Type                                     Weld Neck Flange

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

Outside Projection                            ho    200.0000  mm.
Weld leg size between Nozzle and Pad/Shell    Wo      8.0000  mm.
Groove weld depth between Nozzle and Vessel Wgnv     10.0000  mm.
Inside Projection                              h      0.0000  mm.
Weld leg size, Inside Element to Shell        Wi      0.0000  mm.

Pad Material                                        SA-516 70
Pad Allowable Stress at Temperature           Sp      137.90  N./mm^2
Pad Allowable Stress At Ambient              Spa      137.90  N./mm^2
Diameter of Pad along vessel surface          Dp    290.0000  mm.
Thickness of Pad                              te     10.0000  mm.
Weld leg size between Pad and Shell           Wp      8.0000  mm.
Groove weld depth between Pad and Nozzle    Wgpn     10.0000  mm.
Reinforcing Pad Width                                60.8625  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              6.625  in.
 Actual Thickness Used in Calculation                     0.378  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.0*293.5)/(138*1.0-0.6*23.0)
  = 4.9450 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*84.1375)/(118*1.0+0.4*23.0)
  = 1.6287 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.5944 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl   310.1452  mm.
 Parallel to Vessel Wall, opening length              d   155.0726  mm.
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp    17.5000  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	7.763	4.029	NA
Area in Shell	A1	3.147	2.860	NA
Area in Nozzle Wall	A2	1.488	1.798	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.185	1.185	NA
Area in Element	A5	12.172	12.172	NA
TOTAL AREA AVAILABLE	Atot	17.993	18.015	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:	187.6997	10.0000	mm.
Based on given Pad Diameter:	290.0000	1.5958	mm.
Based on Shell or Nozzle Thickness:	188.5066	9.6012	mm.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (155.0726*4.945*1.0+2*6.6012*4.945*1.0*(1-0.86))
  = 7.763 cm^2
```

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 155.073( 1.0 * 7.0 - 1.0 * 4.945 ) - 2 * 6.601
    ( 1.0 * 7.0 - 1.0 * 4.945 ) * ( 1 - 0.855 )
  = 3.147 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 17.5 ) * ( 6.6 - 1.63 ) * 0.855
  = 1.488 cm^2
```

Area Available in Welds [A41 + A42 + A43]:
```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
  = ( 0.6375 ) * 0.86 + (0.0 ) * 0.86 + 203.2² * 1.0
  = 1.185 cm^2
```

Area Available in Element [A5]:
```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 290.0 - 168.275 ) * 10.0 * 1.0
  = 12.172 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 4.6287 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 7.9450 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 7.9450 mm.
```

```
 Wall Thickness                    tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                       tb3 = 9.2200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 9.22, max( 7.945, 4.5 ) ]
  = 7.9450 mm.
```

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

```
  = max( ta, tb )
  = max( 4.6287, 7.945 )
  = 7.9450 mm.
```

Available Nozzle Neck Thickness = 9.6012 mm. --> OK

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

```
 Sustained  :     55.9,  Allowable :    117.9 N./mm^2  Passed
 Expansion  :      0.0,  Allowable :    238.8 N./mm^2  Passed
 Occasional :     13.0,  Allowable :    156.8 N./mm^2  Passed
 Shear      :     24.1,  Allowable :     82.5 N./mm^2  Passed
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

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

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

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

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

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

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

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

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

Govrn. thk, tg = 9.601, tr = 1.629, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.247, Temp. Reduction = 78 °C

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

Shell to Pad Weld Junction at Pad OD, min(Curve:B, Curve:D)

Govrn. thk, tg = 10.0, tr = 4.945, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.706, Temp. Reduction = 16 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)            -45 °C
```

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

Govrn. thk, tg = 9.601, tr = 1.629, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.247, Temp. Reduction = 78 °C

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

Governing MDMT of the Nozzle                          :  -104 °C
Governing MDMT of the Reinforcement Pad               :   -45 °C
Governing MDMT of all the sub-joints of this Junction :   -45 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ANSI B16.5/47 flange per Matl. Specification     -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)         -86 °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      6.6012  mm.
Intermediate Calc. for pad/shell Welds    TminPad     7.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          4.6208 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
Pad Weld             3.5000 = 0.5*TminPad  5.6560 = 0.7 * Wp mm.
```

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

Weld Load [W]:
```
 = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
 = max( 0, (7.763 - 3.1474 + 2 * 6.6012 * 0.855 *
   (1.0 * 7.0 - 4.945 ) )138)
 = 66.84 kN
```

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

Weld Load [W1]:
```
 = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
 = ( 1.488 + 12.1725 + 1.1851 - 0.0 * 0.86 ) * 138
 = 204.70 kN
```

Weld Load [W2]:
```
 = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
 = ( 1.488 + 0.0 + 0.5472 + ( 0.7902 ) ) * 138
 = 38.96 kN
```

Weld Load [W3]:
```
 = (A2+A3+A4+A5+(2*tn*t*fr1))*S
 = ( 1.488 + 0.0 + 1.1851 + 12.1725 + ( 0.7902 ) ) * 138
 = 215.60 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 ) * 168.275 * 8.0 * 0.49 * 118
  = 122. kN
```

Shear, Pad Element Weld [Spew]:
```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 290.0 * 8.0 * 0.49 * 138
  = 246. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 80.8369) * ( 9.6012 - 3.0 ) * 0.7 * 118
  = 138. kN
```

Tension, Pad Groove Weld [Tpgw]:
```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 168.275 * 10.0 * 0.74 * 138
  = 270. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 168.275 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 189. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 246 + 138 ) = 385 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 122 + 270 + 189 + 0 ) = 581 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 246 + 189 + 0 ) = 435 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 384 kN , must exceed W = 66 kN  or W1 = 204 kN
 Path 2-2 = 580 kN , must exceed W = 66 kN  or W2 = 38 kN
 Path 3-3 = 435 kN , must exceed W = 66 kN  or W3 = 215 kN

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

The Drop for this Nozzle is : 12.4512 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.4512 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    581.000  mm.
 Vessel Thickness                              Tv      10.000  mm.

 Design Temperature                            T1       120.0  °C
 Vessel Material                                  SA-516 70
 Vessel UNS Number                                     K02700
 Vessel Cold S.I. Allowable                   Smc      137.90  N./mm^2
 Vessel Hot  S.I. Allowable                   Smh      137.90  N./mm^2
```

Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

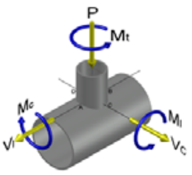
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	168.275	mm.
Nozzle Thickness	Tn	9.601	mm.
Nozzle Material		SA-333 6	
Nozzle UNS Number		K03006	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm^2
Thickness of Reinforcing Pad	Tpad	10.000	mm.
Diameter of Reinforcing Pad	Dpad	290.000	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	6.0	kN
Longitudinal Shear	(SUS)	Vl	6.0	kN
Circumferential Shear	(SUS)	Vc	6.0	kN
Circumferential Moment	(SUS)	Mc	3800.0	N-m
Longitudinal Moment	(SUS)	Ml	3800.0	N-m
Torsional Moment	(SUS)	Mt	4700.0	N-m

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

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



Stress Attenuation Diameter (for Insert Plates) per WRC 297:
```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 168.275 + 2 * 1.65 * sqrt( 297.0 ( 10.0 - 3.0 ) )
  = 318.742 mm.
```

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	6.0	kN
Circumferential Shear	VC	6.0	kN
Longitudinal Shear	VL	6.0	kN
Circumferential Moment	MC	3800.0	N-m
Longitudinal Moment	ML	3800.0	N-m
Torsional Moment	MT	4700.0	N-m

Dimensionless Parameters used :   Gamma =   17.76

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.244	4C	2.697	(A,B)
N(PHI) / (P/Rm)	0.244	3C	1.952	(C,D)
M(PHI) / (P)	0.244	2C1	0.045	(A,B)
M(PHI) / (P)	0.244	1C	0.074	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.244	3A	0.734	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.244	1A	0.085	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.244	3B	1.941	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.244	1B	0.032	(A,B,C,D)
N(x) / (P/Rm)	0.244	3C	1.952	(A,B)
N(x) / (P/Rm)	0.244	4C	2.697	(C,D)
M(x) / (P)	0.244	1C1	0.077	(A,B)
M(x) / (P)	0.244	2C	0.045	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.244	4A	1.267	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.244	2A	0.044	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.244	4B	0.709	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.244	2B	0.051	(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	-3.2	-3.2	-3.2	-3.2	-2.3	-2.3	-2.3	-2.3
Circ. Bend. P	-5.6	5.6	-5.6	5.6	-9.2	9.2	-9.2	9.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	-7.4	-7.4	7.4	7.4
Circ. Memb. MC	0.0	0.0	0.0	0.0	-91.0	91.0	91.0	-91.0
Circ. Memb. ML	-19.5	-19.5	19.5	19.5	0.0	0.0	0.0	0.0
Circ. Bend. ML	-33.9	33.9	33.9	-33.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-62.2	16.8	44.6	-11.9	-109.9	90.5	86.9	-76.7
Long. Memb. P	-2.3	-2.3	-2.3	-2.3	-3.2	-3.2	-3.2	-3.2
Long. Bend. P	-9.6	9.6	-9.6	9.6	-5.6	5.6	-5.6	5.6
Long. Memb. MC	0.0	0.0	0.0	0.0	-12.7	-12.7	12.7	12.7
Long. Bend. MC	0.0	0.0	0.0	0.0	-47.2	47.2	47.2	-47.2
Long. Memb. ML	-7.1	-7.1	7.1	7.1	0.0	0.0	0.0	0.0
Long. Bend. ML	-55.1	55.1	55.1	-55.1	0.0	0.0	0.0	0.0
Tot. Long. Str.	-74.1	55.2	50.4	-40.7	-68.7	37.0	51.2	-32.1
Shear VC	1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.3	-1.3	1.3	1.3
Shear MT	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Tot. Shear	7.5	7.5	4.9	4.9	4.9	4.9	7.5	7.5
Str. Int.	77.7	56.7	53.2	41.5	110.4	91.0	88.4	77.9

Dimensionless Parameters used :   Gamma =   42.43

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.427	4C	3.340	(A,B)
N(PHI) / (P/Rm)	0.427	3C	1.296	(C,D)
M(PHI) / (P)	0.427	2C1	0.008	(A,B)
M(PHI) / (P)	0.427	1C !	0.063	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.427	3A	1.071	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.427	1A	0.061	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.427	3B	1.851	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.427	1B	0.006	(A,B,C,D)
N(x) / (P/Rm)	0.427	3C	1.296	(A,B)
N(x) / (P/Rm)	0.427	4C	3.340	(C,D)
M(x) / (P)	0.427	1C1	0.019	(A,B)
M(x) / (P)	0.427	2C !	0.032	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.427	4A	4.057	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.427	2A	0.024	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.427	4B	1.123	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.427	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	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-9.6	-9.6	-9.6	-9.6	-3.7	-3.7	-3.7	-3.7
Circ. Bend. P	-5.6	5.6	-5.6	5.6	-46.4	46.4	-46.4	46.4
Circ. Memb. MC	0.0	0.0	0.0	0.0	-15.4	-15.4	15.4	15.4
Circ. Memb. MC	0.0	0.0	0.0	0.0	-222.1	222.1	222.1	-222.1
Circ. Memb. ML	-26.7	-26.7	26.7	26.7	0.0	0.0	0.0	0.0
Circ. Bend. ML	-22.7	22.7	22.7	-22.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-64.6	-8.0	34.1	-0.1	-287.6	249.3	187.3	-164.0
Long. Memb. P	-3.7	-3.7	-3.7	-3.7	-9.6	-9.6	-9.6	-9.6
Long. Bend. P	-13.7	13.7	-13.7	13.7	-23.9	23.9	-23.9	23.9
Long. Memb. MC	0.0	0.0	0.0	0.0	-58.4	-58.4	58.4	58.4
Long. Bend. MC	0.0	0.0	0.0	0.0	-89.1	89.1	89.1	-89.1
Long. Memb. ML	-16.2	-16.2	16.2	16.2	0.0	0.0	0.0	0.0
Long. Bend. ML	-38.1	38.1	38.1	-38.1	0.0	0.0	0.0	0.0
Tot. Long. Str.	-71.7	31.9	36.8	-11.9	-181.1	44.9	114.1	-16.5
Shear VC	1.9	1.9	-1.9	-1.9	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.9	-1.9	1.9	1.9
Shear MT	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Tot. Shear	7.0	7.0	3.2	3.2	3.2	3.2	7.0	7.0
Str. Int.	76.0	42.3	38.9	13.4	287.7	249.4	188.0	164.3

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)	38.6	40.9	38.6	40.9	38.6	40.9	38.6	40.9
Circ. Pl	(SUS)	-22.7	-22.7	16.4	16.4	-9.7	-9.7	5.1	5.1
Circ. Q	(SUS)	-39.5	39.5	28.2	-28.2	-100.2	100.2	81.8	-81.8
Long. Pm	(SUS)	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3
Long. Pl	(SUS)	-9.4	-9.4	4.8	4.8	-15.9	-15.9	9.6	9.6
Long. Q	(SUS)	-64.6	64.6	45.5	-45.5	-52.8	52.8	41.6	-41.6
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)	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Pm (SUS)		38.6	40.9	38.6	40.9	38.6	40.9	38.6	40.9
Pm+Pl (SUS)		16.2	18.4	55.0	57.3	29.0	31.3	43.8	46.1
Pm+Pl+Q (Total)		56.5	77.4	84.8	51.3	72.3	131.8	126.5	38.0

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	40.89	137.90	Passed
Pm+Pl (SUS)	57.30	206.85	Passed
Pm+Pl+Q (TOTAL)	131.75	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

WRC 107/537 Stress Summations:

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

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm	(SUS)	95.3	97.6	95.3	97.6	95.3	97.6	95.3	97.6
Circ. Pl	(SUS)	-36.3	-36.3	17.0	17.0	-19.2	-19.2	11.7	11.7
Circ. Q	(SUS)	-28.3	28.3	17.1	-17.1	-268.5	268.5	175.7	-175.7
Long. Pm	(SUS)	47.7	47.7	47.7	47.7	47.7	47.7	47.7	47.7
Long. Pl	(SUS)	-19.9	-19.9	12.4	12.4	-68.1	-68.1	48.8	48.8
Long. Q	(SUS)	-51.8	51.8	24.4	-24.4	-113.0	113.0	65.3	-65.3
Shear Pm	(SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl	(SUS)	1.9	1.9	-1.9	-1.9	-1.9	-1.9	1.9	1.9
Shear Q	(SUS)	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Pm (SUS)		95.3	97.6	95.3	97.6	95.3	97.6	95.3	97.6
Pm+Pl (SUS)		59.1	61.4	112.4	114.7	96.6	98.9	107.3	109.6

Pm+Pl+Q (Total)	56.5	93.2	129.7	97.7	192.5	347.0	283.0	98.5

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	97.61	137.90	Passed
Pm+Pl (SUS)	114.68	206.85	Passed
Pm+Pl+Q (TOTAL)	346.96	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

Input, Nozzle Desc: S3 From: 40

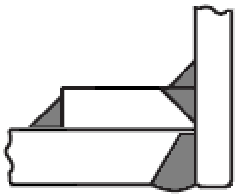
Pressure for Reinforcement Calculations	P	23.034	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	120	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	581.00	mm.
Design Length of Section	L	5880.0005	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		759.18	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		2.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
Diameter of Pad along vessel surface	Dp	170.0000	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	8.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		54.8375	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: S3

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

```
 Actual Outside Diameter Used in Calculation              2.375  in.
 Actual Thickness Used in Calculation                     0.301  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.03*293.5)/(138*1.0-0.6*23.03)
  = 4.9524 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)
  = (23.03*30.1625)/(118*1.0+0.4*23.03)
  = 0.5847 mm.
```

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

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl   102.0684  mm.
 Parallel to Vessel Wall, opening length              d    51.0342  mm.
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp    17.5000  mm.
```

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

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

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

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

Weld Strength Reduction Factor [fr3]:

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	2.594	1.344	NA
Area in Shell	A1	1.017	0.928	NA
Area in Nozzle Wall	A2	1.215	1.293	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.545	0.545	NA
Area in Element	A5	4.174	4.174	NA
TOTAL AREA AVAILABLE	Atot	6.952	6.940	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:	60.3250	10.0000	mm.
Based on given Pad Diameter:	170.0000	0.0000	mm.
Based on Shell or Nozzle Thickness:	60.3250	7.6454	mm.

Area Required [A]:

```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (51.0342*4.9524*1.0+2*4.6454*4.9524*1.0*(1-0.86))
  = 2.594 cm^2
```

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 51.034( 1.0 * 7.0 - 1.0 * 4.952 ) - 2 * 4.645
    ( 1.0 * 7.0 - 1.0 * 4.9524 ) * ( 1 - 0.855 )
  = 1.017 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 17.5 ) * ( 4.65 - 0.58 ) * 0.855
  = 1.215 cm^2
```

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

```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
  = ( 0.6375 ) * 0.86 + (0.0 ) * 0.86 + 0.0² * 1.0
  = 0.545 cm^2
```

Area Available in Element [A5]:

```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 102.0684 - 60.325 ) * 10.0 * 1.0
  = 4.174 cm^2
```

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

```
 Wall Thickness for Internal/External pressures      ta = 3.5847 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
```

```
Wall Thickness, shell/head, internal pressure     trb1 = 7.9524 mm.
Wall Thickness                   tb1 = max(trb1, tr16b) = 7.9524 mm.
Wall Thickness                   tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                      tb3 = 6.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 6.42, max( 7.9524, 4.5 ) ]
  = 6.4200 mm.
```

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

```
  = max( ta, tb )
  = max( 3.5847, 6.42 )
  = 6.4200 mm.
```

Available Nozzle Neck Thickness = 7.6454 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   :     69.1,  Allowable :    117.9 N./mm^2  Passed
Expansion   :      0.0,  Allowable :    225.6 N./mm^2  Passed
Occasional  :      5.8,  Allowable :    156.8 N./mm^2  Passed
Shear       :     28.6,  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: B

Govrn. thk, tg = 7.645, tr = 0.585, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.126, Temp. Reduction = 78 °C

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

Shell to Pad Weld Junction at Pad OD, min(Curve:B, Curve:D)

Govrn. thk, tg = 10.0, tr = 4.952, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.707, Temp. Reduction = 16 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -29 °C
```

```
Min Metal Temp. at Required thickness (UCS 66.1)          -45 °C
```

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

Govrn. thk, tg = 7.645, tr = 0.585, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.126, Temp. Reduction = 78 °C

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

Governing MDMT of the Nozzle                         :   -104 °C
Governing MDMT of the Reinforcement Pad              :    -45 °C
Governing MDMT of all the sub-joints of this Junction :   -45 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ANSI B16.5/47 flange per Matl. Specification      -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)          -85 °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 = 23.03/51.10 = 0.451

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

Weld Size Calculations, Description: S3

```
Intermediate Calc. for nozzle/shell Welds   Tmin      4.6454  mm.
Intermediate Calc. for pad/shell Welds   TminPad      7.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          3.2518 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
Pad Weld             3.5000 = 0.5*TminPad  5.6560 = 0.7 * Wp mm.
```

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (2.5941 - 1.0174 + 2 * 4.6454 * 0.855 *
    (1.0 * 7.0 - 4.9524 ) )138)
  = 23.98 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.2152 + 4.1743 + 0.5451 - 0.0 * 0.86 ) * 138
  = 81.83 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.2152 + 0.0 + 0.5472 + ( 0.5561 ) ) * 138
  = 31.97 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.2152 + 0.0 + 0.5451 + 4.1743 + ( 0.5561 ) ) * 138
  = 89.50 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 ) * 60.325 * 8.0 * 0.49 * 118
  = 44. kN
```

Shear, Pad Element Weld [Spew]:
```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 170.0 * 8.0 * 0.49 * 138
  = 144. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 27.8398) * ( 7.6454 - 3.0 ) * 0.7 * 118
  = 34. kN
```

Tension, Pad Groove Weld [Tpgw]:
```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 60.325 * 10.0 * 0.74 * 138
  = 97. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 60.325 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 68. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 144 + 34 ) = 178 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 44 + 97 + 68 + 0 ) = 208 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 144 + 68 + 0 ) = 212 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 177 kN , must exceed W = 23 kN  or W1 = 81 kN
 Path 2-2 = 208 kN , must exceed W = 23 kN  or W2 = 31 kN
 Path 3-3 = 212 kN , must exceed W = 23 kN  or W3 = 89 kN

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

The Drop for this Nozzle is : 1.5701 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 211.5701 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	581.000	mm.
Vessel Thickness	Tv	10.000	mm.
Design Temperature	T1	120.0	°C
Vessel Material		SA-516 70	
Vessel UNS Number		K02700	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	137.90	N./mm^2

Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.

Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

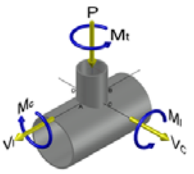
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	60.325	mm.
Nozzle Thickness	Tn	7.645	mm.
Nozzle Material		SA-333 6	
Nozzle UNS Number		K03006	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm^2
Thickness of Reinforcing Pad	Tpad	10.000	mm.
Diameter of Reinforcing Pad	Dpad	170.000	mm.
Design Internal Pressure	Dp	23.034	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	500.0	N-m
Longitudinal Moment	(SUS)	Ml	400.0	N-m
Torsional Moment	(SUS)	Mt	400.0	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))
= 60.325 + 2 * 1.65 * sqrt(297.0 (10.0 - 3.0))
= 210.792 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	500.0	N-m
Longitudinal Moment	ML	400.0	N-m

Torsional Moment MT 400.0 N-m

Dimensionless Parameters used : Gamma = 17.76

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.087	4C	3.397	(A,B)
N(PHI) / (P/Rm)	0.087	3C	3.228	(C,D)
M(PHI) / (P)	0.087	2C1	0.138	(A,B)
M(PHI) / (P)	0.087	1C	0.172	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.087	3A	0.320	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.087	1A	0.102	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.087	3B	1.184	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.087	1B	0.056	(A,B,C,D)
N(x) / (P/Rm)	0.087	3C	3.228	(A,B)
N(x) / (P/Rm)	0.087	4C	3.397	(C,D)
M(x) / (P)	0.087	1C1	0.176	(A,B)
M(x) / (P)	0.087	2C	0.138	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.087	4A	0.416	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.087	2A	0.061	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.087	4B	0.306	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.087	2B	0.092	(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	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3
Circ. Bend. P	-5.7	5.7	-5.7	5.7	-7.2	7.2	-7.2	7.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	-1.2	-1.2	1.2	1.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	-40.3	40.3	40.3	-40.3
Circ. Memb. ML	-3.5	-3.5	3.5	3.5	0.0	0.0	0.0	0.0
Circ. Bend. ML	-17.7	17.7	17.7	-17.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-28.2	18.6	14.1	-9.8	-49.9	45.0	33.1	-33.2
Long. Memb. P	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3
Long. Bend. P	-7.3	7.3	-7.3	7.3	-5.7	5.7	-5.7	5.7
Long. Memb. MC	0.0	0.0	0.0	0.0	-1.5	-1.5	1.5	1.5
Long. Bend. MC	0.0	0.0	0.0	0.0	-23.8	23.8	23.8	-23.8
Long. Memb. ML	-0.9	-0.9	0.9	0.9	0.0	0.0	0.0	0.0
Long. Bend. ML	-28.9	28.9	28.9	-28.9	0.0	0.0	0.0	0.0
Tot. Long. Str.	-38.4	34.1	21.2	-21.9	-32.4	26.7	18.3	-17.9
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	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
Tot. Shear	5.4	5.4	2.9	2.9	2.9	2.9	5.4	5.4
Str. Int.	40.7	35.7	22.2	22.6	50.4	45.5	34.8	34.9

Dimensionless Parameters used : Gamma = 42.43

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.250	4C	5.214	(A,B)
N(PHI) / (P/Rm)	0.250	3C	2.813	(C,D)
M(PHI) / (P)	0.250	2C1	0.022	(A,B)
M(PHI) / (P)	0.250	1C !	0.063	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.250	3A	1.624	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.250	1A	0.068	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.250	3B	3.634	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.250	1B	0.017	(A,B,C,D)
N(x) / (P/Rm)	0.250	3C	2.813	(A,B)
N(x) / (P/Rm)	0.250	4C	5.214	(C,D)
M(x) / (P)	0.250	1C1	0.049	(A,B)
M(x) / (P)	0.250	2C !	0.032	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.250	4A	3.734	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.250	2A	0.030	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.250	4B	1.677	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.250	2B	0.026	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
Circ. Memb. P	-5.0	-5.0	-5.0	-5.0	-2.7	-2.7	-2.7	-2.7
Circ. Bend. P	-5.4	5.4	-5.4	5.4	-15.5	15.5	-15.5	15.5
Circ. Memb. MC	0.0	0.0	0.0	0.0	-5.2	-5.2	5.2	5.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	-56.2	56.2	56.2	-56.2
Circ. Memb. ML	-9.4	-9.4	9.4	9.4	0.0	0.0	0.0	0.0
Circ. Bend. ML	-11.0	11.0	11.0	-11.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-30.8	2.0	9.9	-1.2	-79.6	63.7	43.2	-38.2
Long. Memb. P	-2.7	-2.7	-2.7	-2.7	-5.0	-5.0	-5.0	-5.0
Long. Bend. P	-11.9	11.9	-11.9	11.9	-8.0	8.0	-8.0	8.0
Long. Memb. MC	0.0	0.0	0.0	0.0	-12.1	-12.1	12.1	12.1
Long. Bend. MC	0.0	0.0	0.0	0.0	-24.5	24.5	24.5	-24.5
Long. Memb. ML	-4.3	-4.3	4.3	4.3	0.0	0.0	0.0	0.0
Long. Bend. ML	-17.1	17.1	17.1	-17.1	0.0	0.0	0.0	0.0
Tot. Long. Str.	-36.0	22.0	6.8	-3.5	-49.5	15.3	23.6	-9.5
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	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Tot. Shear	2.3	2.3	0.2	0.2	0.2	0.2	2.3	2.3
Str. Int.	36.9	22.2	10.0	3.5	79.6	63.7	43.5	38.3

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)	38.7	41.0	38.7	41.0	38.7	41.0	38.7	41.0
Circ. Pl	(SUS)	-4.8	-4.8	2.2	2.2	-2.4	-2.4	-0.1	-0.1
Circ. Q	(SUS)	-23.4	23.4	12.0	-12.0	-47.5	47.5	33.1	-33.1
Long. Pm	(SUS)	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3
Long. Pl	(SUS)	-2.2	-2.2	-0.4	-0.4	-2.9	-2.9	0.2	0.2
Long. Q	(SUS)	-36.2	36.2	21.6	-21.6	-29.5	29.5	18.1	-18.1
Shear Pm	(SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl	(SUS)	1.2	1.2	-1.2	-1.2	-1.2	-1.2	1.2	1.2
Shear Q	(SUS)	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
Pm (SUS)		38.7	41.0	38.7	41.0	38.7	41.0	38.7	41.0
Pm+Pl (SUS)		33.9	36.2	40.9	43.2	36.3	38.6	38.7	41.0
Pm+Pl+Q (Total)		31.4	62.6	53.4	34.2	15.2	86.2	72.5	12.4

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	40.95	137.90	Passed
Pm+Pl (SUS)	43.19	206.85	Passed
Pm+Pl+Q (TOTAL)	86.17	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

WRC 107/537 Stress Summations:

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

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm	(SUS)	95.4	97.8	95.4	97.8	95.4	97.8	95.4	97.8
Circ. Pl	(SUS)	-14.4	-14.4	4.4	4.4	-8.0	-8.0	2.5	2.5
Circ. Q	(SUS)	-16.4	16.4	5.6	-5.6	-71.6	71.6	40.7	-40.7
Long. Pm	(SUS)	47.7	47.7	47.7	47.7	47.7	47.7	47.7	47.7
Long. Pl	(SUS)	-7.0	-7.0	1.6	1.6	-17.1	-17.1	7.1	7.1
Long. Q	(SUS)	-29.0	29.0	5.1	-5.1	-32.4	32.4	16.5	-16.5
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)	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Pm (SUS)		95.4	97.8	95.4	97.8	95.4	97.8	95.4	97.8

Pm+Pl (SUS)	81.1	83.4	99.9	102.2	87.5	89.8	98.0	100.3
Pm+Pl+Q (Total)	64.8	99.9	105.4	96.6	17.7	161.4	138.8	59.8

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	97.75	137.90	Passed
Pm+Pl (SUS)	102.15	206.85	Passed
Pm+Pl+Q (TOTAL)	161.44	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

Input, Nozzle Desc: T2 From: 60

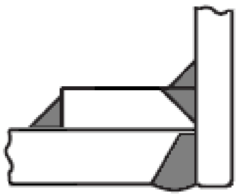
```
Pressure for Reinforcement Calculations        P      23.000  bars
Temperature for Internal Pressure           Temp         120  °C
Design External Pressure                    Pext        1.10  bars
Temperature for External Pressure         Tempex         120  °C

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      581.00  mm.
Design Length of Section                       L    505.4167  mm.
Shell Finished (Minimum) Thickness             t     10.0000  mm.
Shell Internal Corrosion Allowance             c      3.0000  mm.
Shell External Corrosion Allowance            co      0.0000  mm.

Distance from Bottom/Left Tangent                    6849.35  mm.

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

Type of Element Connected to the Shell : Nozzle

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

Diameter Basis (for tr calc only)                         OD
Layout Angle                                           90.00  deg
Diameter                                              6.0000  in.

Size and Thickness Basis                                Minimum
Nominal Thickness                             tn        80

Flange Material                                    SA-350 LF2
Flange Type                                   Weld Neck Flange

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

Outside Projection                            ho    200.0000  mm.
Weld leg size between Nozzle and Pad/Shell    Wo      8.0000  mm.
Groove weld depth between Nozzle and Vessel Wgnv     10.0000  mm.
Inside Projection                              h      0.0000  mm.
Weld leg size, Inside Element to Shell        Wi      0.0000  mm.

Pad Material                                        SA-516 70
Pad Allowable Stress at Temperature           Sp      137.90  N./mm^2
Pad Allowable Stress At Ambient              Spa      137.90  N./mm^2
Diameter of Pad along vessel surface          Dp    290.0000  mm.
Thickness of Pad                              te     10.0000  mm.
Weld leg size between Pad and Shell           Wp      8.0000  mm.
Groove weld depth between Pad and Nozzle    Wgpn     10.0000  mm.
Reinforcing Pad Width                                60.8625  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              6.625  in.
 Actual Thickness Used in Calculation                     0.378  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.0*293.5)/(138*1.0-0.6*23.0)
  = 4.9450 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*84.1375)/(118*1.0+0.4*23.0)
  = 1.6287 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.5944 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl   310.1452  mm.
 Parallel to Vessel Wall, opening length              d   155.0726  mm.
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp    17.5000  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	7.763	1.439	NA
Area in Shell	A1	3.147	7.913	NA
Area in Nozzle Wall	A2	1.488	1.798	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.185	1.185	NA
Area in Element	A5	12.172	12.172	NA
TOTAL AREA AVAILABLE	Atot	17.993	23.068	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:	187.6997	10.0000	mm.
Based on given Pad Diameter:	290.0000	1.5958	mm.
Based on Shell or Nozzle Thickness:	188.5066	9.6012	mm.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (155.0726*4.945*1.0+2*6.6012*4.945*1.0*(1-0.86))
  = 7.763 cm^2
```

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 155.073( 1.0 * 7.0 - 1.0 * 4.945 ) - 2 * 6.601
    ( 1.0 * 7.0 - 1.0 * 4.945 ) * ( 1 - 0.855 )
  = 3.147 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 17.5 ) * ( 6.6 - 1.63 ) * 0.855
  = 1.488 cm^2
```

Area Available in Welds [A41 + A42 + A43]:
```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
  = ( 0.6375 ) * 0.86 + (0.0 ) * 0.86 + 203.2² * 1.0
  = 1.185 cm^2
```

Area Available in Element [A5]:
```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 290.0 - 168.275 ) * 10.0 * 1.0
  = 12.172 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 4.6287 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 7.9450 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 7.9450 mm.
```

```
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                     tb3 = 9.2200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 9.22, max( 7.945, 4.5 ) ]
  = 7.9450 mm.
```

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

```
  = max( ta, tb )
  = max( 4.6287, 7.945 )
  = 7.9450 mm.
```

Available Nozzle Neck Thickness = 9.6012 mm. --> OK

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

```
 Sustained   :     55.9,  Allowable :    117.9 N./mm^2  Passed
 Expansion   :      0.0,  Allowable :    238.8 N./mm^2  Passed
 Occasional  :     13.0,  Allowable :    156.8 N./mm^2  Passed
 Shear       :     24.1,  Allowable :     82.5 N./mm^2  Passed
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

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

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

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

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

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

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

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

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

Govrn. thk, tg = 9.601, tr = 1.629, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.247, Temp. Reduction = 78 °C

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

Shell to Pad Weld Junction at Pad OD, min(Curve:B, Curve:D)

Govrn. thk, tg = 10.0, tr = 4.945, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.706, Temp. Reduction = 16 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              -29 °C
 Min Metal Temp. at Required thickness (UCS 66.1)            -45 °C
```

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

Govrn. thk, tg = 9.601, tr = 1.629, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.247, Temp. Reduction = 78 °C

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

Governing MDMT of the Nozzle                         :  -104 °C
Governing MDMT of the Reinforcement Pad              :   -45 °C
Governing MDMT of all the sub-joints of this Junction :  -45 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ANSI B16.5/47 flange per Matl. Specification     -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)         -86 °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      6.6012  mm.
Intermediate Calc. for pad/shell Welds   TminPad      7.0000  mm.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.6208 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.
Pad Weld	3.5000 = 0.5*TminPad	5.6560 = 0.7 * Wp mm.

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

Weld Load [W]:
```
= max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max( 0, (7.763 - 3.1474 + 2 * 6.6012 * 0.855 *
  (1.0 * 7.0 - 4.945 ) )138)
= 66.84 kN
```

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

Weld Load [W1]:
```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 1.488 + 12.1725 + 1.1851 - 0.0 * 0.86 ) * 138
= 204.70 kN
```

Weld Load [W2]:
```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 1.488 + 0.0 + 0.5472 + ( 0.7902 ) ) * 138
= 38.96 kN
```

Weld Load [W3]:
```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 1.488 + 0.0 + 1.1851 + 12.1725 + ( 0.7902 ) ) * 138
= 215.60 kN
```

Strength of Connection Elements for Failure Path Analysis

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-3 ECONOMIZER
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for ECONOMIZER E-PK6101-3 ----
Nozzle Calcs.: T2 Nozl: 13 11:46pm Dec 22,2021

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 168.275 * 8.0 * 0.49 * 118
  = 122. kN
```

Shear, Pad Element Weld [Spew]:
```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 290.0 * 8.0 * 0.49 * 138
  = 246. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 80.8369) * ( 9.6012 - 3.0 ) * 0.7 * 118
  = 138. kN
```

Tension, Pad Groove Weld [Tpgw]:
```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 168.275 * 10.0 * 0.74 * 138
  = 270. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 168.275 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 189. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 246 + 138 ) = 385 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 122 + 270 + 189 + 0 ) = 581 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 246 + 189 + 0 ) = 435 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 384 kN , must exceed W = 66 kN  or W1 = 204 kN
 Path 2-2 = 580 kN , must exceed W = 66 kN  or W2 = 38 kN
 Path 3-3 = 435 kN , must exceed W = 66 kN  or W3 = 215 kN

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

The Drop for this Nozzle is : 12.4512 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 222.4512 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    581.000  mm.
 Vessel Thickness                                Tv     10.000  mm.

 Design Temperature                              T1      120.0  °C
 Vessel Material                                    SA-516 70
 Vessel UNS Number                                       K02700
 Vessel Cold S.I. Allowable                     Smc      137.90  N./mm^2
 Vessel Hot  S.I. Allowable                     Smh      137.90  N./mm^2
```

Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	168.275	mm.
Nozzle Thickness	Tn	9.601	mm.
Nozzle Material		SA-333 6	
Nozzle UNS Number		K03006	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm^2
Thickness of Reinforcing Pad	Tpad	10.000	mm.
Diameter of Reinforcing Pad	Dpad	290.000	mm.
Design Internal Pressure	Dp	23.000	bars
Include Pressure Thrust		No	

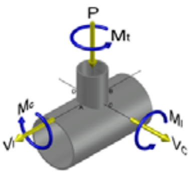
External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	6.0	kN
Longitudinal Shear	(SUS)	Vl	6.0	kN
Circumferential Shear	(SUS)	Vc	6.0	kN
Circumferential Moment	(SUS)	Mc	3800.0	N-m
Longitudinal Moment	(SUS)	Ml	3800.0	N-m
Torsional Moment	(SUS)	Mt	4700.0	N-m

Use Interactive Control		No	
WRC107 Version	Version	March	1979

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

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



Stress Attenuation Diameter (for Insert Plates) per WRC 297:
```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 168.275 + 2 * 1.65 * sqrt( 297.0 ( 10.0 - 3.0 ) )
  = 318.742 mm.
```

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	6.0	kN
Circumferential Shear	VC	6.0	kN
Longitudinal Shear	VL	6.0	kN
Circumferential Moment	MC	3800.0	N-m
Longitudinal Moment	ML	3800.0	N-m
Torsional Moment	MT	4700.0	N-m

Dimensionless Parameters used : Gamma = 17.76

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.244	4C	2.697	(A,B)
N(PHI) / (P/Rm)	0.244	3C	1.952	(C,D)
M(PHI) / (P)	0.244	2C1	0.045	(A,B)
M(PHI) / (P)	0.244	1C	0.074	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.244	3A	0.734	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.244	1A	0.085	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.244	3B	1.941	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.244	1B	0.032	(A,B,C,D)
N(x) / (P/Rm)	0.244	3C	1.952	(A,B)
N(x) / (P/Rm)	0.244	4C	2.697	(C,D)
M(x) / (P)	0.244	1C1	0.077	(A,B)
M(x) / (P)	0.244	2C	0.045	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.244	4A	1.267	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.244	2A	0.044	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.244	4B	0.709	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.244	2B	0.051	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-3.2	-3.2	-3.2	-3.2	-2.3	-2.3	-2.3	-2.3
Circ. Bend. P	-5.6	5.6	-5.6	5.6	-9.2	9.2	-9.2	9.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	-7.4	-7.4	7.4	7.4
Circ. Memb. MC	0.0	0.0	0.0	0.0	-91.0	91.0	91.0	-91.0
Circ. Memb. ML	-19.5	-19.5	19.5	19.5	0.0	0.0	0.0	0.0
Circ. Bend. ML	-33.9	33.9	33.9	-33.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-62.2	16.8	44.6	-11.9	-109.9	90.5	86.9	-76.7
Long. Memb. P	-2.3	-2.3	-2.3	-2.3	-3.2	-3.2	-3.2	-3.2
Long. Bend. P	-9.6	9.6	-9.6	9.6	-5.6	5.6	-5.6	5.6
Long. Memb. MC	0.0	0.0	0.0	0.0	-12.7	-12.7	12.7	12.7
Long. Bend. MC	0.0	0.0	0.0	0.0	-47.2	47.2	47.2	-47.2
Long. Memb. ML	-7.1	-7.1	7.1	7.1	0.0	0.0	0.0	0.0
Long. Bend. ML	-55.1	55.1	55.1	-55.1	0.0	0.0	0.0	0.0
Tot. Long. Str.	-74.1	55.2	50.4	-40.7	-68.7	37.0	51.2	-32.1
Shear VC	1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.3	-1.3	1.3	1.3
Shear MT	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Tot. Shear	7.5	7.5	4.9	4.9	4.9	4.9	7.5	7.5
Str. Int.	77.7	56.7	53.2	41.5	110.4	91.0	88.4	77.9

Dimensionless Parameters used : Gamma = 42.43

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.427	4C	3.340	(A,B)
N(PHI) / (P/Rm)	0.427	3C	1.296	(C,D)
M(PHI) / (P)	0.427	2C1	0.008	(A,B)
M(PHI) / (P)	0.427	1C !	0.063	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.427	3A	1.071	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.427	1A	0.061	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.427	3B	1.851	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.427	1B	0.006	(A,B,C,D)
N(x) / (P/Rm)	0.427	3C	1.296	(A,B)
N(x) / (P/Rm)	0.427	4C	3.340	(C,D)
M(x) / (P)	0.427	1C1	0.019	(A,B)
M(x) / (P)	0.427	2C !	0.032	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.427	4A	4.057	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.427	2A	0.024	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.427	4B	1.123	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.427	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	-9.6	-9.6	-9.6	-9.6	-3.7	-3.7	-3.7	-3.7
Circ. Bend. P	-5.6	5.6	-5.6	5.6	-46.4	46.4	-46.4	46.4
Circ. Memb. MC	0.0	0.0	0.0	0.0	-15.4	-15.4	15.4	15.4
Circ. Memb. MC	0.0	0.0	0.0	0.0	-222.1	222.1	222.1	-222.1
Circ. Memb. ML	-26.7	-26.7	26.7	26.7	0.0	0.0	0.0	0.0
Circ. Bend. ML	-22.7	22.7	22.7	-22.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-64.6	-8.0	34.1	-0.1	-287.6	249.3	187.3	-164.0
Long. Memb. P	-3.7	-3.7	-3.7	-3.7	-9.6	-9.6	-9.6	-9.6
Long. Bend. P	-13.7	13.7	-13.7	13.7	-23.9	23.9	-23.9	23.9
Long. Memb. MC	0.0	0.0	0.0	0.0	-58.4	-58.4	58.4	58.4
Long. Bend. MC	0.0	0.0	0.0	0.0	-89.1	89.1	89.1	-89.1
Long. Memb. ML	-16.2	-16.2	16.2	16.2	0.0	0.0	0.0	0.0
Long. Bend. ML	-38.1	38.1	38.1	-38.1	0.0	0.0	0.0	0.0
Tot. Long. Str.	-71.7	31.9	36.8	-11.9	-181.1	44.9	114.1	-16.5
Shear VC	1.9	1.9	-1.9	-1.9	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.9	-1.9	1.9	1.9
Shear MT	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Tot. Shear	7.0	7.0	3.2	3.2	3.2	3.2	7.0	7.0
Str. Int.	76.0	42.3	38.9	13.4	287.7	249.4	188.0	164.3

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)	38.6	40.9	38.6	40.9	38.6	40.9	38.6	40.9
Circ. Pl (SUS)	-22.7	-22.7	16.4	16.4	-9.7	-9.7	5.1	5.1
Circ. Q (SUS)	-39.5	39.5	28.2	-28.2	-100.2	100.2	81.8	-81.8
Long. Pm (SUS)	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3
Long. Pl (SUS)	-9.4	-9.4	4.8	4.8	-15.9	-15.9	9.6	9.6
Long. Q (SUS)	-64.6	64.6	45.5	-45.5	-52.8	52.8	41.6	-41.6
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)	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Pm (SUS)	38.6	40.9	38.6	40.9	38.6	40.9	38.6	40.9
Pm+Pl (SUS)	16.2	18.4	55.0	57.3	29.0	31.3	43.8	46.1
Pm+Pl+Q (Total)	56.5	77.4	84.8	51.3	72.3	131.8	126.5	38.0

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	40.89	137.90	Passed
Pm+Pl (SUS)	57.30	206.85	Passed
Pm+Pl+Q (TOTAL)	131.75	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

WRC 107/537 Stress Summations:

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

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
Circ. Pm (SUS)	95.3	97.6	95.3	97.6	95.3	97.6	95.3	97.6
Circ. Pl (SUS)	-36.3	-36.3	17.0	17.0	-19.2	-19.2	11.7	11.7
Circ. Q (SUS)	-28.3	28.3	17.1	-17.1	-268.5	268.5	175.7	-175.7
Long. Pm (SUS)	47.7	47.7	47.7	47.7	47.7	47.7	47.7	47.7
Long. Pl (SUS)	-19.9	-19.9	12.4	12.4	-68.1	-68.1	48.8	48.8
Long. Q (SUS)	-51.8	51.8	24.4	-24.4	-113.0	113.0	65.3	-65.3
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.9	1.9	-1.9	-1.9	-1.9	-1.9	1.9	1.9
Shear Q (SUS)	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Pm (SUS)	95.3	97.6	95.3	97.6	95.3	97.6	95.3	97.6
Pm+Pl (SUS)	59.1	61.4	112.4	114.7	96.6	98.9	107.3	109.6

Pm+Pl+Q (Total)	56.5	93.2	129.7	97.7	192.5	347.0	283.0	98.5

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	97.61	137.90	Passed
Pm+Pl (SUS)	114.68	206.85	Passed
Pm+Pl+Q (TOTAL)	346.96	413.70	Passed

*Because only sustained loads were specified, the Pm+Pl+Q allowable was 3 * Smh.*

Input, Nozzle Desc: T3 From: 60

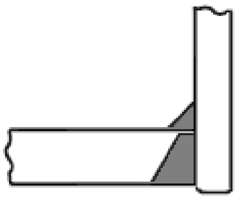
Pressure for Reinforcement Calculations	P	23.034	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	120	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	581.00	mm.
Design Length of Section	L	505.4167	mm.
Shell Finished (Minimum) Thickness	t	10.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		6852.35	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		SA-350 LF2	
Flange Type		Slip on	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: T3

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

```
 Actual Inside Diameter Used in Calculation              1.000  in.
 Actual Thickness Used in Calculation                    0.563  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.03*293.5)/(138*1.0-0.6*23.03)
  = 4.9524 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([23.03/(137.9*1.0]-1)
  = 0.2645 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3056 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl     68.0000   mm.
 Parallel to Vessel Wall                        Rn+tn+t     34.0000   mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     17.5000   mm.
```

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

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

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.555	0.288	NA
Area in Shell	A1	0.749	1.891	NA

Area in Nozzle Wall	A2	3.862	3.848	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.630	0.630	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	5.242	6.369	NA

The Internal Pressure Case Governs the Analysis.

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

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (31.4*4.9524*1.0+2*11.3*4.9524*1.0*(1-1.0))
  = 1.555 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 )
  = 36.6( 1.0 * 7.0 - 1.0 * 4.952 ) - 2 * 11.3
    ( 1.0 * 7.0 - 1.0 * 4.9524 ) * ( 1 - 1.0 )
  = 0.749 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 17.5 )( 11.3 - 0.26 )1.0
  = 3.862 cm^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = ( Wo² - Area Lost )*fr2 + ( (Wi-can/0.707)² - Area Lost)*fr2
  = ( 8.0² - 0.01 ) * 1.0 + ( 0.0² -0.0 ) * 1.0
  = 0.630 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures        ta = 3.3056 mm.
 Wall Thickness per UG16(b),                        tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure       trb1 = 7.9524 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 7.9524 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 6.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 6.42, max( 7.9524, 4.5 ) ]
  = 6.4200 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.3056, 6.42 )
  = 6.4200 mm.
```

Available Nozzle Neck Thickness = 14.3000 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

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

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

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

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

Govrn. thk, tg = 10.0, tr = 4.952, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.707, Temp. Reduction = 16 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D              -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)            -85 °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 = 23.03/51.10 = 0.451

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

Weld Size Calculations, Description: T3

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      7.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
 Nozzle Weld         4.9000 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
```

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (1.5551 - 0.7494 + 2 * 11.3 * 1.0 *
    (1.0 * 7.0 - 4.9524 ) )138)
  = 17.49 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.8624 + 0.0 + 0.63 - 0.0 * 1.0 ) * 138
  = 61.95 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.8624 + 0.0 + 0.63 + ( 1.582 ) ) * 138
  = 83.76 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.8624 + 0.0 + 0.63 + 0.0 + ( 1.582 ) ) * 138
  = 83.76 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 * 8.0 * 0.49 * 138
  = 46. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 21.35) * ( 14.3 - 3.0 ) * 0.7 * 138
  = 73. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 54.0 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 61. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 46 + 73 ) = 119 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 46 + 0 + 61 + 0 ) = 106 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 46 + 61 + 0 ) = 106 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 119 kN , must exceed W = 17 kN  or W1 = 61 kN
 Path 2-2 = 106 kN , must exceed W = 17 kN  or W2 = 83 kN
 Path 3-3 = 106 kN , must exceed W = 17 kN  or W3 = 83 kN

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

The Drop for this Nozzle is : 1.2575 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 211.2574 mm.

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-3 ECONOMIZER
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for ECONOMIZER E-PK6101-3 ----
Nozzle Schedule: Step: 21 11:46pm Dec 22,2021

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	SlipOn	1.872	14.250	...	...	210.97	300
T3	1.000 in	Actual	SlipOn	2.126	14.300	...	...	211.26	300
S3	2.000 in	160	WNF	2.375	8.738	170.00	10.00	211.57	300
T1	4.000 in	120	WNF	4.500	11.125	230.00	10.00	215.68	300
S2	6.000 in	80	WNF	6.625	10.973	290.00	10.00	222.45	300
S1	6.000 in	80	WNF	6.625	10.973	290.00	10.00	222.45	300
T2	6.000 in	80	WNF	6.625	10.973	290.00	10.00	222.45	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	10.000	8.000	...	...	...
T3	SA-350 LF2	10.000	8.000	...	...	...
S3	SA-333 6	10.000	8.000	8.000	10.000	...
T1	SA-333 6	10.000	8.000	8.000	10.000	...
S2	SA-333 6	10.000	8.000	8.000	10.000	...
S1	SA-333 6	10.000	8.000	8.000	10.000	...
T2	SA-333 6	10.000	8.000	8.000	10.000	...

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

Nozzle Miscellaneous Data:

Description	Elev/Distance From Datum mm.	Layout Angle deg	Proj Outside mm.	Proj Inside mm.	Installed in Component
T4	203.000	90.0	200.00	0.00	CHANNEL 01

Nozzle Schedule: Step: 21 11:46pm Dec 22,2021

T3	6802.351	270.0	200.00	0.00	CHANNEL 002
S3	709.175	270.0	200.00	0.00	SHELL
T1	203.000	270.0	200.00	0.00	CHANNEL 01
S2	759.175	90.0	200.00	0.00	SHELL
S1	6243.176	90.0	200.00	0.00	SHELL
T2	6799.351	90.0	200.00	0.00	CHANNEL 002

Weld Sizes for Slip On/Socket Weld Nozzle Flanges per UW-21:

Nozzle to Flange Fillet Weld Leg dimension [xmin]:
= min(1.4 * tn, Hub Thickness)

The Nozzle Wall thicknesses shown below are in the corroded condition. Hubs are considered to be straight.

Description	Nominal or Actual Size	Schd or FVC Type	Flg Type	Noz. O/Dia in	Wall Thk mm.	Hub Thk mm.	Throat Thk mm.	xmin Thk mm.
T4	0.750 in	Actua	SlipOn	1.872	11.250	10.033	7.023	10.033
T3	1.000 in	Actua	SlipOn	2.126	11.300	9.652	6.756	9.652

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	10.0000	mm.
Shell Internal Corrosion Allowance	cas	3.0000	mm.
Shell External Corrosion Allowance	caext	0.0000	mm.
Inside Diameter of Shell	Ds	581.000	mm.
Shell Circumferential Joint Efficiency	Esw	1.000	
Shell Temperature for Internal Pressure	Ts	120.00	°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	10.0000	mm.
Channel Corrosion Allowance	cac	3.0000	mm.
Inside Diameter of Channel	Dc	581.000	mm.
Channel Design Temperature	TEMPC	120.00	°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	241	
Tube Wall Thickness	et	2.1080	mm.
Tube Outside Diameter	D	25.4000	mm.
Total Straight Tube Length	Lt	6000.00	mm.
Straight Tube Length (bet. inner tubsht faces)	L	5876.00	mm.
Design Temperature of the Tubes		120.00	°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	217.36	N./mm^2
Tube Pitch (Center to Center Spacing)	P	32.0000	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		b-1	
Radius to Outermost Tube Hole Center	ro	270.770	mm.
Largest Center-to-Center Tube Distance	Ul	40.0000	mm.
Length of Expanded Portion of Tube	ltx	50.0000	mm.
Tube-side pass partition groove depth	hg	5.0000	mm.
Area of Tube Layout	Ap	226.8	cm^2

Tubesheet Data:

Tubesheet TYPE: Fixed Tubesheet Exchanger, Conf B

Tubesheet Design Metal Temperature	T	120.00	°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	62.0000	mm.
Tubesheet Corr. Allowance (Shell side)	Cats	3.0000	mm.
Tubesheet Corr. Allowance (Channel side)	Catc	3.0000	mm.
Tubesheet Outside Diameter	A	715.000	mm.

Additional Data for Stepped Tubesheets:

Is the Tubesheet Stepped?		YES	
Is the Tubesheet Flat on Tubeside?		NO	
Step 1 Diameter on the Tubeside	dt1	644.00	mm.
Step 1 Depth on the Tubeside	ht1	6.00	mm.
Step 2 Diameter on the Tubeside	dt2	578.00	mm.
Step 2 Depth on the Tubeside	ht2	5.00	mm.
Is the Tubesheet Flat on Shellside?		NO	
Step 1 Diameter on the Shellside	ds1	0.00	mm.
Step 1 Depth on the Shellside	hs1	0.00	mm.
Step 2 Diameter on the Shellside	ds2	578.00	mm.
Step 2 Depth on the Shellside	hs2	5.00	mm.
Calculated Tubesheet Diameter as per UHX-10(b)		644.00	mm.

Note: Tubesheet diameter is now: 644.000 mm. per UHX-10(b).

Area of the Untubed Lanes	AL	226.8	cm^2

Additional Data for Fixed/Floating Tubesheet Exchangers:

Unsupported Tube Span under consideration	l	712.000	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

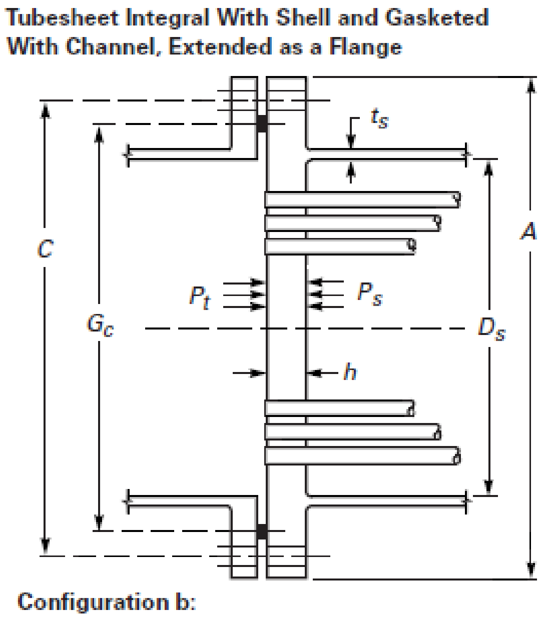
Perform Differential Pressure Design		N	
Run Multiple Load Cases		YES	
Shell Side Min. Design Pressure	Psd,min	1.0342	bars
Channel Side Min. Design Pressure	Ptd,min	1.0314	bars
Mean Shell Metal Temp. along Shell len.	Tsm	28.10	°C
Mean Tube Metal Temp. along Tube length	Ttm	21.09	°C
Junction Stress Reduction option	Perform Plastic Calculation		

Additional Data for Gasketed Tubesheets:

Tubesheet Gasket on which Side		Channel	
Flange Outside Diameter	A	715.000	mm.
Flange Inside Diameter	B	581.000	mm.
Flange Face Outside Diameter	Fod	644.000	mm.
Flange Face Inside Diameter	Fid	581.000	mm.
Gasket Outside Diameter	Go	641.000	mm.
Gasket Inside Diameter	Gi	611.000	mm.
Small end Hub thk.	g0	10.0000	mm.
Large end Hub thk.	g1	17.0000	mm.
Gasket Factor,	m	3.78	
Gasket Design Seating Stress	y	62.05	N./mm^2
Flange Facing Sketch	Code Sketch 1a		
Column for Gasket Seating	Code Column II		
Gasket Thickness	tg	3.0000	mm.
Full face Gasket Flange Option	Program Selects		
Length of Partition Gasket	lp	1078.000	mm.
Width of Partition Gasket	wp	6.0000	mm.
Partition Gasket Factor,	mPart	3.7500	
Partition Gasket Design Seating Stress	yPart	62.05	N./mm^2
Partition Gasket Facing Sketch	Code Sketch 1a		
Partition Gasket Column for Gasket Seating	Code Column II		

Bolting Information:

Diameter of Bolt Circle	C	673.000	mm.
Nominal Bolt Diameter	dB	19.0500	mm.
Type of Thread Series	UNC Thread Series		
Number of Bolts	n	32	




```
                                         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      46.0000  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    28.1 °C    0.0000115945 /°C
 Elastic Mod. at Design Temperature      120.0 °C      0.19691E+09 KPa.
 Th. Exp. Coeff. Metal Temp. at Tubsht    21.1 °C    0.0000115190 /°C
 Elastic Mod. at Metal Temp. along Len    28.1 °C      0.20230E+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      120.0 °C      0.19691E+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    21.1 °C    0.0000115187 /°C
Elastic Mod. at Design Temperature      120.0 °C      0.19691E+09 KPa.
Elastic Mod. at Metal Temp. along Len    21.1 °C      0.20270E+09 KPa.
Elastic Mod. at Tubsht. Design Temp.    120.0 °C      0.19691E+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      120.0 °C      0.19691E+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*(25.4/2-0.0)/(117.9*1.0+0.4*24.03)
  = 0.2568 + 0.0000 = 0.2568 mm.
```

Tube Required Thickness under External Pressure (Shellside pressure) :

```
External Pressure Chart     CS-2             at       120.00   °C
Elastic Modulus for Material                   199943392.00   KPa.
```

Results for Max. Allowable External Pressure (Emawp):

```
     TCA        ODCA      SLEN        D/T        L/D    Factor A        B
   2.1080      25.40    5876.00     12.05    50.0000   0.0075765       122.73
 EMAWP = (4*B)/(3*(D/T)) = ( 4 *122.731 )/( 3 *12.0493 ) = 135.8015 bars
```

Results for Reqd Thickness for Ext. Pressure (Tca):

```
     TCA        ODCA      SLEN        D/T        L/D    Factor A        B
   0.6452      25.40    5876.00     39.37    50.0000   0.0007098        70.96
 EMAWP = (4*B)/(3*(D/T)) = ( 4 *70.9611 )/( 3 *39.3675 ) = 24.0324 bars
```

Summary of Tube Required Thickness Results:

```
Total Required Thickness including Corrosion all.          0.6452  mm.
Allowable Internal Pressure at Corroded thickness          209.61  bars
Required Internal Design Pressure                           24.03  bars
Allowable External Pressure at Corroded thickness          135.80  bars
Required External Design Pressure                           24.03  bars
Required Thickness due to Shell Side pressure              0.6452  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            15.000   mm.
Basic Gasket Width,        b0 = N / 2.0                   7.500   mm.
```

```
Effective Gasket Width,     b = SQRT(b0) * 2.5           6.899  mm.
Gasket Reaction Diameter,   G = Go-2.0*b               627.203  mm.
```

Bolting Information for UNC Thread Series (Non Mandatory):

```
Distance Across Corners for Nuts                        35.128  mm.
Circular Wrench End Diameter                       a    52.388  mm.
```

	Minimum	Actual	Maximum
Bolt Area, cm^2	60.575	62.348	
Radial Distance between Hub and Bolts:	20.637	36.000	
Radial Distance between Bolts and Edge:	20.637	21.000	
Circ. Spacing between the Bolts:	44.450	65.966	84.100

```
Flange Design Bolt Load, Seating Condition    W  :     1059.36  kN
Flange Design Bolt Load, Operating Condition  Wm1:     1002.73  kN
```

<u>Results for ASME Fixed Tubesheet Calculations for Configuration b,</u>

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 )
  = 50.0/62.0 = 0.8065 ( must be 0 <= rho <= 1 )
```

Compute the Effective Tube Hole Diameter [d*]:
```
  = Max( dt - 2tt*( Et/E )( StT/S )( rho ), dt - 2tt)
  = Max( 25.4 -2*2.108 *(.19691E+09/.19691E+09)*
    ( 117/137 )*( 0.806 ), 25.4 -2*2.108 )
  = 22.4930 mm.
```

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
```
  = 2 * ro + dt = 2 * 270.77 + 25.4 = 566.94 mm.
```

Determine the Basic Ligament Efficiency for Shear [mu]:
```
  = (p - dt)/p = (32.0 - 25.4 )/32.0 = 0.2062
```

Compute the Equivalent Outer Tube Limit Radius [ao]:
```
  = Do/2 = 566.94/2 = 283.47 mm.
```

Compute the Effective Tube Pitch [p*]:
```
  = p / sqrt( 1 - 4 * min( AL * CNV_factor, 4*Do*p)/(Pi * Do²) )
  = 32.0/sqrt( 1 - 4 * min( 226.77 *100.0, 4*566.94 *32.0 )/( 3.141 * 566.94²) )
  = 33.5420 mm.
```

Compute the Effective Ligament Efficiency for Bending [mu*]:
```
  = (p* - d*)/p* = (33.542 - 22.493 )/33.542 = 0.3294
```

Compute the Ratio [Rhos]:
```
  = as/ao = 290.5/283.47 = 1.0248
```

Compute the Ratio [Rhoc]:
```
  = ac/ao = 313.6014/283.47 = 1.106295
```

Compute Parameter [xt]:
```
  = 1 - Nt * (( dt - 2 * tt )/( 2 * ao ))²
```

= 1 - 241 * ((25.4 - 2 * 2.108)/(2 * 283.47))² = 0.6635

Determine Parameter [xs]:
= 1 - Nt*(dt/(2*ao))²
= 1 - 241 *(25.4/(2*283.47))² = 0.5163

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 * 10.0 (581.0 + 10.0).19691E+09/5876.0
= 622191808.0000 KPa. * mm.

Determine the Axial Tube Stiffness [Kt]:
= pi * tt(Dt - tt)Et/L
= 3.1416 * 2.108 (25.4 - 2.108).19691E+09/5876.0
= 5169092.0000 KPa. * mm.

Compute the Stiffness Factor [Ks,t]:
= Ks/(Nt * Kt) = 0.62219E+09/(241 * 5169092) = 0.49945

Rigidty Ratio [J]:
= 1 / (1 + Ks/Kj)
= 1/(1 + 0.62219E+09/0.0) = 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)/((581.0 + 10.0) * 10.0)^0.5
= 0.0236 1/mm.

Determine Shell Coefficient [ks]:
= betas * Es * ts³ / (6 * (1 - nus²))
= 0.024 * 0.19691E+09 * 10.0³/(6 * (1 - 0.3²))
= 8527819.0000 bars*mm.²

Determine Shell Coefficient [Lambdas]:
= (6*Ds*ks)/(h³) * (1 + h*betas + 0.5*(h*betas)²)
= 6*581.0 *8527819/(62.0³) * (1 + 62.0 * 0.024 + 1.075)
= 441656.3750 bars

Determine Shell Coefficient [deltaS]:
= Ds²/(4 * Es * Ts) * (1 - nus/2)
= 581.0²/(4 * 0.19691E+09 * 10.0) * (1 - 0.3/2)
= 0.0364264846 mm./N./mm^2

Intermediate parameters for Tubesheet Gasketed on the Channel Side:
betac, kc, deltaC, Lambdac = 0

UHX-13.5.3 Step 3:

E*/E and nu* for Triangular pattern from Fig. UHX-11.3.
h/p = 1.937500 ; mu* = 0.329408
E*/E = 0.322262 ; nu* = 0.334182 ; E* = 63456788. KPa.

Compute the Tube Bundle Stiffness Factor [Xa]:
= ((24 *(1 - nu*²)*Nt * Et* tt* (dt - tt)* ao²) /
(E* * L * H³))^0.25

$= ((24 *(1 - 0.334^2)*241 *.19691E+09*2.108 * (25.4 - 2.108)*283.47^2)/(63456788 * 5876.0 * 62.0^3))^{0.25}$
= 2.5888

Values from Table UHX-13.1
Zd = 0.082771 ; Zv = 0.130480 ; Zm = 0.578202
Za = 0.138738E+01 ; Zw = 0.130480

UHX-13.5.4 Step 4:

Compute the Diameter Ratio [K]:
= A/Do = 644.0/566.94 = 1.1359

Compute Coefficient [F]:
= (1 - nu*) / (E*) * (Lambdas + Lambdac + E * ln(K))
= (1 - 0.33)/(63456788) * (441656.38 + 0.0 + 0.19691E+09 * ln(1.14))
= 0.7267

Compute Parameter [Phi]:
= (1 + nu*) * F = (1 + 0.3342) * 0.7267 = 0.9696

Compute Parameter [Q1]:
= (Rhos - 1 - Phi * Zv)/(1 + Phi * Zm)
= (1.0248 - 1 - 0.9696 * 0.1305)/(1 + 0.9696 * 0.5782)
= -0.065173514

Compute Parameter [Qz1]:
$= (Zd + Q1*Zw)/2 *Xa^4$
$= (0.08277 + -0.06517 * 0.13048)/2 *2.58885^4 = 1.668$

Compute Parameter [Qz2]:
$= (Zv + Q1*Zm)/2 *Xa^4$
$= (0.13048 + -0.06517 * 0.5782)/2 *2.58885^4 = 2.0841$

Compute Parameter [U]:
$= (Zw + (Rhos - 1)*Zm)*Xa^4 / (1 + Phi*Zm)$
$= (0.1305 + (1.0248 - 1)* 0.5782)*2.58885^4/(1 + 0.9696 * 0.5782)$
= 4.1683

UHX-13.5.5 Step 5:

Determine factor [gamab]:
= (Gc - C) / Do (config b)
= (627.2029 - 673.0)/566.94 = -0.08078

Compute Parameter [gamma]:
= 0.000 mm. (For Pressure only cases)

Calculate Parameter [OmegaS]:
= rhos * ks * Betas * deltaS(1 + h * Betas)
= 1.0248 * 8527819 * 0.0236 * 0.036426 (1 + 62.0 * 0.0236)
$= 1856.4625 mm.^2$

Calculate Parameter [Omega*S]:
$= Ao^2 * (Rhos^2 - 1) * (Rhos - 1) / 4 - OmegaS$
$= 283.47^2 * (1.025^2 - 1) * (1.025 - 1)/4 - 1856.463$
$= -1831.4457 mm.^2$

Calculate Parameter [OmegaC]:

```
  = rhoc * kc * Betac * deltaC( 1 + h * Betac )
  = 1.1063 * 0.0 * 0.0 * 0. ( 1 + 62.0 * 0.0 )
  = 0.0000 mm.²
```

Calculate Parameter [Omega*C]:

```
  = ao²[( Rhoc²+1 )*( Rhoc-1 )/4 -(Rhos-1)/2]- OmegaC
  = 283.47²[( 1.10629²+1 )*( 1.10629 -1 )/4 -(1.0248 -1)/2]- 0.
  = 3752.3599 mm.²
```

Compute the Pressure [P*S]:
= 0 For Pressure only cases or Configurations d,e,f,A,B,C,D

Compute the Pressure [P*C]:
= 0 For Pressure only cases or Configurations b,c,d,B,C,D

UHX-13.5.6 Step 6:

Compute the Pressure [P's]:

```
  = Ps * {xs + 2( 1 - xs )nut + [2/Kst(Ds/Do)²]nus -
    [(rhos²-1)/(J*Kst)]-[(1-J)/(2J*Kst)][(Dj²-(Ds)²)/Do²]}
  = 23.0 * { 0.516 + 2( 1 - 0.516 ) 0.3 +
    [2/0.499 (581.0/566.94 )²] 0.3 -
    [(1.025²-1)/( 1.0 * 0.499 )] -
    [(1 - 1.0 )/(2 * 1.0 * 0.499 )][(0.0²-(581.0 )²)/566.94²]}
  = 45.2550 bars
```

Compute the Pressure [P't]:

```
  = [ xt + 2(1 - xt)nut + 1/(J * Kst) ]*Pt
  = [ 0.664 + 2(1 - 0.664 ) 0.3 +
    1/(1. * 0.499 ) ]* 23.0
  = 65.9549 bars
```

Compute the Pressure [Pgama]:

```
  = Nt * Kt * gama / ( pi * ao² )
  = 241 * 5169092 * 0.0/(3.142 * 283.47²) = 0.0 bars
```

Compute the Pressure [Pw]:

```
  = -gamab * U * W* / (2 * pi * ao²)
  = --0.081 * 4.168 * 1002.73/(2 * 3.142 * 283.47²)
  = 6.6874 bars
```

Calculate the Pressure [Prim]:

```
  = -( U/ao²)(Omega*S * Ps - Omega*C * Pt )
  = -( 4.168/283.47²)(-2.839 * 23.0 - 5.816 * 23.0 )
  = 6.6619 bars
```

Calculate the Pressure [POmega]:

```
  = U/ao²(OmegaS * P*s - OmegaC * P*c )
  = 4.168/283.47²( 2.8775 * 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 * 0.499/(1 + 1.0 * 0.499 *(1.668 + (1.025 -
    1) * 2.084 )) * (45.255 - 65.955 + 0.0 + 6.687 + 6.662 )
  = -1.9750 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)
  = [( ( -1831.446 * 23.0 - 3752.36 * 23.0 ) -
    ( 1856.463 * 0.0 - 0.0 * 0.0 )) * 0. +
    1002.7 * -0.081/(2*3.141)]/(1 + 0.96957 * 0.5782 )
  = -16.489673615 kN
```

Calculate Factor [Q3]:

```
  = Q1 + 2 * Q2 / ( Pe * ao² )
  = -0.065 + 2 * -16.49/( -1.975 * 283.47² )
  = 2.012980
```

Fm Value from Table UHX-13.1 = 1.035901

The Tubesheet Bending Stress - Original Thickness [Sigma]:

```
  = (1.5 * Fm / mu* ) * (2 * ao/(H - h'g)² * Pe
  = (1.5 * 1.0359/0.3294 ) * (2 * 283.47/(62.0 - 5.0 ))² * -1.97
  = -92.1695 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 * 1.9125/0.3294 ) * (2 * 283.47/(40.563 - 5.0 ))² * 0.93
  = 206.8453 N./mm^2
```

Reqd Tubesheet Thickness, for Bending Stress (Including CA) [HReqB]:

```
  = h + Cats + Catc = 40.5633 + 0.0 + 0.0 = 40.5633 mm.
```

UHX-13.5.8 Step 8:

Shear Stress check [Tau_limit]:

```
  = 1.6 * S * MU * h / ao
  = 1.6 * 137.9 * 0.206 * 62.0/283.47
  = 9.9532 N./mm^2
```

The Shear Stress is not required to be computed; [Pe] <= Tau_limit

Note: Tubesheet Shear Stress is probably low, use the following req. thk:

```
  Tubesheet thickness (Incl. Corr.)= 3.8100 mm.
  Tubesheet Shear Stress           = 35.3559 N./mm^2
```

Reqd Tubesheet Thickness for Given Loadings (Including CA) [Hreqd] :

```
  = Max( HreqB, HreqS ) = Max( 40.5633, 3.81 ) = 40.5633 mm.
```

UHX-13.5.9 Step 9:

The Ftmin and Ftmax Coefficients from Table UHX-13.2:

```
  Ftmin = -5.0157, Ftmax = 7.758
```

First Extreme Tube Axial Stress from among all the tubes [Sigmat1]:

```
  = ( (Ps * xs - Pt * xt) - Pe * Ftmin ) / ( Xt - Xs )
  = ( (23.0 * 0.5163 - 23.0 * 0.6635 ) - (-1.975 ) * -5.016 )/
    ( 0.6635 - 0.5163 ) )
  = -9.0274 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 * 0.5163 - 23.0 * 0.6635 ) - (-1.975 ) * 7.758 )/
```

```
    ( 0.6635 - 0.5163 ) )
  = 8.1052 N./mm^2
```

Maximum Tube Axial Stress [Sigmat,max]:
```
  = MAX( abs(Sigmat1), abs(Sigmat2) ) = 9.027 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*( 0.083 + 2.013 * 0.13 )*2.589^4), 1.25 )
  = 1.2500 (Should be <= 2 )
```

Determine the Factor [rt]:
$= ((dt^2 + (dt - 2*tt)^2)^{.5})/4$
$= ((25.4^2 + (25.4 - 2*2.108)^2)^{.5})/4 = 8.2686$ mm.

Determine the Factor [Ct]:
$= (2 * PI^2 * Et/Syt)^{0.5}$
$= (2 * 3.14^2 * 0.19691E+09/217)^{0.5} = 133.728$

Determine the Factor [Ft]:
```
  = k * L/r = 0.8 * 712.0/8.269 = 68.8869
```

The Buckling Allowable Stress [Stb]:
```
  = Sy,t/Fs*( 1 - Ft/(2*Ct) )
  = 217/1.25 *( 1 - 68.887/(2*133.728 ) )
  = 117.905 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 = 9.03 * 1.5425 = 1.39 kN
```

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:
```
  = 3.1415 * t * ( do - t ) * Sa
  = 3.1415 * 2.108 * ( 25.4 - 2.108 ) * 117.9 = 18.185 kN
```

Fillet Weld Strength [Ff]:
```
  = 0.55 * 3.1415 * af * (do + 0.67*af) * Sw (but not > Ft)
  = 0.55 * 3.1415 * 1.5 * (25.4 + 0.67*1.5 ) * 117.9
  = 8.0683  kN
```

Groove Weld Strength [Fg]:
```
  = 0.85 * 3.1415 * ag * (do + 0.67*ag) * Sw (but not > Ft)
  = 0.85 * 3.1415 * 1.5 * (25.4 + 0.67*1.5 ) * 117.9
  = 12.4692  kN
```

```
 Max. Allow. Tube-Tubesheet Joint load, Lmax
  = Ft = 18.1853 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)
  = 2.6646  mm.

 Minimum Required Fillet Weld Leg            afr      1.3323  mm.
 Minimum Required Groove Weld Leg            agr      1.3323  mm.

 Tube-Tubesheet Jt allowable, 18.19 is >= tube strength 18.19 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)
  = 283.47²/((581.0 +10.0 )*10.0 )* [-1.97 + (1.025²-1)
    (23.0 -23.0 )] + 290.5²*23.0/((581.0 +10.0 )
    * 10.0 )
  = 30.1587 N./mm^2
```

UHX-13.5.11 Step 11:

Note:
For a given Shell thickness of 10.0 mm., the minimum Shell
length adjacent to the tubesheet should be 137.202 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)
  = 283.47²/((581.0 +10.0 )*10.0 )[-1.97 + (1.025²-1)
    (23.0 -23.0 )] + 290.5²*23.0/((581.0 +10.0 )
    * 10.0 )
  = 30.1587 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 * 8527819/10.0² { 0.024 [ 0.036 * 23.0 + 290.5²
    * 0.0/(.19691E+1 ) ] +
    6(1 - 0.33²)/(63456788 )(283.47/62.0 )³(1 + 62.0 *
    0.02/2)[ -2.0 ( 0.13 + 0.578 * -0.065 ) +
    2/283.47² * 0.578 * -16.49 ] }
  = -80.6076 N./mm^2
```

Shell Stress Summation vs. Allowable

```
  abs(Sigmasm) + abs(Sigmasb) <= 1.5 * Ss
  abs(30.2 ) + abs(-80.6 ) <= 206.85 N./mm^2
  110.77 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	92.2	<=	206.9 N./mm^2	Ok
Tubesheet Shear Stress	2.2	<=	110.3 N./mm^2	Ok

Maximum Tube Stress	9.0	<=	117.9	N./mm^2	Ok
Minimum Tube Stress (Buckling)	-9.0	<=	-117.9	N./mm^2	Ok
Maximum Force on any one Tube	1.4	<=	18.2	kN	Ok
Axial Membrane Stress in Shell	30.2	<=	137.9	N./mm^2	Ok
Shell Stress (jt. inter.)	110.8	<=	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 :	40.563	62.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.332	1.500	Ok
Tube-Tubesheet Groove Weld Leg :	1.332	1.500	Ok

Fixed Tubesheet results per ASME UHX-13 2017

Results for 16 Load Cases:

Case#	--Reqd. Thk. + CA Tbsht	Extnsn	---- Tubesheet Stresses Bend	Allwd	Shear	Allwd	Case Type		Pass/ Fail
D1uc	38.444	23.085	114	207	17	110	Ps+Pt-Th	D1	Ok
D2uc	23.041	...	56	207	15	110	Ps+Pt-Th	D2	Ok
D3uc	40.563	...	92	207	2	110	Ps+Pt-Th	D3	Ok
D4uc	6.585	...	2	207	...	110	Ps+Pt-Th	D4	Ok
O1uc	3.810	...	117	447	23	110	Ps+Pt+Th	O1	Ok
O2uc	16.879	...	64	447	9	110	Ps+Pt+Th	O2	Ok
O3uc	16.735	...	89	447	9	110	Ps+Pt+Th	O3	Ok
O4uc	6.394	...	46	447	5	110	Ps+Pt+Th	O4	Ok
D1c	46.468	23.085	131	207	18	110	Ps+Pt-Th-c	D1	Ok
D2c	21.253	...	56	207	16	110	Ps+Pt-Th-c	D2	Ok
D3c	45.568	...	108	207	3	110	Ps+Pt-Th-c	D3	Ok
D4c	9.810	...	3	207	...	110	Ps+Pt-Th-c	D4	Ok
O1c	28.098	...	139	447	24	110	Ps+Pt+Th-c	O1	Ok
O2c	25.900	...	78	447	11	110	Ps+Pt+Th-c	O2	Ok
O3c	29.435	...	111	447	9	110	Ps+Pt+Th-c	O3	Ok
O4c	22.314	...	60	447	3	110	Ps+Pt+Th-c	O4	Ok
Max:	46.4684	23.085	mm.	0.633		0.213	(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:

Case#	---- Shell Stresses Ten	Allwd	Cmp	---- Allwd	:	---- Shell Band Stress Ten	Allwd	Cmp	---- Allwd	: Pass Fail
D1uc	10	137	...	...		...	...	...	...	Ok
D2uc	19	137	...	...		...	...	...	...	Ok
D3uc	30	137	...	...		...	...	...	...	Ok
D4uc	1	137	-1	-117		...	...	...	...	Ok
O1uc	3	471	...	...		...	...	...	...	Ok
O2uc	13	471	...	...		...	...	...	...	Ok
O3uc	22	471	...	...		...	...	...	...	Ok
O4uc	6	471	-6	-117		...	...	...	...	Ok
D1c	15	137	...	...		...	...	...	...	Ok
D2c	26	137	...	...		...	...	...	...	Ok
D3c	43	137	...	...		...	...	...	...	Ok
D4c	2	137	-2	-111		...	...	...	...	Ok
O1c	7	471	...	...		...	...	...	...	Ok
O2c	21	471	...	...		...	...	...	...	Ok
O3c	34	471	...	...		...	...	...	...	Ok
O4c	5	471	-5	-111		...	...	...	...	Ok
Max RATIO		0.312		0.052			...		...	

Tube, Shell and Channel Stress Summary:

Case#	---- Tube Stresses Ten	Allwd	Cmp	Allwd	Tube Loads Ld	Allwd	Shell Stress Stress	Allwd	Channel Stress Stress	Allwd	Pass Fail
D1uc	14	117	-14	-80	2	18	256	471	...	...	Ok
D2uc	6	117	-6	-80	1	18	184	206	...	...	Ok
D3uc	9	117	-9	-117	1	18	111	206	...	...	Ok
D4uc	...	117	...	-100	...	18	2	206	...	...	Ok
O1uc	20	235	-13	-80	3	36	287	471	...	...	Ok
O2uc	4	235	...	...	1	36	52	471	...	...	Ok
O3uc	15	235	-8	-97	2	36	148	471	...	...	Ok
O4uc	9	235	-3	-95	1	36	125	471	...	...	Ok
D1c	18	117	-18	-86	3	18	308	471	...	...	Ok
D2c	8	117	-7	-80	1	18	255	471	...	...	Ok
D3c	11	117	-11	-117	2	18	105	206	...	...	Ok
D4c	...	117	...	-107	...	18	3	206	...	...	Ok
O1c	24	235	-18	-83	4	36	335	471	...	...	Ok
O2c	3	235	...	...	1	36	110	471	...	...	Ok
O3c	18	235	-11	-117	3	36	140	471	...	...	Ok
O4c	10	235	-5	-117	1	36	137	471	...	...	Ok
Max RATIO	0.154		0.218			0.154		0.889		...	

Summary of Thickness Comparisons for 16 Load Cases:

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	46.468	62.000	Ok
Tubesheet Thickness Flanged Extension :	23.085	46.000	Ok
Tube Thickness :	0.645	2.108	Ok
Tube-Tubesheet Fillet Weld Leg :	1.332	1.500	Ok
Tube-Tubesheet Groove Weld Leg :	1.332	1.500	Ok

Min Shell length of thk, (10.000) adj. to tubesheet: 137.202 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 : -0.478 mm.
Due to Pressure Shell Compresses by : -0.103 mm.
Due to Pressure + Thermal Shell Compresses by : -0.580 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	37.177	1.000	91.595	1.000
Tubesheet Shear Stress	128.592	1.000	172.522	1.000
Tube Tensile Stress	152.147	1.000	383.662	1.000
Tube Compressive Stress	92.679	0.801	303.414	1.000
Tube-Tubesheet Joint load	152.147	1.000	383.661	1.000
Shell Stress (Axial, Junction)	35.612	1.000	43.964	1.000
Tube Pressure Stress	209.607	1.000	135.801	1.000
Tubesheet Extension Stress	24.648	...	No Calc	No Calc
Minimum MAWP	24.648		43.964	

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	40.660	0.995	91.595	1.000
Tubesheet Shear Stress	155.495	1.000	179.588	1.000
Tube Tensile Stress	192.723	1.000	537.675	1.000
Tube Compressive Stress	144.474	1.000	403.546	1.000
Tube-Tubesheet Joint load	192.722	1.000	537.674	1.000
Shell Stress (Axial, Junction)	40.660	0.995	68.157	1.000
Tube Pressure Stress	209.607	1.000	135.801	1.000
Tubesheet Extension Stress	24.648	...	No Calc	No Calc
Minimum MAPnc	24.648		68.157	

(*) All load cases were analyzed to compute the MAWP for determining the test pressure.

Tubesheet MDMT Calculations:

Note: The loading conditions from this case will be used to determine the tubesheet MDMT.

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(62.0/4, min(62.0, 10.0))
= 15.500 mm.

Thickness Ratio = 0.933, Temperature Reduction per Fig. UCS 66.1 = 4 °C

Min Metal Temp. w/o impact per UCS-66, Curve D -46 °C
Min Metal Temp. at Required thickness (UCS 66.1) -48 °C

Channel Side MDMT calculation:

Governing thickness for the channel side:
```
  = tubesheet thickness/4
  = 62.0/4
  = 15.500 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( 23.0/24.65, 23.0/68.16 )
  = 0.933
```

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-3 ECONOMIZER
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for ECONOMIZER E-PK6101-3 ----
MDMT Summary: Step: 23 11:46pm Dec 22,2021

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]	D	-48	-48	-29	0.707	10.000	1.00	No
S2	[1]	B	-29	-45	-29	0.706	10.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
S1	[1]	B	-29	-45	-29	0.706	10.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
S3	[1]	B	-29	-45	-29	0.707	10.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
Tubesheet: SS	[13]	D	-46	-48	-29	0.933	15.500	1.00	No
Warmest MDMT:			-29	-45					
BODY FLANGE 0	[11]	!	-46	-46		0.711	10.000	1.00	No
BODY FLANGE 0	[11]	!	-46	-46		0.710	10.000	1.00	No
HEAD 1	[10]	D	-48	-48	-29	0.692	10.000	1.00	No
HEAD 1	[7]	D	-48	-48	-29	0.550	12.000	1.00	No
CHANNEL 01	[8]	D	-48	-48	-29	0.707	10.000	1.00	No
CHANNEL 002	[8]	D	-48	-48	-29	0.707	10.000	1.00	No
HEAD 002	[10]	D	-48	-48	-29	0.692	10.000	1.00	No
HEAD 002	[7]	D	-48	-48	-29	0.550	12.000	1.00	No
T4	[1]	D	-48	-48	-29	0.706	10.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
T1	[1]	B	-29	-45	-29	0.707	10.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
T2	[1]	B	-29	-45	-29	0.706	10.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
T3	[1]	D	-48	-48	-29	0.707	10.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
Tubesheet: CS	[14]	!	-46	-46		0.933	15.500	1.00	No
Warmest MDMT:			-29	-45					

Exchanger Side	Computed MDMT °C	Required MDMT °C	Pass/Fail
Shell	-45.0	-45.0	Pass
Channel/Tube	-45.0	-45.0	Pass

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

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

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

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

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-3 ECONOMIZER
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for ECONOMIZER E-PK6101-3 ----
Vessel Design Summary: Step: 24 11:46pm Dec 22,2021

ASME Code, Section VIII Division 1, 2017

```
Diameter Spec : 581.000 mm. ID
Vessel Design Length, Tangent to Tangent          7106.35  mm.

Specified Datum Line Distance                       50.00  mm.

Shell  Side  Design Temperature                       120  °C
Channel Side Design Temperature                       120  °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
```

Materials of Construction:

Component Type	Material	Class	Thickness	UNS #	Normalized	Impact Tested
Shell	SA-516 70	...	...	K02700	Yes	No
Head	SA-516 70	...	...	K02700	Yes	No
Flange	SA-350 LF2	1	...	K03011	No	Yes
Nozzle	SA-350 LF2	1	...	K03011	No	Yes
Nozzle	SA-333 6	...	...	K03006	No	Yes
Re-Pad	SA-516 70	...	...	K02700	No	No
Nozzle Flg	SA-350 LF2	1	...	K03011	No	Yes
Tubes	SA-334 6	...	...	K03006	No	Yes
Tubesheet	SA-350 LF2	1	...	K03011	No	Yes
Flg Bolting	SA-320 L7	...	<= 2 1/2	G41400	No	Yes
Hrz Bolting	SA-193 B7	...	2 1/2 < t <= 4	G41400	No	No

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

Element Pressures and MAWP (bars & mm.):

Element Description or Type	Design Pressure + Stat. head	Ext. Press.	Element M.A.W.P	Corrosion Allowance	Str. Flg. Gov.	In Creep Range
HEAD 1	23.034	1.10	No Calc	3.0000	No	No
CHANNEL 01	23.034	1.10	No Calc	3.0000	N/A	No
BODY FLANGE 01	23.037	1.10	No Calc	3.0000	N/A	No
SHELL	23.034	1.10	No Calc	3.0000	N/A	No
BODY FLANGE 002	23.034	1.10	No Calc	3.0000	N/A	No
CHANNEL 002	23.034	1.10	No Calc	3.0000	N/A	No
HEAD 002	23.034	1.10	No Calc	3.0000	No	No

Liquid Level: 581.00 mm. Dens.: 0.001 kg./cm^3 Sp. Gr.: 0.600

Element Types and Properties:

Element Type	"To" Elev mm.	Element Length mm.	Nominal Thickness mm.	Finished Thickness mm.	Reqd Thk Internal mm.	Reqd Thk External mm.	Long Eff	Circ Eff
Ellipse	0.0	50.0	12.0	10.0	7.8	4.6	1.00	1.00
Cylinder	407.0	407.0	10.0	10.0	8.0	4.8	1.00	1.00

Body Flg	495.0	88.0	79.0	62.0	60.8	50.8	1.00	1.00
Cylinder	6443.2	5880.0	10.0	10.0	8.0	8.1	1.00	1.00
Body Flg	6537.4	88.0	79.0	62.0	60.8	50.8	1.00	1.00
Cylinder	7006.4	407.0	10.0	10.0	8.0	4.8	1.00	1.00
Ellipse	7056.4	50.0	12.0	10.0	7.8	4.6	1.00	1.00

Saddle Parameters:

Saddle Width	150.000	mm.
Saddle Bearing Angle	120.000	deg.
Centerline Dimension	600.000	mm.
Wear Pad Width	225.000	mm.
Wear Pad Thickness	10.000	mm.
Wear Pad Bearing Angle	132.000	deg.
Distance from Saddle to Tangent	992.000	mm.
Baseplate Length	545.000	mm.
Baseplate Thickness	16.000	mm.
Baseplate Width	180.000	mm.
Number of Ribs (including outside ribs)	4	
Rib Thickness	10.000	mm.
Web Thickness	10.000	mm.
Height of Center Web	273.000	mm.
Number of Bolts in Baseplate	4	

Baseplate Sketch

```
|------------------- 545.000 mm. --------------------|
------------------------------------------------------ ---
|                                                    |
|                                                    | 180.000 mm.
|                                                    |
------------------------------------------------------ ---
```

Baseplate Plan View

```
------------------------------------------------------ ---
|                                                    | 16.000 mm.
------------------------------------------------------ ---
```

Baseplate Side View

Maximum Tensile Bolt Load	0.	kN

Summary of Maximum Saddle Loads, Operating Case :

Maximum Vertical Saddle Load	42.83	kN
Maximum Transverse Saddle Shear Load	5.74	kN
Maximum Longitudinal Saddle Shear Load	11.49	kN

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

Maximum Vertical Saddle Load	51.07	kN
Maximum Transverse Saddle Shear Load	19.23	kN
Maximum Longitudinal Saddle Shear Load	16.41	kN

Summary of Maximum Saddle Loads, Hydrotest Case :

Maximum Vertical Saddle Load	30.92	kN
Maximum Transverse Saddle Shear Load	1.00	kN
Maximum Longitudinal Saddle Shear Load	0.20	kN

Local Stress Analysis Results:

	Analysis	Max Stress	Pass

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Vessel Design Summary: Step: 24 11:46pm Dec 22,2021

Description	Type	Ratio	Fail
T1	WRC-107/537	0.709	Passed
S2	WRC-107/537	0.839	Passed
S1	WRC-107/537	0.839	Passed
S3	WRC-107/537	0.709	Passed
T2	WRC-107/537	0.839	Passed

Weights:

Fabricated	- Bare W/O Removable Internals	3902.4 kg.
Shop Test	- Fabricated + Water (Full)	5602.4 kg.
Shipping	- Fab. + Rem. Intls.+ Shipping App.	3902.4 kg.
Erected	- Fab. + Rem. Intls.+ Insul. (etc)	3902.4 kg.
Empty	- Fab. + Intls. + Details + Wghts.	4058.1 kg.
Operating	- Empty + Operating Liquid (No CA)	5131.2 kg.
Field Test	- Empty Weight + Water (Full)	5463.0 kg.