	DEHDASHT PETROCHEMICAL INDUSTRY COMPANY DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT	
NARGAN	DOCUMENT TITLE: Mechanical Calculation for Oil Cooler	POI: IFA
Contract No.: DPIC/98-12	DOCUMENT NUMBER: DPIC9812-000-VD-1002-ME-CLN-0091	Rev. No.: D0

native file to be submitted

DOCUMENT TITLE:

Mechanical Calculation for Oil Cooler

(E-PK6101-1A/B)

PURCHASER'S COMMENT/APPROVAL STATUS		Purchaser: NARGAN
1	AP: Approved (Released for Manufacturing)	Requisition No.: DPIC98-12-001-000-ME-MR-4150-0001-D1
X	AN: Approved With Minor Comments (Fabrication may Proceed)	
3	NF: Approved With Comments (Fabrication not Proceed)	Item No. (Tag No.): PK-6101
4	RJ: Rejected	
5	NR: Not be Returned	Vendor Doc. No.: DPIC9812-000-VD-1002-ME-CLN-0091-D0
	Date: 11.01.2022 Signature: A.AB	

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

KASRAVAND Engineering & Construction

	DEHDASHT PETROCHEMICAL INDUSTRY COMPANY DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT	
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24	x				
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64	x				
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66	x				
67	x				
68	x				
69	x				
70	x				

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT	
DOCUMENT TITLE: Mechanical Calculation for Oil Cooler	POI: IFA
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135	x				
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137	x				
138	x				
139	x				
140	x				

	DEHDASHT PETROCHEMICAL INDUSTRY COMPANY DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT	
NARGAN	DOCUMENT TITLE: Mechanical Calculation for Oil Cooler	POI: IFA
Contract No.: DPIC/98-12	DOCUMENT NUMBER: DPIC9812-000-VD-1002-ME-CLN-0091	Rev. No.: D0

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DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-1 AB OIL COOLER

DESIGN CALCULATION

In Accordance with ASME Section VIII Division 1

ASME Code Version : 2017

Analysis Performed by : SPLM Licensed User

Job File :

Date of Analysis : Dec 23,2021 8:06am

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 8:06am Dec 23,2021

Class From To : Basic Element Checks.
==

Class From To: Check of Additional Element Data
==

There were no geometry errors or warnings.

please send native file in PVELITE 2018

PV Elite Vessel Analysis Program: Input Data

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-1 AB   OIL COOLER

Exchanger Design Pressures and Temperatures

Shell Side Design Pressure	25	bars
Channel Side Design Pressure	25	bars
Shell Side Design Temperature	120.0	°C
Channel Side Design Temperature	190.0	°C
Radiography, Shell Side	RT-1	
Radiography, Channel Side	RT-1	
Service Type, Shell Side	None	
Service Type, Channel Side	None	
MDMT (CET), Shell Side	-10.0	°C
MDMT (CET), Tube Side	-10.0	°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

hydrotest to be considered

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   8:06am Dec 23,2021

Wind Design Code		ASCE-7 2010	
Wind Load Reduction Scale Factor		0.600	
Basic Wind Speed	[V]	195	Km/hr 200
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	20
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	1.25 or 1.5
Table Value Fa		1.000	
Table Value Fv		1.300	
Short Period Acceleration value Ss		~~1.163~~	0.9
Long Period Acceleration Value Sl		~~0.600~~	0.537
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~~	0.624
User Value of Sd1 (used if > 0)		~~0.000~~	0.39
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	381	mm.
Element Thickness	11.113	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	14	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	25	bars
Design Temperature Internal Pressure	190	°C
Design External Pressure	1.1	bars
Design Temperature External Pressure	190	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70 [Normalized]	
Allowable Stress, Ambient	137.9	N./mm^2
Allowable Stress, Operating	137.9	N./mm^2
Allowable Stress, Hydrotest	235.81	N./mm^2
Material Density	0.00775	kg./cm^3
P Number Thickness	30.988	mm.
Yield Stress, Operating	226.06	N./mm^2
UCS-66 Chart Curve Designation	D	
External Pressure Chart Name	CS-2	
UNS Number	K02700	
Product Form	Plate	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	0.85	
Elliptical Head Factor	2.0	
Weld is pre-Heated	No	

material of standard cap to be considered

Element From Node	10	
Detail Type	Liquid	
Detail ID	1	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	381	mm.
Liquid Density	0.0009996	kg./cm^3

Element From Node	20	
Element To Node	30	
Element Type	Cylinder	
Description	CHANNEL 01	
Distance "FROM" to "TO"	321	mm.
Inside Diameter	381	mm.
Element Thickness	11.113	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	12.7	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	25	bars
Design Temperature Internal Pressure	190	°C
Design External Pressure	1.1	bars
Design Temperature External Pressure	190	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-106 B	
Allowable Stress, Ambient	117.9	N./mm^2
Allowable Stress, Operating	117.9	N./mm^2
Allowable Stress, Hydrotest	217.19	N./mm^2
Material Density	0.00775	kg./cm^3
P Number Thickness	31.75	mm.
Yield Stress, Operating	208.13	N./mm^2

```
     UCS-66 Chart Curve Designation                         B
     External Pressure Chart Name                        CS-2
     UNS Number                                        K03006
     Product Form                                  Smls. pipe
 Efficiency, Longitudinal Seam                            1.0
 Efficiency, Circumferential Seam                         1.0
 Weld is pre-Heated                                        No

     Element From Node                                     20
     Detail Type                                       Liquid
     Detail ID                                              2
     Dist. from "FROM" Node / Offset dist                   0  mm.
     Height/Length of Liquid                              381  mm.
     Liquid Density                                 0.0009996  kg./cm^3

     Element From Node                                     20
     Detail Type                                       Nozzle
     Detail ID                                             T2
     Dist. from "FROM" Node / Offset dist                 160  mm.
     Nozzle Diameter                                        3  in.
     Nozzle Schedule                                      160
     Nozzle Class                                         300
     Layout Angle                                        90.0
     Blind Flange (Y/N)                                     N
     Weight of Nozzle ( Used if > 0 )                  0.1895  kN
     Grade of Attached Flange                          GR 1.1
     Nozzle Matl                                     SA-106 B

     Element From Node                                     20
     Detail Type                                       Nozzle
     Detail ID                                             T1
     Dist. from "FROM" Node / Offset dist                 160  mm.
     Nozzle Diameter                                        3  in.
     Nozzle Schedule                                      160
     Nozzle Class                                         300
     Layout Angle                                       270.0
     Blind Flange (Y/N)                                     N
     Weight of Nozzle ( Used if > 0 )                  0.1968  kN
     Grade of Attached Flange                          GR 1.1
     Nozzle Matl                                     SA-106 B

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 Element From Node                                         30
 Element To Node                                           40
 Element Type                                        Flange
 Description                                   BODY FLANGE 01
 Distance "FROM" to "TO"                                   74  mm.
 Flange Inside Diameter                                   381  mm.
 Element Thickness                                         48  mm.
 Internal Corrosion Allowance                               3  mm.
 Nominal Thickness                                         79  mm.
 External Corrosion Allowance                               0  mm.
 Design Internal Pressure                                  25  bars
 Design Temperature Internal Pressure                     190  °C
 Design External Pressure                                 1.1  bars
 Design Temperature External Pressure                     190  °C
 Effective Diameter Multiplier                            1.2
 Material Name                                       SA-266 2
     Allowable Stress, Ambient                          137.9  N./mm^2
     Allowable Stress, Operating                        137.9  N./mm^2
```

normalized

```
     Allowable Stress, Hydrotest                     223.4  N./mm^2
     Material Density                              0.00775  kg./cm^3
     P Number Thickness                              31.75  mm.
     Yield Stress, Operating                        214.16  N./mm^2
     UCS-66 Chart Curve Designation                      B
     External Pressure Chart Name                     CS-2
     UNS Number                                     K03506
     Product Form                                 Forgings
 Perform Flange Stress Calculation (Y/N)                 Y
 Weight of ANSI B16.5/B16.47 Flange                      0  kN
 Class of ANSI B16.5/B16.47 Flange
 Grade of ANSI B16.5/B16.47 Flange
 Weld is pre-Heated                                     No

     Element From Node                                  30
     Detail Type                                    Liquid
     Detail ID                                           3
     Dist. from "FROM" Node / Offset dist                0  mm.
     Height/Length of Liquid                           381  mm.
     Liquid Density                              0.0009996  kg./cm^3

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

     Element From Node                                  40
     Detail Type                                    Saddle
     Detail ID                                Fixed Saddle
     Dist. from "FROM" Node / Offset dist              464  mm.
     Width of Saddle                                   140  mm.
     Height of Saddle at Bottom                        500  mm.
     Saddle Contact Angle                            120.0
     Height of Composite Ring Stiffener                  0  mm.
```

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     Width of Wear Plate                                200  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              2444  mm.
     Width of Saddle                                    140  mm.
     Height of Saddle at Bottom                         500  mm.
     Saddle Contact Angle                             120.0
     Height of Composite Ring Stiffener                   0  mm.
     Width of Wear Plate                                200  mm.
     Thickness of Wear Plate                             10  mm.
     Contact Angle, Wear Plate (degrees)              132.0
     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                            381  mm.
     Liquid Density                               0.0008747  kg./cm^3

     Element From Node                                   40
     Detail Type                                     Nozzle
     Detail ID                                           S2
     Dist. from "FROM" Node / Offset dist               164  mm.
     Nozzle Diameter                                      3  in.
     Nozzle Schedule                                    160
     Nozzle Class                                       300
     Layout Angle                                      90.0
     Blind Flange (Y/N)                                   N
     Weight of Nozzle ( Used if > 0 )                0.1968  kN
     Grade of Attached Flange                        GR 1.1
     Nozzle Matl                                   SA-106 B

     Element From Node                                   40
     Detail Type                                     Nozzle
     Detail ID                                           S1
     Dist. from "FROM" Node / Offset dist              2698  mm.
     Nozzle Diameter                                      3  in.
     Nozzle Schedule                                    160
     Nozzle Class                                       300
     Layout Angle                                      90.0
     Blind Flange (Y/N)                                   N
     Weight of Nozzle ( Used if > 0 )                0.1968  kN
     Grade of Attached Flange                        GR 1.1
     Nozzle Matl                                   SA-106 B
```

```
     Element From Node                                  40
     Detail Type                                    Nozzle
     Detail ID                                          S3
     Dist. from "FROM" Node / Offset dist              164  mm.
     Nozzle Diameter                                     2  in.
     Nozzle Schedule                                   160
     Nozzle Class                                      300
     Layout Angle                                    270.0
     Blind Flange (Y/N)                                  N
     Weight of Nozzle ( Used if > 0 )               0.1162  kN
     Grade of Attached Flange                       GR 1.1
     Nozzle Matl                                  SA-106 B

     Element From Node                                  40
     Detail Type                                    Weight
     Detail ID                               WEIGHT BAFFLE
     Dist. from "FROM" Node / Offset dist             1456  mm.
     Miscellaneous Weight                           0.4903  kN
     Offset from Element Centerline                      0  mm.
```

vendor is full responsible

```
 --------------------------------------------------------------------

 Element From Node                                      50
 Element To Node                                        60
 Element Type                                       Flange
 Description                                 BODY FLANGE 002
 Distance "FROM" to "TO"                                74  mm.
 Flange Inside Diameter                                381  mm.
 Element Thickness                                      48  mm.
 Internal Corrosion Allowance                            3  mm.
 Nominal Thickness                                      79  mm.
 External Corrosion Allowance                            0  mm.
 Design Internal Pressure                               25  bars
 Design Temperature Internal Pressure                  190  °C
 Design External Pressure                              1.1  bars
 Design Temperature External Pressure                  190  °C
 Effective Diameter Multiplier                         1.2
 Material Name                                    SA-266 2
     Allowable Stress, Ambient                       137.9  N./mm^2
     Allowable Stress, Operating                     137.9  N./mm^2
     Allowable Stress, Hydrotest                     223.4  N./mm^2
     Material Density                              0.00775  kg./cm^3
     P Number Thickness                              31.75  mm.
     Yield Stress, Operating                        214.16  N./mm^2
     UCS-66 Chart Curve Designation                      B
     External Pressure Chart Name                     CS-2
     UNS Number                                     K03506
     Product Form                                 Forgings
 Perform Flange Stress Calculation (Y/N)                 Y
 Weight of ANSI B16.5/B16.47 Flange                      0  kN
 Class of ANSI B16.5/B16.47 Flange
 Grade of ANSI B16.5/B16.47 Flange
 Weld is pre-Heated                                     No

     Element From Node                                  50
     Detail Type                                    Liquid
     Detail ID                                           5
     Dist. from "FROM" Node / Offset dist                0  mm.
     Height/Length of Liquid                           381  mm.
     Liquid Density                              0.0009996  kg./cm^3
```

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-1 AB   OIL COOLER
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for OIL COOLER E-PK6101-1AB   --
Input Echo: Step: 1   8:06am Dec 23,2021

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

Element From Node	60	
Detail Type	Liquid	
Detail ID	5	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	381	mm.
Liquid Density	0.0009996	kg./cm^3

Element From Node	60	
Detail Type	Nozzle	
Detail ID	T4	
Dist. from "FROM" Node / Offset dist	160	mm.
Nozzle Diameter	0.75	in.
Nozzle Schedule	None	
Nozzle Class	300	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.04839	kN
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-350 LF2 [Impact Tested]	

SA-105

Element From Node	60	
Detail Type	Nozzle	
Detail ID	T3	
Dist. from "FROM" Node / Offset dist	160	mm.
Nozzle Diameter	1	in.
Nozzle Schedule	None	
Nozzle Class	300	
Layout Angle	270.0	
Blind Flange (Y/N)	N	

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-1 AB OIL COOLER
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for OIL COOLER E-PK6101-1AB --
Input Echo: Step: 1 8:06am Dec 23,2021

SA-105

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

CAP material to be considered

Element From Node	70	
Detail Type	Liquid	
Detail ID	6	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	381	mm.
Liquid Density	0.0009996	kg./cm^3

XY Coordinate Calculations:

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
	HEAD 1	50	...	50	...
	CHANNEL 01	371	...	321	...
	BODY FLANGE 01	445	...	74	...
	SHELL	3405.17	...	2908	...
	BODY FLANGE 002	3485.35	...	74	...
	CHANNEL 002	3852.35	...	321	...
	HEAD 002	3902.35	...	50	...

```
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-1 AB    OIL COOLER
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for OIL COOLER E-PK6101-1AB    --
Flg Calc [Int P]: FLANGE                Flng:    3   8:06am  Dec 23,2021
```

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

BODY FLANGE 01

```
 Description of Flange Geometry (Type)          Integral Weld Neck
 Design Pressure                          P            25.04  bars
 Design Temperature                                      190  °C
 Internal Corrosion Allowance            ci           3.0000  mm.
 External Corrosion Allowance            ce           0.0000  mm.
 Use Corrosion Allowance in Thickness Calcs.              Yes

 Flange Inside Diameter                   B          381.000  mm.
 Flange Outside Diameter                  A          515.000  mm.
 Flange Thickness                         t          48.0000  mm.
 Thickness of Hub at Small End           go          10.0000  mm.
 Thickness of Hub at Large End           g1          17.0000  mm.
 Length of Hub                            h          26.0000  mm.

 Flange Material                                   SA-266 2
 Flange Material UNS number                          K03506
 Flange Allowable Stress At Temperature  Sfo          137.90  N./mm^2
 Flange Allowable Stress At Ambient      Sfa          137.90  N./mm^2

 Bolt Material                                    SA-193 B7
 Bolt Allowable Stress At Temperature     Sb          172.38  N./mm^2
 Bolt Allowable Stress At Ambient         Sa          172.38  N./mm^2

 Diameter of Bolt Circle                  C          473.000  mm.
 Nominal Bolt Diameter                    a          19.0500  mm.
 Type of Threads                          UNC Thread Series
 Number of Bolts                                          28

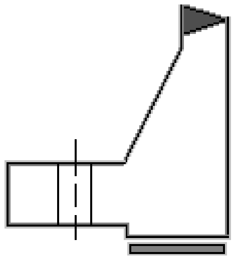
 Flange Face Outside Diameter            Fod         447.000  mm.
 Flange Face Inside Diameter             Fid         381.000  mm.
 Flange Facing Sketch                     1, Code Sketch 1a

 Gasket Outside Diameter                  Go         444.000  mm.
 Gasket Inside Diameter                   Gi         404.000  mm.
 Gasket Factor                             m          3.7800
 Gasket Design Seating Stress              y           62.05  N./mm^2

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

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

g0 shall be same as shell attachment



ASME Code, Section VIII Division 1, 2017

Hub Small End Required Thickness due to Internal Pressure:

```
  = (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
  = (25.04*(381.0/2+3.0))/(137.9*1.0-0.6*25.04)+Ca
  = 6.5521 mm.
```

Hub Small End Hub MAWP:

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9 * 1.0 * 7.0)/(193.5 + 0.6 * 7.0 )
  = 48.824 bars
```

```
 Corroded Flange Thickness, tc = T-ci                      45.000  mm.
 Corroded Flange ID,      Bcor = B+2*Fcor                 387.000  mm.
 Corroded Large Hub,     g1Cor = g1-ci                     14.000  mm.
 Corroded Small Hub,     g0Cor = go-ci                      7.000  mm.
 Code R Dimension,           R = ((C-Bcor)/2)-g1cor        29.000  mm.

 Gasket Contact Width,       N = (Go - Gi) / 2             20.000  mm.
 Basic Gasket Width,        bo = N / 2                     10.000  mm.
 Effective Gasket Width,     b = Cb sqrt(bo)                7.969  mm.
 Gasket Reaction Diameter,   G = Go - 2 * b               428.063  mm.
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:

```
  = 0.785 * G² * Peq
  = 0.785 * 428.0626² * 25.037
  = 360.314 kN
```

Contact Load on Gasket Surfaces [Hp]:

```
  = 2 * b * Pi * G * m * P + 2 * lp * bPart * mPart * P
  = 2 * 7.9687 * 3.1416 * 428.0626 * 3.78 * 25.04
    + 2.0 * 1078.0 * 3.0 * 3.75 * 25.0373
  = 263.561 kN
```

Hydrostatic End Load at Flange ID [Hd]:

```
  = Pi * Bcor² * P  / 4
  = 3.1416 * 387.0² *25.0373/4
  = 294.502 kN
```

Pressure Force on Flange Face [Ht]:

```
  = H - Hd
  = 360 - 295
  = 65.812 kN
```

Operating Bolt Load [Wm1]:

```
  = max( H + Hp + H'p, 0 )
  = max( 360 + 264 + 0, 0 )
  = 623.875 kN
```

Gasket Seating Bolt Load [Wm2]:

```
  = y * b * Pi * G  + yPart * bPart * lp
  = 62.05*7.9687*3.141*428.063+62.05*3.0*1078.0
  = 865.581 kN
```

Required Bolt Area [Am]:

```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 624/172, 866/172
  = 50.219 cm^2
```

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

```
  = 2a + 6t/(m + 0.5)
  = 2 * 19.05 + 6 * 45.0/(3.78 + 0.5)
  = 101.184 mm.
```

Actual Circumferential Bolt Spacing [Bs]:

```
  = C * sin( pi / n )
  = 473.0 * sin( 3.142/28 )
  = 52.959 mm.
```

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

```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 52.959/( 2 * 19.05 + 45.0 )), 1 )
  = 1.0000
```

Bolting Information for UNC Thread Series (Non Mandatory):

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

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

```
  = Ab * Sa/( y * Pi * (Go + Gi) )
  = 54.555 * 172.38/(62.05 * 3.14 * (444.0 + 404.0) )
  = 5.689 mm.
```

Flange Design Bolt Load, Gasket Seating [W]:

```
  = Sa * ( Am + Ab ) / 2
  = 172.38 * ( 50.2192 + 54.5547 )/2
  = 902.94 kN
```

Gasket Load for the Operating Condition [HG]:

```
  = Wm1 - H
  = 624 - 360
  = 263.56 kN
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
  = (C - G ) / 2
  = ( 473.0 - 428.0626 )/2
  = 22.4687 mm.
```

Distance to Face Pressure Reaction [ht]:

```
  = ( R + g1 + hg ) / 2
  = ( 29.0 + 14.0 + 22.4687 )/2
  = 32.7343 mm.
```

Distance to End Pressure Reaction [hd]:

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

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

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

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

Effective Hub Length, ho = sqrt(Bcor*goCor)          52.048  mm.
Hub Ratio,          h/h0 = HL / H0                    0.500
```

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

Flange Factors for Integral Flange:

```
 Factor F                                              0.826
 Factor V                                              0.227
 Factor f                                              1.228
 Factors from Figure 2-7.1                    K =      1.331
                    T =      1.784            U =      7.636
                    Y =      6.948            Z =      3.594
                    d =  85637.820 mm.³       e =    0.0159 mm.^-1
 Stress Factors                           ALPHA =      1.714
                 BETA =      1.952        GAMMA =      0.961
                DELTA =      1.064        Lamda =      2.025
```

Longitudinal Hub Stress, Operating [SHo]:

```
  = ( f * Mop / Bcor ) / ( L * g1² )
  = (1.2277*18686/387.0)/(2.0247*14.0²)
  = 149.32 N./mm^2
```

Longitudinal Hub Stress, Seating [SHa]:

```
  = ( f * Matm / Bcor ) / ( L * g1² )
  = (1.2277*20296/387.0)/(2.0247*14.0²)
  = 162.19 N./mm^2
```

Radial Flange Stress, Operating [SRo]:

```
  = ( Beta * Mop / Bcor ) / ( L * t² )
  = (1.9519*18686/387.0)/(2.0247*45.0²)
  = 22.98 N./mm^2
```

Radial Flange Stress, Seating [SRa]:

```
  = ( Beta * Matm/Bcor ) / ( L * t² )
  = (1.9519*20296/387.0)/(2.0247*45.0²)
  = 24.96 N./mm^2
```

Tangential Flange Stress, Operating [STo]:

```
  = ( Y * Mo / (t² * Bcor) ) - Z * SRo
  = (6.9484*18686/(45.0²*387.0))-3.5944*23
  = 83.03 N./mm^2
```

Tangential Flange Stress, Seating [STa]:

```
  = ( y * Matm / (t² * Bcor) ) - Z * SRa
  = (6.9484*20296/(45.0²*387.0))-3.5944*25
  = 90.18 N./mm^2
```

Average Flange Stress, Operating [SAo]:

```
  = ( SHo + max( SRo, STo ) ) / 2
  = (149+max(23,83))/2
  = 116.17 N./mm^2
```

Average Flange Stress, Seating [SAa]:

```
  = ( SHa + max( SRa, STa ) ) / 2
  = (162+max(25,90))/2
  = 126.19 N./mm^2
```

Bolt Stress, Operating [BSo]:

```
  = Wm1 / Ab
  = 624/54.5547
  = 114.37 N./mm^2
```

Bolt Stress, Seating [BSa]:

```
  = ( Wm2 / Ab )
  = (866/54.5547)
  = 158.68 N./mm^2
```

Flange Stress Analysis Results: N./mm^2

	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Longitudinal Hub	149.	207.	162.	207.
Radial Flange	23.	138.	25.	138.
Tangential Flange	83.	138.	90.	138.
Maximum Average	116.	138.	126.	138.
Bolting	114.	172.	159.	172.

Minimum Required Flange Thickness	45.136	mm.
Estimated M.A.W.P. (Operating)	29.719	bars
Estimated Finished Weight of Flange at given Thk.	38.5	kg.
Estimated Unfinished Weight of Forging at given Thk	54.1	kg.

Flange Rigidity Based on Required Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
= 52.14 * Ma / Bsc * Cnv_fac * V / (Lambda * Eamb * go² * ho * Ki)
= 52.14 * 20296.2/1.0 * 999.68 * 0.227/(1.809 * 202713 * 7.0² * 52.048 * 0.3)
= 0.858 (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 * 18685.8/1.0 * 999.68 * 0.227/(1.809 * 193088 * 7.0² * 52.048 * 0.3)
= 0.829 (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 * 20296.2/1.0 * 999.68 * 0.227/(2.025 * 202713 * 7.0² * 52.048 * 0.3)
= 0.766 (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 * 18685.8/1.0 * 999.68 * 0.227/(2.025 * 193088 * 7.0² * 52.048 * 0.3)
= 0.740 (should be <= 1)

Minimum Design Metal Temperature Results:
Thickness Ratio = 0.436, Temperature Reduction per Fig. UCS 66.1 = 43 °C

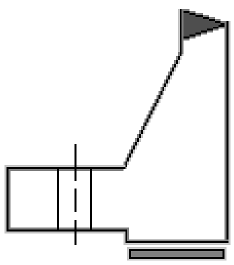
Min Metal Temp. w/o impact per UCS-66, Curve B	-29 °C
Min Metal Temp. at Required thickness (UCS 66.1)	-48 °C

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



ASME Code, Section VIII Division 1, 2017

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

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

```
 Corroded Flange Thickness, tc = T-ci                      45.000  mm.
 Corroded Flange ID,      Bcor = B+2*Fcor                 387.000  mm.
 Corroded Large Hub,     g1Cor = g1-ci                     14.000  mm.
 Corroded Small Hub,     g0Cor = go-ci                      8.113  mm.
 Code R Dimension,           R = ((C-Bcor)/2)-g1cor        29.000  mm.

 Gasket Contact Width,       N = (Go - Gi) / 2             20.000  mm.
 Basic Gasket Width,        bo = N / 2                     10.000  mm.
 Effective Gasket Width,     b = Cb sqrt(bo)                7.969  mm.
 Gasket Reaction Diameter,   G = Go - 2 * b               428.063  mm.
```

Basic Flange and Bolt Loads:

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

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

Actual Circumferential Bolt Spacing [Bs]:

```
  = C * sin( pi / n )
  = 473.0 * sin( 3.142/28 )
  = 52.959 mm.
```

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

```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 52.959/( 2 * 19.05 + 45.0 )), 1 )
  = 1.0000
```

Bolting Information for UNC Thread Series (Non Mandatory):

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

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

```
  = Ab * Sa/( y * Pi * (Go + Gi) )
  = 54.555 * 172.38/(62.05 * 3.14 * (444.0 + 404.0) )
  = 5.689 mm.
```

Flange Design Bolt Load, Gasket Seating [W]:

```
  = Sa * ( Am + Ab ) / 2
  = 172.38 * ( 50.2192 + 54.5547 )/2
  = 902.94 kN
```

Gasket Load for the Operating Condition [HG]:

```
  = Wm1 - H
  = 624 - 360
  = 263.56 kN
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
  = (C - G ) / 2
  = ( 473.0 - 428.0626 )/2
  = 22.4687 mm.
```

Distance to Face Pressure Reaction [ht]:

```
  = ( R + g1 + hg ) / 2
  = ( 29.0 + 14.0 + 22.4687 )/2
  = 32.7343 mm.
```

Distance to End Pressure Reaction [hd]:

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

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

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

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

Effective Hub Length, ho = sqrt(Bcor*goCor)           56.032  mm.
Hub Ratio,          h/h0 = HL / H0                     0.464
```

```
 Thickness Ratio,   g1/g0 = (g1Cor/goCor)              1.726
```

Flange Factors for Integral Flange:

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

Longitudinal Hub Stress, Operating [SHo]:

```
  = ( f * Mop / Bcor ) / ( L * g1² )
  = (1.0*18686/387.0)/(1.8294*14.0²)
  = 134.61 N./mm^2
```

Longitudinal Hub Stress, Seating [SHa]:

```
  = ( f * Matm / Bcor ) / ( L * g1² )
  = (1.0*20296/387.0)/(1.8294*14.0²)
  = 146.21 N./mm^2
```

Radial Flange Stress, Operating [SRo]:

```
  = ( Beta * Mop / Bcor ) / ( L * t² )
  = (1.9019*18686/387.0)/(1.8294*45.0²)
  = 24.78 N./mm^2
```

Radial Flange Stress, Seating [SRa]:

```
  = ( Beta * Matm/Bcor ) / ( L * t² )
  = (1.9019*20296/387.0)/(1.8294*45.0²)
  = 26.92 N./mm^2
```

Tangential Flange Stress, Operating [STo]:

```
  = ( Y * Mo / (t² * Bcor) ) - Z * SRo
  = (6.9484*18686/(45.0²*387.0))-3.5944*25
  = 76.55 N./mm^2
```

Tangential Flange Stress, Seating [STa]:

```
  = ( y * Matm / (t² * Bcor) ) - Z * SRa
  = (6.9484*20296/(45.0²*387.0))-3.5944*27
  = 83.15 N./mm^2
```

Average Flange Stress, Operating [SAo]:

```
  = ( SHo + max( SRo, STo ) ) / 2
  = (135+max(25,77))/2
  = 105.58 N./mm^2
```

Average Flange Stress, Seating [SAa]:

```
  = ( SHa + max( SRa, STa ) ) / 2
  = (146+max(27,83))/2
  = 114.68 N./mm^2
```

Bolt Stress, Operating [BSo]:

```
  = Wm1 / Ab
  = 624/54.5547
  = 114.37 N./mm^2
```

Bolt Stress, Seating [BSa]:

```
  = ( Wm2 / Ab )
  = (866/54.5547)
  = 158.68 N./mm^2
```

Flange Stress Analysis Results: N./mm^2

	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Longitudinal Hub	135.	207.	146.	207.
Radial Flange	25.	138.	27.	138.
Tangential Flange	77.	138.	83.	138.
Maximum Average	106.	138.	115.	138.
Bolting	114.	172.	159.	172.

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

Flange Rigidity Based on Required Thickness [ASME]:

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

```
  = 52.14 * Ma / Bsc * Cnv_fac * V / ( Lambda * Eamb * go² * ho * Ki )
  = 52.14 * 20296.2/1.0 * 999.68 * 0.275/( 1.437 * 202713 *
    8.113² * 56.032 * 0.3 )
  = 0.902  (should be <= 1)
```

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

```
  = 52.14 * Mo / Bsc * Cnv_fac * V / ( Lambda * Eop * goc² * ho * Ki )
  = 52.14 * 18685.8/1.0 * 999.68 * 0.275/( 1.437 * 193088
    * 8.113² * 56.032 * 0.3 )
  = 0.872  (should be <= 1)
```

Flange Rigidity Based on Given Thickness [ASME]:

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

```
  = 52.14 * Ma / Bsc * Cnv_fac * V / ( Lambda * Eamb * go² * ho * Ki )
  = 52.14 * 20296.2/1.0 * 999.68 * 0.275/( 1.829 * 202713 *
    8.113² * 56.032 * 0.3 )
  = 0.709  (should be <= 1)
```

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

```
  = 52.14 * Mo / Bsc * Cnv_fac * V / ( Lambda * Eop * goc² * ho * Ki )
  = 52.14 * 18685.8/1.0 * 999.68 * 0.275/( 1.829 * 193088
    * 8.113² * 56.032 * 0.3 )
  = 0.685  (should be <= 1)
```

Minimum Design Metal Temperature Results:
Thickness Ratio = 0.436, Temperature Reduction per Fig. UCS 66.1 = 43 °C

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

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

```
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-1 AB    OIL COOLER
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for OIL COOLER E-PK6101-1AB    --
Internal Pressure Calculations:       Step:    5   8:06am  Dec 23,2021
```

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	25.038	14	3	381	137.9
	CHANNEL 01	25.038	12.7	3	381	117.9
	BODY FLANGE 01	25.037	79	3	381	137.9
	SHELL	25.033	12.7	3	381	117.9
	BODY FLANGE 002	25.037	79	3	381	137.9
	CHANNEL 002	25.038	12.7	3	381	117.9
	HEAD 002	25.038	14	3	381	137.9

Element Required Thickness and MAWP :

From	To	Design Pressure bars	M.A.W.P. Corroded bars	M.A.P. New & Cold bars	Minimum Thickness mm.	Required Thickness mm.
	HEAD 1	25	No Calc	No Calc	11.1125	6.44875
	CHANNEL 01	25	No Calc	No Calc	11.1125	7.16235
	BODY FLANGE 01	25	No Calc	No Calc	48	45.1358
	SHELL	25	No Calc	No Calc	11.1125	7.16156
	BODY FLANGE 002	25	No Calc	No Calc	48	41.4274
	CHANNEL 002	25	No Calc	No Calc	11.1125	7.16235
	HEAD 002	25	No Calc	No Calc	11.1125	6.44875

Internal Pressure Calculation Results :

ASME Code, Section VIII Division 1, 2017

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

HEAD 1

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
```
  = (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
  = (25.038*387.0*0.98)/(2*137.9*1.0-0.2*25.038)
  = 3.4487 + 3.0000 = 6.4487 mm.
```

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

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

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

= 75.803 - 0.038 = 75.765 bars

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

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

MDMT Calculations in the Knuckle Portion:

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

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

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 14.0, tr = 3.552, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.323, Temp. Reduction = 78 °C

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

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

CHANNEL 01

Material UNS Number: K03006

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

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

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 11.113, tr = 5.046, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.622, Temp. Reduction = 21 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -26 °C
Min Metal Temp. at Required thickness (UCS 66.1) -47 °C
Min Metal Temp. w/o impact per UG-20(f) -29 °C

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

SHELL

Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)


```
  = (25.033*193.5)/(117.9*1.0-0.6*25.033)
  = 4.1616 + 3.0000 = 7.1616 mm.
```

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

```
  = (P*(R+0.6*t))/(E*t)
  = (25.033*(193.5+0.6*8.1125))/(1.0*8.1125)
  = 61.214 N./mm^2
```

Minimum Design Metal Temperature Results:

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

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

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

CHANNEL 002

Material UNS Number: K03006

Required Thickness due to Internal Pressure [tr]:

```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (25.038*193.5)/(117.9*1.0-0.6*25.038)
  = 4.1623 + 3.0000 = 7.1623 mm.
```

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

```
  = (P*(R+0.6*t))/(E*t)
  = (25.038*(193.5+0.6*8.1125))/(1.0*8.1125)
  = 61.226 N./mm^2
```

Minimum Design Metal Temperature Results:

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

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

Elliptical Head From 70 To 80 SA-516 70 , UCS-66 Crv. D at 190 °C

HEAD 002

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
  = (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
  = (25.038*387.0*0.98)/(2*137.9*1.0-0.2*25.038)
  = 3.4487 + 3.0000 = 6.4487 mm.
```

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

```
  = (P*(Kcor*D+0.2*t))/(2*E*t)
  = (25.038*(0.98*387.0+0.2*8.1125))/(2*1.0*8.1125)
  = 58.767 N./mm^2
```

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

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

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

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

MDMT Calculations in the Knuckle Portion:

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

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

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 14.0, tr = 3.552, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.323, Temp. Reduction = 78 °C

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

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

Hydrostatic Test Pressure Results:

Exchanger Shell Side Hydrostatic Test Pressures:

```
 Pressure per UG99b[36] = 1.30 * Design Pres * Sa/S       32.500  bars
 Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)    35.750  bars
 Pressure per App 27-4  = M.A.W.P.                        45.967  bars
```

Exchanger Channel Side Hydrostatic Test Pressures:

```
 Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S          32.229  bars
 Pressure per UG99b[36] = 1.30 * Design Pres * Sa/S       32.500  bars
 Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)       49.023  bars
 Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S          27.270  bars
 Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)    35.750  bars
 Pressure per App 27-4  = M.A.W.P.                        24.791  bars
```

UG-99(b) Note 36, Test Pressure Calculation [Shell Side]:
```
  = Test Factor * Design Pressure * Stress Ratio
  = 1.3 * 25.0 * 1.0
  = 32.500 bars
```

UG-99(b) Note 36, Test Pressure Calculation [Channel Side]:
```
  = Test Factor * Design Pressure * Stress Ratio
  = 1.3 * 25.0 * 1.0
```

= 32.500 bars

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

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

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

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

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

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

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

Description	Ambient	Operating	Ratio
HEAD 1	137.90	137.90	1.000
CHANNEL 01	117.90	117.90	1.000
BODY FLANGE 01	137.90	137.90	1.000
SHELL	117.90	117.90	1.000
BODY FLANGE 002	137.90	137.90	1.000
CHANNEL 002	117.90	117.90	1.000
HEAD 002	137.90	137.90	1.000
Minimum			1.000

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

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

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

Description	Ambient	Operating	Ratio
T2	20.18	217.19	0.093
T1	20.18	217.19	0.093
S2	20.18	217.19	0.093
S1	20.18	217.19	0.093
S3	19.83	217.19	0.091
T4	5.56	223.40	0.025
T3	6.47	223.40	0.029

Elements Suitable for Internal Pressure.

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PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for OIL COOLER E-PK6101-1AB --
External Pressure Calculations: Step: 6 8:06am Dec 23,2021

External Pressure Calculation Results :

External Pressure Calculations:

From	To	Section Length mm.	Outside Diameter mm.	Corroded Thickness mm.	Factor A	Factor B N./mm^2
10	20	No Calc	403.225	8.1125	0.0027943	100.758
20	30	402.75	403.225	8.1125	0.0038853	105.978
30	40	No Calc	...	45	No Calc	No Calc
40	50	2908	403.225	8.1125	0.00050303	50.292
50	60	No Calc	...	45	No Calc	No Calc
60	70	402.75	403.225	8.1125	0.0038853	105.978
70	80	No Calc	403.225	8.1125	0.0027943	100.758

External Pressure Calculations:

From	To	External Actual T. mm.	External Required T. mm.	External Design Pressure bars	External M.A.W.P. bars
10	20	11.1125	4.5	1.1	22.5225
20	30	11.1125	4.34351	1.1	28.4274
30	40	48	45.1358	1.1	No Calc
40	50	11.1125	6.07728	1.1	13.4903
50	60	48	41.4274	1.1	No Calc
60	70	11.1125	4.34351	1.1	28.4274
70	80	11.1125	4.5	1.1	22.5225
Minimum					13.490

External Pressure Calculations:

From	To	Actual Length Bet. Stiffeners mm.	Allowable Length Bet. Stiffeners mm.	Ring Inertia Required cm**4	Ring Inertia Available cm**4
10	20	No Calc	No Calc	No Calc	No Calc
20	30	402.75	26273.1	No Calc	No Calc
30	40	No Calc	No Calc	No Calc	No Calc
40	50	2908	111055	No Calc	No Calc
50	60	No Calc	No Calc	No Calc	No Calc
60	70	402.75	26273.1	No Calc	No Calc
70	80	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

ASME Code, Section VIII Division 1, 2017

Elliptical Head From 10 to 20 Ext. Chart: CS-2 at 190 °C

HEAD 1

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

Results for Maximum Allowable External Pressure (MAEP):

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

```
   8.113     403.23       49.70   0.0027943      100.76
 EMAP = B/(K0*D/t) = 100.7576/( 0.9 *49.7042 ) = 22.5225 bars
```

Results for Required Thickness (Tca):

```
     Tca         OD          D/t     Factor A           B
   1.091     403.23      369.68   0.0003757       36.60
 EMAP = B/(K0*D/t) = 36.6038/( 0.9 *369.677 ) = 1.1001 bars
```

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

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
  = (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
  = (1.837*387.0*0.98)/(2*137.9*1.0-0.2*1.837)
  = 0.2526 + 3.0000 = 3.2526 mm.
```

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

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

Maximum Allowable External Pressure [MAEP]:

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

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

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

CHANNEL 01

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

Results for Maximum Allowable External Pressure (MAEP):

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

Results for Required Thickness (Tca):

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

Results for Maximum Stiffened Length (Slen):

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

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

SHELL

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

Results for Maximum Allowable External Pressure (MAEP):

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

```
   8.113     403.23     2908.00     49.70    7.2119  0.0005030    50.29
 EMAP = (4*B)/(3*(D/t)) = (4*50.292)/(3*49.7042) = 13.4903 bars
```

Results for Required Thickness (Tca):

```
     Tca         OD         SLEN        D/t        L/D   Factor A        B
   3.077     403.23     2908.00    131.03    7.2119  0.0001081    10.81
 EMAP = (4*B)/(3*(D/t)) = (4*10.8112)/(3*131.0331) = 1.1 bars
```

Results for Maximum Stiffened Length (Slen):

```
     Tca         OD         SLEN        D/t        L/D   Factor A        B
   8.113     403.23   111054.98     49.70   50.0000  0.0004463    44.62
 EMAP = (4*B)/(3*(D/t)) = (4*44.6199)/(3*49.7042) = 11.9688 bars
```

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

CHANNEL 002

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

Results for Maximum Allowable External Pressure (MAEP):

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

Results for Required Thickness (Tca):

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

Results for Maximum Stiffened Length (Slen):

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

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

HEAD 002

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

Results for Maximum Allowable External Pressure (MAEP):

```
     Tca         OD          D/t     Factor A          B
   8.113     403.23        49.70   0.0027943      100.76
 EMAP = B/(K0*D/t) = 100.7576/( 0.9 *49.7042 ) = 22.5225 bars
```

Results for Required Thickness (Tca):

```
     Tca         OD          D/t     Factor A          B
   1.091     403.23       369.68   0.0003757       36.60
 EMAP = B/(K0*D/t) = 36.6038/( 0.9 *369.677 ) = 1.1001 bars
```

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

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
  = (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
  = (1.837*387.0*0.98)/(2*137.9*1.0-0.2*1.837)
  = 0.2526 + 3.0000 = 3.2526 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
```
  = ((2*S*E*t)/(Kcor*D+0.2*t))/1.67 per Appendix 1-4 (c)
  = ((2*137.9*1.0*8.1125)/(0.98*387.0+0.2*8.1125))/1.67
  = 35.181 bars
```

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

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

Element and Detail Weights:

From	To	Element Metal Wgt. kg.	Element ID Volume Cm3	Corroded Metal Wgt. kg.	Corroded ID Volume Cm3	Extra due Misc % kg.
10	20	26.995	12942.4	21.2103	13470.9	1.34975
20	30	39.08	36603.5	30.0759	37765.5	1.954
30	40	61.1093	12259.1	58.1641	12353.2	3.05547
40	50	354.033	193985	272.463	204511	17.7016
50	60	61.2532	12259.1	58.3079	12353.2	3.06266
60	70	39.08	36603.5	30.0759	37765.5	1.954
70	80	26.995	12942.4	21.2103	13470.9	1.34975
Total		608	317594.72	491	331690.12	30

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

Weight of Details:

From	Type	Weight of Detail kg.	X Offset, Dtl. Cent. mm.	Y Offset, Dtl. Cent. mm.	Description
10	Liqd	12.9345	-31.75	...	1
20	Liqd	36.5812	160.5	...	2
20	Nozl	20.2925	160	234.95	T2
20	Nozl	21.078	160	234.95	T1
30	Liqd	12.2516	37	...	3
40	Sadl	32.8035	464	334.694	Fixed Saddle
40	Sadl	32.8035	2444	334.694	Sliding Saddle
40	Liqd	169.633	1454	...	4
40	Nozl	21.078	164	234.95	S2
40	Nozl	21.078	2698	234.95	S1
40	Nozl	12.4379	164	220.662	S3
40	Wght	50	1456	...	WEIGHT BAFFLE
50	Liqd	12.2516	37	...	5
60	Liqd	36.5812	160.5	...	5
60	Nozl	5.18177	160	200.025	T4
60	Nozl	6.25877	160	203.2	T3
70	Liqd	12.9345	81.75	...	6
30	FTsh	60.2678	103	...	TUBE SHEET
30	Tube	454.709	1580	...	
30	RTsh	60.2678	3057	...	

Total Weight of Each Detail Type:

Saddles	65.6
Liquid	293.2
Nozzles	107.4
Weights	50.0
Exchanger Components	575.2
Liquid in Tubes	86.0
Sum of the Detail Weights	1177.5 kg.

Weight Summation Results: (kg.)

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FileName : Calculation Book for OIL COOLER E-PK6101-1AB --
Element and Detail Weights: Step: 7 8:06am Dec 23,2021

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	639.0	639.0	639.0	639.0	639.0	639.0
Saddles	65.6	65.6	65.6	65.6	65.6	65.6
Nozzles	107.4	107.4	107.4	107.4	107.4	107.4
Wld Weights	50.0	50.0	50.0	50.0	50.0	50.0
Exchanger	575.2	575.2	575.2	575.2	575.2	575.2
Ope. Liquid	...	...	...	...	...	293.2
Tube Ope Lqd	...	...	...	...	...	86.0
Test Liquid	...	317.4	...	...	...	...
Tube Tst Lqd	...	86.0	...	...	...	...
Totals	1437.2	1840.7	1437.2	1437.2	1437.2	1816.4

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	1437.2 kg.
Shop Test Wt.	- Fabricated Weight + Water (Full)	1840.7 kg.
Shipping Wt.	- Fab. Weight + removable Intls.+ Shipping App.	1437.2 kg.
Erected Wt.	- Fab. Wt + or - loose items (trays,platforms etc.)	1437.2 kg.
Ope. Wt. no Liq	- Fab. Weight + Internals. + Details + Weights	1437.2 kg.
Operating Wt.	- Empty Weight + Operating Liq. Uncorroded	1816.4 kg.
Oper. Wt. + CA	- Corr Wt. + Operating Liquid	1693.5 kg.
Field Test Wt.	- Empty Weight + Water (Full)	1731.9 kg.

Exchanger Tube Data

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

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

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

Outside Surface Areas of Elements:

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

Nozzle Flange MAWP Results:

Nozzle Description	Flange Rating Ope. bars	Flange Rating Ambient bars	Design Temp °C	Class	Grade/ Group	Equiv. Press	Max Pressure PVP	Max Pressure 50%	Max Pressure DNV bars
T2	44.06	51.10	190	300	GR 1.1	...	...	...	...
T1	44.06	51.10	190	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	...	...	...	...
T4	44.06	51.10	190	300	GR 1.1	...	...	...	...
T3	44.06	51.10	190	300	GR 1.1	...	...	...	...

Shellside Flange Rating

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

Channelside Flange Rating

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

Selected Method for Derating ANSI 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*0.837)/(1+1.7*3.4*0.143)))
  = min(0.85, 0.856 )
  = 0.850

 Natural Frequency of Vessel (Operating)                33.000 Hz
 Natural Frequency of Vessel (Empty)                    33.000 Hz
 Natural Frequency of Vessel (Test)                     33.000 Hz

 Force Coefficient                                 [Cf] 0.618
 Structure Height to Diameter ratio                     10.289
```

This is classified as a rigid structure. Static analysis performed.

Sample Calculation for the First Element

The ASCE code performs all calculations in Imperial Units
only. The wind pressure is therefore computed in these units.

Value of [Alpha] and [Zg]:
```
  Exposure Category: C from Table 26.9.1
  Alpha = 9.5: Zg = 274320. mm.
```

Effective Height [z]:
```
  = Centroid Height + Vessel Base Elevation
  = 500.0 + 123000. = 123500. mm.
  = 405.184 ft. Imperial Units
```

Velocity Pressure coefficient evaluated at height z [Kz]:
  Because z (405.184 ft.) > 15 ft.
  $= 2.01 * (z / Zg)^{2 / Alpha}$
  $= 2.01 * (405.184/900.0)^{2/9.5}$
  = 1.699

Type of Hill: No Hill

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

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FileName : Calculation Book for OIL COOLER E-PK6101-1AB --
Wind Load Calculation: Step: 9 8:06am Dec 23,2021

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 [296.231] Kgs/m^2

Force on the first element [F]:
= qz * G * Cf * WindArea
= 60.672 * 0.85 * 0.618 * 0.623
= 19.9 lbs. [0.1] kN

Element	Hgt (z) mm.	K1	K2	K3	Kz	Kzt	qz Kgs/m^2
HEAD 1	*******	0.000	0.000	0.000	1.699	1.000	296.231
CHANNEL 01	*******	0.000	0.000	0.000	1.699	1.000	296.231
BODY FLANGE 01	*******	0.000	0.000	0.000	1.699	1.000	296.231
SHELL	*******	0.000	0.000	0.000	1.699	1.000	296.231
BODY FLANGE 002	*******	0.000	0.000	0.000	1.699	1.000	296.231
CHANNEL 002	*******	0.000	0.000	0.000	1.699	1.000	296.231
HEAD 002	*******	0.000	0.000	0.000	1.699	1.000	296.231

Wind Loads on Masses/Equipment/Piping

ID	Wind Area cm^2	Elevation mm.	Pressure Kgs/m^2	Force kN
WEIGHT BAFFLE	0.00	123500.00	296.23	0.00

Wind Load Calculation:

From	To	Wind Height mm.	Wind Diameter mm.	Wind Area cm^2	Wind Pressure Kgs/m^2	Element Wind Load kN
10	20	123500	483.87	578.777	296.231	0.053013
20	30	123500	483.87	1553.22	296.231	0.14227
30	40	123500	457.2	338.328	296.231	0.030989
40	50	123500	483.87	14070.9	296.231	1.28883
50	60	123500	457.2	338.328	296.231	0.030989
60	70	123500	483.87	1553.22	296.231	0.14227
70	80	123500	483.87	578.777	296.231	0.053013

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 * ($2.2654^{0.75}$)
= 0.037 seconds

The Coefficient Cu from Table 12.8-1 is : 1.400

Fundamental Period (1/Frequency) [T]:
= (1/Natural Frequency) = (1/33.0)
= 0.030

Check the Value of T which is the smaller of Cu*Ta and T:
= Minimum Value of (1.4 * 0.037, 0.03) per 12.8.2
= 0.030

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

Compute the Base Shear per equation 15.4-5, [V]:
= 0.3 * Sds * W * I
= 0.3 * 0.775 * 17 * 1.5
= 5.794 kN

Final Base Shear, V = 4.06 kN

Earthquake Load Calculation:

From	To	Earthquake Height mm.	Earthquake Weight kN	Ope	Element Load kN
10	20	190.5	1.8452		0.45065

20	30	190.5	1.8452	0.45065
30	40	190.5	1.8452	0.45065
40	Sadl	190.5	1.8452	0.45065
Sadl	50	190.5	1.8452	0.45065
40	50	190.5	1.8452	0.45065
50	60	190.5	1.8452	0.45065
60	70	190.5	1.8452	0.45065
70	80	190.5	1.8452	0.45065

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

Shop/Field Installation Options :

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

Center of Gravity of Saddles	1951.175 mm.
Center of Gravity of Liquid	1949.253 mm.
Center of Gravity of Nozzles	1307.450 mm.
Center of Gravity of Added Weights (Operating)	1953.175 mm.
Center of Gravity of Added Weights (Empty)	1953.175 mm.
Center of Gravity of Tubesheet(s)	1951.000 mm.
Center of Gravity of Tubes	1951.000 mm.
Center of Gravity of Bare Shell New and Cold	1946.910 mm.
Center of Gravity of Bare Shell Corroded	1946.170 mm.
Vessel CG in the Operating Condition	1908.482 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition	1901.172 mm.
Vessel CG in the Test Condition	1911.817 mm.

Rigging Analysis Results:

Total Effective Length of Vessel for this analysis		3798.00 mm.
Total vessel weight (No Liquid)	Twt	14.09 kN
Impact weight multiplication factor	Imp	1.50
Design lifting weight, DWT = Imp * Twt		21.14 kN
Distance to the Lug on the Left End		1070.00 mm.
Distance to the Lug on the Right End		2870.00 mm.
Design Reaction force at the Left End Lug		11.38 kN
Design Reaction force at the Right End Lug		9.76 kN
CG Distance from the Left End Lug		831.17 mm.
CG Distance from the Nearer Lifting Lug		831.17 mm.

Critical Values:

	Max Stress N./mm^2	Elevation mm.	Allowables N./mm^2	
Bending	5.47	1026.60	117.90	(UG-23)
Shear	0.77	1026.60	82.53	(0.7*S)

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

Distance mm.	Bending Moment N-m	Bending Stress N./mm^2	Shear Force kN	Shear Stress N./mm^2
0.00	0.0	0.0	4.1	0.3
114.20	520.9	0.4	4.9	0.4
400.60	1863.8	1.4	7.7	0.6
2189.80	4881.8	3.7	0.2	0.0
3412.20	1120.8	0.9	3.1	0.2
3748.00	179.3	0.1	0.3	0.0

Unity Check (Actual Stress / Allowable Stress):

Maximum Unity Check is 0.0464 at elevation 1026.6001 mm. - Must be <=1

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

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

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

Horizontal Vessel Stress Calculations : Operating Case

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

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

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

Input and Calculated Values:

Vessel Mean Radius	Rm	197.56	mm.
Stiffened Vessel Length per 4.15.6	L	2908.00	mm.
Distance from Saddle to Vessel tangent	a	500.00	mm.
Saddle Width	b	140.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Shell Allowable Stress used in Calculation		117.90	N./mm^2
Head Allowable Stress used in Calculation		137.90	N./mm^2
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Operating Case		16.64	kN

Horizontal Vessel Analysis Results:	Actual N./mm^2	Allowable N./mm^2
Long. Stress at Top of Midspan	26.55	117.90
Long. Stress at Bottom of Midspan	34.37	117.90
Long. Stress at Top of Saddles	42.90	117.90
Long. Stress at Bottom of Saddles	23.57	117.90
Tangential Shear in Shell	7.98	94.32
Circ. Stress at Horn of Saddle	22.58	147.38
Circ. Compressive Stress in Shell	0.77	117.90

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:

```
 = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
 = 3.0 * ( 1.7/2 + 0 ) * 500.0/366.5236
 = 3.6 kN
```

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

```
 = max( Fl, Friction Load, Sum of X Forces) * B / Ls
 = max( 0.27, 0.0, 0 ) * 500.0/1980.0005
 = 0.1 kN
```

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

```
 = max( Fl, Friction Force, Sum of X Forces ) * B / Ls
 = max( 4.06, 0.0, 0 ) * 500.0/1980.0005
 = 1.0 kN
```

Saddle Reaction Force due to Earthquake Ft [Fst]:
```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0 * ( 4/2 + 0 ) * 500.0/366.5236
  = 8.3 kN
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 8 + Max( 0.1, 4, 1, 8 )
  = 16.6 kN
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		16.96	kN
Transverse Shear Load Saddle	Ft	2.03	kN
Longitudinal Shear Load Saddle		4.06	kN

Formulas and Substitutions for Horizontal Vessel Analysis:

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

The Computed K values from Table 4.15.1:

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

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

Moment per Equation 4.15.3 [M1]:
```
  = -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -17*500.0[1-(1-500.0/2908.0+(197.556²-0.0²)/
    (2*500.0*2908.0))/(1+(4*0.0)/(3*2908.0))]
  = -1319.3 N-m
```

Moment per Equation 4.15.4 [M2]:
```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 17*2908/4(1+2(198²-0²)/(2908²))/(1+(4*0)/
    (3*2908))-4*500/2908
  = 3890.3 N-m
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 25.016 * 197.556/(2*8.113) - 3890.3/(pi*197.6²*8.113)
  = 26.55 N./mm^2
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 25.016 * 197.556/(2 * 8.113) + 3890.3/(pi * 197.6² * 8.113 )
  = 34.37 N./mm^2
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 25.016*197.556/(2*8.113)--1319.3/(0.1066*pi*197.6²*8.113)
  = 42.90 N./mm^2
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 25.016*197.556/(2*8.113)+-1319.3/(0.1923*pi*197.6²*8.113)
  = 23.57 N./mm^2
```

Maximum Shear Force in the Saddle (4.15.5) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 17( 2908.0 - 2 * 500.0)/(2908.0 + ( 4 * 0.0/3))
```



```
  = 10.9 kN
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 10.92/( 197.5563 * 8.1125 )
  = 7.98 N./mm^2
```

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

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 17 * 0.1/( 8.113 * ( 140.0 + 31.23 + 31.23 ) )
  = -0.77 N./mm^2
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.24) [sigma7]:
```
  = -Q/(4*t*(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -17/(4*8.113*(140.0+31.226+31.226)) -
     3* 0.0529*17/(2*8.113²)
  = -22.58 N./mm^2
```

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

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

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	370.0000	mm.
Baseplate Thickness	Bpthk	12.0000	mm.
Baseplate Width	Bpwid	150.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	2	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	206.9	N./
Height of Web at Center	Hw,c	275.0	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	261.8	8.1	4.1	21.2	8615.1	0.266E+04
Wearplate	200.0	10.0	13.1	20.0	26225.0	0.212E+04
Web	10.0	276.4	156.3	27.6	432010.9	0.221E+04
BasePlate	150.0	12.0	300.5	18.0	540899.9	0.613E+04
Totals	...	...	...	86.9	1007750.9	0.131E+05

Distance to Centroid [C1]:
```
  = AY / A
  = 396.752/86.878
  = 115.996 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 * 16.639
  = 3.3864 kN

 Tension Stress, St = ( Fh/As )       =          0.5160  N./mm^2
 Allowed Stress, Sa = 0.6 * Yield Str =        124.1100  N./mm^2

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

 Bending Moment, M  = Fh * d          =       1151.7756  N-m

 Bending Stress, Sb = ( M * C1 / I  ) =          1.0180  N./mm^2
 Allowed Stress, Sa = 2/3 * Yield Str =        137.9000  N./mm^2
```

Minimum Thickness of Baseplate per Moss:

```
  = ( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))½
  = ( 3(17 + 0.3)150.0/( 2 * 370.0 * 137.9 ))½
  = 8.649 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 )( 190.5 + 11.113 + 10.0 )
  = 366.524 mm.

Distance between Ribs [e]:
  = Web Length / ( Nribs - 1 )
  = 366.5236/( 2 - 1 )
  = 366.524 mm.

Baseplate Pressure Area [Ap]:
  = e * Bpwid / 2
  = 366.5236 * 150.0/2
  = 274.893 cm^2

Axial Load [P]:
  = Ap * Bp
  = 274.9 * 0.03
  = 8.241 kN

Area of the Rib and Web [Ar]:
  = Rib Area + Web Area
  = 13.0 + 18.326
  = 31.326 cm^2
```

Compressive Stress [Sc]:
 = P/Ar
 = 8.2/31.3262
 = 2.631 N./mm^2

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	10.0	130.0	75.0	13.0	97500.0	401.
Web	183.3	10.0	5.0	18.3	9163.1	156.
Totals	...	...	...	31.3	106663.1	557.

Rib dimension [D]:
 = Saddle Width - Web Thickness
 = 140.0 - 10.0
 = 130.000 mm.

Distance to Centroid from Datum [ytot]:
 = AY / A
 = 106663.086/31.326
 = 34.049 mm.

Distance to Centroid [C1]:
 = max(ytot, Saddle Width - ytot)
 = max(34.049, 140.0 - 34.049)
 = 105.951 mm.

Radius of Gyration [r]:
 = sqrt(Total Inertia / Total Area)
 = sqrt(557.3/31.326)
 = 42.177 mm.

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

Slenderness ratio [KL/r]:
 = KL/r
 = 1 * 58.719/42.177
 = 1.392

Bending Moment [Rm]:
 = Fl /(2 * Bplen) * e * L / 2
 = 4.1/(2 * 370.0) * 366.524 * 58.72/2
 = 59.004 N-m

Compressive Allowable, KL/r < Cc (1.3922 < 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-$(1.39)^2/(2 * 138.13^2)$)207/
 (5/3+3*(1.39)/(8* 138.13)-$(1.39^3)/(8*138.13^3)$)
 = 123.8 N./mm^2

AISC Unity Check of Outside Ribs (must be <= 1)
 = Sc/Sca + (Rm * C1 / I)/Sba
 = 2.63/123.82 + (59.0 * 105.951/5572630)/137.9
 = 0.029

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	172.38	N./mm^2
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	85.0	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	2.1705	cm^2
Saddle Load QO (Weight)	QO	8.7	kN
Saddle Load QL (Wind/Seismic contribution)	QL	1.0	kN
Maximum Transverse Force	Ft	2.0	kN
Maximum Longitudinal Force	Fl	4.1	kN
Saddle Bolted to Steel Foundation		Yes	

Shear Stress in a Single Bolt [taub]:
```
  = Shear Force / ( 2 * Bolt Area * Number of Bolts )
  = 4/( 2 * 2.17 * 2 )
  = 4.7 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)
  = 4.06/(172.38 * 2.0)
  = 0.1177 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 500.0 * 2.03 + 0.0
  = 1014.38 N-m
```

Eccentricity (e):
```
  = Rmom / QO
  = 1014.38/8.66
  = 117.07 mm. > Bplen/6 --> Uplift in Transverse direction

 f = Bplen / 2 - Edgedis
   = 370.0/2 - 85.0
   = 100.00 mm.

 K1 = 3 (e - 0.5 * Bplen)
    = 3 (117.07 - 0.5*370.0)
    = -203.80 mm.

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 1.0 * 2.17/150.0 * (100.0 + 117.07)
    = 1884.58 mm.²

 K3 = -K2 * (0.5 * Bplen + f)
    = -1884.58 * (0.5 * 370.0 + 100.0)
    = -537105.21 mm.³
```

Iteratively Solving for the Effective Bearing Length:
```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + -203.8 * Y² + 1884.58 * Y + -537105.19 = 0
 Y  = 207.21 mm.

 Num = (Bplen / 2 - Y / 3 - e)
     = (370.0/2 - 207.21/3 - 117.07)
     = -1.14

 Denom = (Bplen / 2 - Y / 3 + f)
       = (370.0/2 - 207.21/3 + 100.0)
       = 215.93
```

Total Bolt Tension Force [Tforce]:
```
  = - QO * Num / Denom
  = - 8.66 * -1.14/215.93
  = 0.05 kN
```

Bolt Area Required due to Transverse Load [Bltareart]:
```
  = Tforce / (Stba * Nbt)
  = 0.05/( 172.38 * 1.0 )
  = 0.0026 cm^2
```

Required Area of a Single Bolt [Bltarear]:
```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0.0, 0.1177, 0.0026]
  = 0.1177 cm^2
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)
```
  = 2(QO + Tforce) / (Y * Bpwid)
  = 2(8.66 + 0.05)/(207.21 * 150.0)
  = 5.60 bars
```

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

Overturning Moment due To Bolt Tension [Mt]:
```
  = Tforce * Adist
  = 0.05 * 25.4
  = 1.16 N-m
```

Equivalent Bearing Pressure (f1):
```
  = fc * (Y - Adist) / Y
  = 5.6 * (207.21 - 25.4)/207.21
  = 4.92 bars
```

Overturning Moment due to Bearing Pressure [Mc]:
```
  = (Adist² * Bpwid / 6) * (f1 + 2 * fc)
  = (25.4² * 150.0/6) * (4.92 + 2 * 5.6)
  = 26.01 N-m
```

Baseplate Required Thickness [Treq]:
```
  = (6 * max(Mt,Mc) / (Bpwid * Sba))½
  = (6 *max(1.16,26.01/(150.0 * 162.38))½
  = 2.5310 mm.
```

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

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

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

Input and Calculated Values:

```
 Vessel Mean Radius                               Rm      197.56  mm.
 Stiffened Vessel Length per 4.15.6                L     2908.00  mm.
 Distance from Saddle to Vessel tangent            a      500.00  mm.

 Saddle Width                                      b      140.00  mm.
 Saddle Bearing Angle                          theta      120.00  degrees

 Shell Allowable Stress used in Calculation               117.90  N./mm^2
 Head Allowable Stress used in Calculation                137.90  N./mm^2
 Circumferential Efficiency in Plane of Saddle              1.00
 Circumferential Efficiency at Mid-Span                     1.00

 Saddle Force Q, Operating Case                            15.92  kN

 Horizontal Vessel Analysis Results:        Actual |    Allowable |
                                           N./mm^2 |      N./mm^2 |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan           26.72 |       117.90 |
 Long. Stress at Bottom of Midspan           34.20 |       117.90 |
 Long. Stress at Top    of Saddles           42.36 |       117.90 |
 Long. Stress at Bottom of Saddles           23.86 |       117.90 |
 ----------------------------------------------------------------
 Tangential Shear in Shell                    7.63 |        94.32 |
 Circ. Stress at Horn of Saddle              21.61 |       147.38 |
 Circ. Compressive Stress in Shell            0.74 |       117.90 |
 ----------------------------------------------------------------
```

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:
```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0 * ( 1.7/2 + 0 ) * 500.0/366.5236
  = 3.6 kN
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 0.27, 3.18, 0 ) * 500.0/1980.0005
  = 0.8 kN
```

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:
```
  = max( Fl, Friction Force, Sum of X Forces ) * B / Ls
  = max( 4.06, 3.18, 0 ) * 500.0/1980.0005
  = 1.0 kN
```

Saddle Reaction Force due to Earthquake Ft [Fst]:
```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
```

```
  = 3.0 * ( 4/2 + 0 ) * 500.0/366.5236
  = 8.3 kN
```

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

```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 8 + Max( 0.8, 4, 1, 8 )
  = 15.9 kN
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		16.24	kN
Transverse Shear Load Saddle	Ft	2.03	kN
Longitudinal Shear Load Saddle		4.06	kN

Formulas and Substitutions for Horizontal Vessel Analysis:

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

The Computed K values from Table 4.15.1:

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

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

Moment per Equation 4.15.3 [M1]:

```
  = -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -16*500.0[1-(1-500.0/2908.0+(197.556²-0.0²)/
    (2*500.0*2908.0))/(1+(4*0.0)/(3*2908.0))]
  = -1262.6 N-m
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 16*2908/4(1+2(198²-0²)/(2908²))/(1+(4*0)/
    (3*2908))-4*500/2908
  = 3722.9 N-m
```

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

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 25.016 * 197.556/(2*8.113) - 3722.9/(pi*197.6²*8.113)
  = 26.72 N./mm^2
```

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

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 25.016 * 197.556/(2 * 8.113) + 3722.9/(pi * 197.6² * 8.113 )
  = 34.20 N./mm^2
```

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

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 25.016*197.556/(2*8.113)--1262.6/(0.1066*pi*197.6²*8.113)
  = 42.36 N./mm^2
```

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

```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 25.016*197.556/(2*8.113)+-1262.6/(0.1923*pi*197.6²*8.113)
  = 23.86 N./mm^2
```

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

```
  = Q(L-2a)/(L+(4*h2/3))
  = 16( 2908.0 - 2 * 500.0)/(2908.0 + ( 4 * 0.0/3))
  = 10.4 kN
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 10.45/( 197.5563 * 8.1125 )
  = 7.63 N./mm^2
```

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

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 16 * 0.1/( 8.113 * ( 140.0 + 31.23 + 31.23 ) )
  = -0.74 N./mm^2
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.24) [sigma7]:
```
  = -Q/(4*t*(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -16/(4*8.113*(140.0+31.226+31.226)) -
     3* 0.0529*16/(2*8.113²)
  = -21.61 N./mm^2
```

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

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	370.0000	mm.
Baseplate Thickness	Bpthk	12.0000	mm.
Baseplate Width	Bpwid	150.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	2	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	206.9	N./
Height of Web at Center	Hw,c	275.0	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	261.8	8.1	4.1	21.2	8615.1	0.266E+04
Wearplate	200.0	10.0	13.1	20.0	26225.0	0.212E+04
Web	10.0	276.4	156.3	27.6	432010.9	0.221E+04
BasePlate	150.0	12.0	300.5	18.0	540899.9	0.613E+04
Totals	...	...	...	86.9	1007750.9	0.131E+05

Distance to Centroid [C1]:
```
  = AY / A
  = 396.752/86.878
  = 115.996 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 * 15.923
  = 3.2407 kN

 Tension Stress, St = ( Fh/As )       =         0.4938  N./mm^2
 Allowed Stress, Sa = 0.6 * Yield Str =       124.1100  N./mm^2

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

 Bending Moment, M  = Fh * d          =      1102.2029  N-m

 Bending Stress, Sb = ( M * C1 / I  ) =         0.9742  N./mm^2
 Allowed Stress, Sa = 2/3 * Yield Str =       137.9000  N./mm^2
```

Minimum Thickness of Baseplate per Moss:

```
  = ( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))½
  = ( 3(16 + 0.3)150.0/( 2 * 370.0 * 137.9 ))½
  = 8.464 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 )( 190.5 + 11.113 + 10.0 )
  = 366.524 mm.

Distance between Ribs [e]:
  = Web Length / ( Nribs - 1 )
  = 366.5236/( 2 - 1 )
  = 366.524 mm.

Baseplate Pressure Area [Ap]:
  = e * Bpwid / 2
  = 366.5236 * 150.0/2
  = 274.893 cm^2

Axial Load [P]:
  = Ap * Bp
  = 274.9 * 0.03
  = 7.887 kN

Area of the Rib and Web [Ar]:
  = Rib Area + Web Area
  = 13.0 + 18.326
  = 31.326 cm^2

Compressive Stress [Sc]:
  = P/Ar
  = 7.9/31.3262
  = 2.518 N./mm^2
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	10.0	130.0	75.0	13.0	97500.0	401.
Web	183.3	10.0	5.0	18.3	9163.1	156.
Totals	...	...	...	31.3	106663.1	557.

Rib dimension [D]:
```
  = Saddle Width - Web Thickness
  = 140.0 - 10.0
  = 130.000 mm.
```

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 106663.086/31.326
  = 34.049 mm.
```

Distance to Centroid [C1]:
```
  = max( ytot, Saddle Width - ytot )
  = max( 34.049, 140.0 - 34.049 )
  = 105.951 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 557.3/31.326 )
  = 42.177 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 * 64.323/42.177
  = 1.525
```

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 4.1/( 2 * 370.0 ) * 366.524 * 64.32/2
  = 64.635 N-m
```

Compressive Allowable, KL/r < Cc (1.5251 < 138.1347) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 1.53 )²/(2 * 138.13² ))207/
    ( 5/3+3*(1.53)/(8* 138.13)-( 1.53³)/(8*138.13³)
  = 123.8 N./mm^2
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 2.52/123.79 + ( 64.64 * 105.951/5572630 )/137.9
  = 0.029
```

<u>Input Data for Base Plate Bolting Calculations:</u>

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

```
 Bolt Corrosion Allowance                          Bca         0.0  mm.
 Distance from Bolts to Edge                   Edgedis        85.0  mm.
 Nominal Bolt Diameter                             Bnd     20.0000  mm.
 Thread Series                                  Series   TEMA Metric
 BasePlate Allowable Stress                          S      108.25  N./mm^2
 Area Available in a Single Bolt               BltArea      2.1705  cm^2
 Saddle Load QO (Weight)                            QO         7.9  kN
 Saddle Load QL (Wind/Seismic contribution)         QL         1.0  kN
 Maximum Transverse Force                           Ft         2.0  kN
 Maximum Longitudinal Force                         Fl         4.1  kN
 Saddle Bolted to Steel Foundation                          Yes
```

Shear Stress in a Single Bolt [taub]:

```
  = Shear Force / ( 2 * Bolt Area * Number of Bolts )
  = 4/( 2 * 2.17 * 2 )
  = 4.7 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)
  = 4.06/(172.38 * 2.0)
  = 0.1177 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
  = B * Ft + Sum of X Moments
  = 500.0 * 2.03 + 0.0
  = 1014.38 N-m
```

Eccentricity (e):

```
  = Rmom / QO
  = 1014.38/7.95
  = 127.62 mm. > Bplen/6 --> Uplift in Transverse direction

 f = Bplen / 2 - Edgedis
   = 370.0/2 - 85.0
   = 100.00 mm.

 K1 = 3 (e - 0.5 * Bplen)
    = 3 (127.62 - 0.5*370.0)
    = -172.14 mm.

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 1.0 * 2.17/150.0 * (100.0 + 127.62)
    = 1976.19 mm.²

 K3 = -K2 * (0.5 * Bplen + f)
    = -1976.19 * (0.5 * 370.0 + 100.0)
    = -563214.38 mm.³
```

Iteratively Solving for the Effective Bearing Length:

```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + -172.14 * Y² + 1976.19 * Y + -563214.38 = 0
 Y  = 178.72 mm.

 Num = (Bplen / 2 - Y / 3 - e)
```

```
     = (370.0/2 - 178.72/3 - 127.62)
     = -2.19

 Denom = (Bplen / 2 - Y / 3 + f)
       = (370.0/2 - 178.72/3 + 100.0)
       = 225.43
```

Total Bolt Tension Force [Tforce]:

```
  = - QO * Num / Denom
  = - 7.95 * -2.19/225.43
  = 0.08 kN
```

Bolt Area Required due to Transverse Load [Bltareart]:

```
  = Tforce / (Stba * Nbt)
  = 0.08/( 172.38 * 1.0 )
  = 0.0045 cm^2
```

Required Area of a Single Bolt [Bltarear]:

```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0.0, 0.1177, 0.0045]
  = 0.1177 cm^2
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)

```
  = 2(QO + Tforce) / (Y * Bpwid)
  = 2(7.95 + 0.08)/(178.72 * 150.0)
  = 5.99 bars
```

Distance from Baseplate Edge to the Web [ADIST]:

```
  = (Bplen - Weblngth) / 2
  = (370.0 - 319.2)/2
  = 25.4000 mm.
```

Overturning Moment due To Bolt Tension [Mt]:

```
  = Tforce * Adist
  = 0.08 * 25.4
  = 1.96 N-m
```

Equivalent Bearing Pressure (f1):

```
  = fc * (Y - Adist) / Y
  = 5.99 * (178.72 - 25.4)/178.72
  = 5.13 bars
```

Overturning Moment due to Bearing Pressure [Mc]:

```
  = (Adist² * Bpwid / 6) * (f1 + 2 * fc)
  = (25.4² * 150.0/6) * (5.13 + 2 * 5.99)
  = 27.60 N-m
```

Baseplate Required Thickness [Treq]:

```
  = (6 * max(Mt,Mc) / (Bpwid * Sba))½
  = (6 *max(1.96,27.6/(150.0 * 162.38))½
  = 2.6071 mm.
```

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

Horizontal Vessel Stress Calculations : Test Case

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

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

Input and Calculated Values:

Vessel Mean Radius	Rm	197.56	mm.
Stiffened Vessel Length per 4.15.6	L	2908.00	mm.
Distance from Saddle to Vessel tangent	a	500.00	mm.
Saddle Width	b	140.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Shell Allowable Stress used in Calculation		217.19	N./mm^2
Head Allowable Stress used in Calculation		217.19	N./mm^2
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Test Case, no Ext. Forces		10.24	kN

Horizontal Vessel Analysis Results:	Actual N./mm^2	Allowable N./mm^2
Long. Stress at Top of Midspan	37.19	217.19
Long. Stress at Bottom of Midspan	42.00	217.19
Long. Stress at Top of Saddles	47.25	217.19
Long. Stress at Bottom of Saddles	35.36	217.19
Tangential Shear in Shell	4.91	173.75
Circ. Stress at Horn of Saddle	13.89	325.79
Circ. Compressive Stress in Shell	0.47	217.19

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:
```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0 * ( 0.6/2 + 0 ) * 500.0/366.5236
  = 1.2 kN
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 0.09, 0.0, 0 ) * 500.0/1980.0005
  = 0.0 kN
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 9 + Max( 0.0, 1, 0, 0 )
  = 10.2 kN
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		10.56	kN
Transverse Shear Load Saddle	Ft	0.29	kN
Longitudinal Shear Load Saddle		0.09	kN

Hydrostatic Test Pressure at center of Vessel: 32.519 bars

Formulas and Substitutions for Horizontal Vessel Analysis:

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

The Computed K values from Table 4.15.1:

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

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

Moment per Equation 4.15.3 [M1]:

```
= -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
= -10*500.0[1-(1-500.0/2908.0+(197.556²-0.0²)/
  (2*500.0*2908.0))/(1+(4*0.0)/(3*2908.0))]
= -811.8 N-m
```

Moment per Equation 4.15.4 [M2]:

```
= Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
= 10*2908/4(1+2(198²-0²)/(2908²))/(1+(4*0)/
  (3*2908))-4*500/2908
= 2393.6 N-m
```

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

```
= P * Rm/(2t) - M2/(pi*Rm²t)
= 32.519 * 197.556/(2*8.113) - 2393.6/(pi*197.6²*8.113)
= 37.19 N./mm^2
```

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

```
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 32.519 * 197.556/(2 * 8.113) + 2393.6/(pi * 197.6² * 8.113 )
= 42.00 N./mm^2
```

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

```
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 32.519*197.556/(2*8.113)--811.8/(0.1066*pi*197.6²*8.113)
= 47.25 N./mm^2
```

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

```
= P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
= 32.519*197.556/(2*8.113)+-811.8/(0.1923*pi*197.6²*8.113)
= 35.36 N./mm^2
```

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

```
= Q(L-2a)/(L+(4*h2/3))
= 10( 2908.0 - 2 * 500.0)/(2908.0 + ( 4 * 0.0/3))
= 6.7 kN
```

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

```
= K2 * T / ( Rm * t )
= 1.1707 * 6.72/( 197.5563 * 8.1125 )
= 4.91 N./mm^2
```

Decay Length (4.15.22) [x1,x2]:

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

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

```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 10 * 0.1/( 8.113 * ( 140.0 + 31.23 + 31.23 ) )
  = -0.47 N./mm^2
```

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

```
  = -Q/(4*t*(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -10/(4*8.113*(140.0+31.226+31.226)) -
     3* 0.0529*10/(2*8.113²)
  = -13.89 N./mm^2
```

Effective reinforcing plate width (4.15.1) [B1]:

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

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	370.0000	mm.
Baseplate Thickness	Bpthk	12.0000	mm.
Baseplate Width	Bpwid	150.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	2	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	206.9	N./
Height of Web at Center	Hw,c	275.0	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	261.8	8.1	4.1	21.2	8615.1	0.266E+04
Wearplate	200.0	10.0	13.1	20.0	26225.0	0.212E+04
Web	10.0	276.4	156.3	27.6	432010.9	0.221E+04
BasePlate	150.0	12.0	300.5	18.0	540899.9	0.613E+04
Totals	...	...	...	86.9	1007750.9	0.131E+05

Distance to Centroid [C1]:

```
  = AY / A
  = 396.752/86.878
  = 115.996 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 * 10.238
  = 2.0836 kN

 Tension Stress, St = ( Fh/As )       =         0.3175  N./mm^2
 Allowed Stress, Sa = 0.6 * Yield Str =       124.1100  N./mm^2
```

Saddle Splitting Dimension [d]:

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

 Bending Moment, M  = Fh * d          =       708.6639  N-m

 Bending Stress, Sb = ( M * C1 / I  ) =         0.6264  N./mm^2
 Allowed Stress, Sa = 2/3 * Yield Str =       137.9000  N./mm^2
```

Minimum Thickness of Baseplate per Moss:

```
  = ( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))½
  = ( 3(10 + 0.3)150.0/( 2 * 370.0 * 137.9 ))½
  = 6.824 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 )( 190.5 + 11.113 + 10.0 )
  = 366.524 mm.
```

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 366.5236/( 2 - 1 )
  = 366.524 mm.
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 366.5236 * 150.0/2
  = 274.893 cm^2
```

Axial Load [P]:

```
  = Ap * Bp
  = 274.9 * 0.02
  = 5.071 kN
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 13.0 + 18.326
  = 31.326 cm^2
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 5.1/31.3262
  = 1.619 N./mm^2
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	10.0	130.0	75.0	13.0	97500.0	401.
Web	183.3	10.0	5.0	18.3	9163.1	156.

```
 Totals          ... |         ... |         ... |        31.3 |    106663.1 |    557.     |
```

Rib dimension [D]:
```
  = Saddle Width - Web Thickness
  = 140.0 - 10.0
  = 130.000 mm.
```

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 106663.086/31.326
  = 34.049 mm.
```

Distance to Centroid [C1]:
```
  = max( ytot, Saddle Width - ytot )
  = max( 34.049, 140.0 - 34.049 )
  = 105.951 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 557.3/31.326 )
  = 42.177 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 * 69.477/42.177
  = 1.647
```

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 0.1/( 2 * 370.0 ) * 366.524 * 69.48/2
  = 1.517 N-m
```

Compressive Allowable, KL/r < Cc (1.6473 < 138.1347) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 1.65 )²/(2 * 138.13² ))207/
    ( 5/3+3*(1.65)/(8* 138.13)-( 1.65³)/(8*138.13³)
  = 123.8 N./mm^2
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 1.62/123.77 + ( 1.52 * 105.951/5572630 )/137.9
  = 0.013
```

<u>Input Data for Base Plate Bolting Calculations:</u>

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	172.38	N./mm^2
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	85.0	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	2.1705	cm^2
Saddle Load QO (Weight)	QO	9.4	kN


```
 Saddle Load QL (Wind/Seismic contribution)         QL         0.0   kN
 Maximum Transverse Force                           Ft         0.3   kN
 Maximum Longitudinal Force                         Fl         0.1   kN
 Saddle Bolted to Steel Foundation                              Yes
```

Shear Stress in a Single Bolt [taub]:
```
  = Shear Force / ( 2 * Bolt Area * Number of Bolts )
  = 0.3/( 2 * 2.17 * 2 )
  = 0.3 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)
  = 0.09/(172.38 * 2.0)
  = 0.0026 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 500.0 * 0.29 + 0.0
  = 143.72 N-m
```

Eccentricity (e):
```
  = Rmom / QO
  = 143.72/9.38
  = 15.31 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, 0.0026, 0.0]
  = 0.0026 cm^2
```

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

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

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

Input and Calculated Values:

```
 Vessel Mean Radius                            Rm      197.56  mm.
 Stiffened Vessel Length per 4.15.6             L     2908.00  mm.
 Distance from Saddle to Vessel tangent         a      500.00  mm.

 Saddle Width                                   b      140.00  mm.
 Saddle Bearing Angle                       theta      120.00  degrees
```

Shell Allowable Stress used in Calculation	217.19	N./mm^2
Head Allowable Stress used in Calculation	217.19	N./mm^2
Circumferential Efficiency in Plane of Saddle	1.00	
Circumferential Efficiency at Mid-Span	1.00	
Saddle Force Q, Test Case, no Ext. Forces	9.52	kN

Horizontal Vessel Analysis Results:	Actual N./mm^2	Allowable N./mm^2
Long. Stress at Top of Midspan	37.36	217.19
Long. Stress at Bottom of Midspan	41.84	217.19
Long. Stress at Top of Saddles	46.71	217.19
Long. Stress at Bottom of Saddles	35.65	217.19
Tangential Shear in Shell	4.56	173.75
Circ. Stress at Horn of Saddle	12.92	325.79
Circ. Compressive Stress in Shell	0.44	217.19

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:
```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0 * ( 0.6/2 + 0 ) * 500.0/366.5236
  = 1.2 kN
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 0.09, 0.0, 0 ) * 500.0/1980.0005
  = 0.0 kN
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 8 + Max( 0.0, 1, 0, 0 )
  = 9.5 kN
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		9.84	kN
Transverse Shear Load Saddle	Ft	0.29	kN
Longitudinal Shear Load Saddle		0.09	kN

Hydrostatic Test Pressure at center of Vessel: 32.519 bars

Formulas and Substitutions for Horizontal Vessel Analysis:

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

The Computed K values from Table 4.15.1:

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

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

Moment per Equation 4.15.3 [M1]:
```
  = -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -10*500.0[1-(1-500.0/2908.0+(197.556²-0.0²)/
    (2*500.0*2908.0))/(1+(4*0.0)/(3*2908.0))]
  = -754.9 N-m
```

Moment per Equation 4.15.4 [M2]:
```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 10*2908/4(1+2(198²-0²)/(2908²))/(1+(4*0)/
    (3*2908))-4*500/2908
  = 2225.9 N-m
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 32.519 * 197.556/(2*8.113) - 2225.9/(pi*197.6²*8.113)
  = 37.36 N./mm^2
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 32.519 * 197.556/(2 * 8.113) + 2225.9/(pi * 197.6² * 8.113 )
  = 41.84 N./mm^2
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 32.519*197.556/(2*8.113)--754.9/(0.1066*pi*197.6²*8.113)
  = 46.71 N./mm^2
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 32.519*197.556/(2*8.113)+-754.9/(0.1923*pi*197.6²*8.113)
  = 35.65 N./mm^2
```

Maximum Shear Force in the Saddle (4.15.5) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 10( 2908.0 - 2 * 500.0)/(2908.0 + ( 4 * 0.0/3))
  = 6.2 kN
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 6.25/( 197.5563 * 8.1125 )
  = 4.56 N./mm^2
```

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

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 10 * 0.1/( 8.113 * ( 140.0 + 31.23 + 31.23 ) )
  = -0.44 N./mm^2
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.24) [sigma7]:
```
  = -Q/(4*t*(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -10/(4*8.113*(140.0+31.226+31.226)) -
     3* 0.0529*10/(2*8.113²)
  = -12.92 N./mm^2
```

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

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	370.0000	mm.

Baseplate Thickness	Bpthk	12.0000	mm.
Baseplate Width	Bpwid	150.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	2	
Rib Thickness	Ribtk	10.0000	mm.
Web Thickness	Webtk	10.0000	mm.
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	206.9	N./
Height of Web at Center	Hw,c	275.0	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	261.8	8.1	4.1	21.2	8615.1	0.266E+04
Wearplate	200.0	10.0	13.1	20.0	26225.0	0.212E+04
Web	10.0	276.4	156.3	27.6	432010.9	0.221E+04
BasePlate	150.0	12.0	300.5	18.0	540899.9	0.613E+04
Totals	...	...	...	86.9	1007750.9	0.131E+05

Distance to Centroid [C1]:
= AY / A
= 396.752/86.878
= 115.996 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 * 9.52
= 1.9376 kN

Tension Stress, St = (Fh/As) = 0.2952 N./mm^2
Allowed Stress, Sa = 0.6 * Yield Str = 124.1100 N./mm^2

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

Bending Moment, M = Fh * d = 658.9939 N-m

Bending Stress, Sb = (M * C1 / I) = 0.5825 N./mm^2
Allowed Stress, Sa = 2/3 * Yield Str = 137.9000 N./mm^2

Minimum Thickness of Baseplate per Moss:
= (3(Q + Saddle_Wt)BasePlateWidth / (2 * BasePlateLength * AllStress))½
= (3(10 + 0.3)150.0/(2 * 370.0 * 137.9))½
= 6.588 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 )( 190.5 + 11.113 + 10.0 )
  = 366.524 mm.
```

Distance between Ribs [e]:
```
  = Web Length / ( Nribs - 1 )
  = 366.5236/( 2 - 1 )
  = 366.524 mm.
```

Baseplate Pressure Area [Ap]:
```
  = e * Bpwid / 2
  = 366.5236 * 150.0/2
  = 274.893 cm^2
```

Axial Load [P]:
```
  = Ap * Bp
  = 274.9 * 0.02
  = 4.715 kN
```

Area of the Rib and Web [Ar]:
```
  = Rib Area + Web Area
  = 13.0 + 18.326
  = 31.326 cm^2
```

Compressive Stress [Sc]:
```
  = P/Ar
  = 4.7/31.3262
  = 1.505 N./mm^2
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	10.0	130.0	75.0	13.0	97500.0	401.
Web	183.3	10.0	5.0	18.3	9163.1	156.
Totals	...	...	...	31.3	106663.1	557.

Rib dimension [D]:
```
  = Saddle Width - Web Thickness
  = 140.0 - 10.0
  = 130.000 mm.
```

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 106663.086/31.326
  = 34.049 mm.
```

Distance to Centroid [C1]:
```
  = max( ytot, Saddle Width - ytot )
  = max( 34.049, 140.0 - 34.049 )
  = 105.951 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 557.3/31.326 )
  = 42.177 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 * 74.274/42.177
  = 1.761
```

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 0.1/( 2 * 370.0 ) * 366.524 * 74.27/2
  = 1.622 N-m
```

Compressive Allowable, KL/r < Cc (1.761 < 138.1347) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 1.76 )²/(2 * 138.13² ))207/
    ( 5/3+3*(1.76)/(8* 138.13)-( 1.76³)/(8*138.13³)
  = 123.7 N./mm^2
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 1.51/123.74 + ( 1.62 * 105.951/5572630 )/137.9
  = 0.012
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	172.38	N./mm^2
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	85.0	mm.
Nominal Bolt Diameter	Bnd	20.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	2.1705	cm^2
Saddle Load QO (Weight)	QO	8.7	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.0	kN
Maximum Transverse Force	Ft	0.3	kN
Maximum Longitudinal Force	Fl	0.1	kN
Saddle Bolted to Steel Foundation		Yes	

Shear Stress in a Single Bolt [taub]:
```
  = Shear Force / ( 2 * Bolt Area * Number of Bolts )
  = 0.3/( 2 * 2.17 * 2 )
  = 0.3 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)
  = 0.09/(172.38 * 2.0)
  = 0.0026 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 500.0 * 0.29 + 0.0
  = 143.72 N-m
```

Eccentricity (e):
```
  = Rmom / QO
  = 143.72/8.67
  = 16.58 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, 0.0026, 0.0]
  = 0.0026 cm^2
```

Nozzle Calculation Summary:

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

MAWP Summary:

Minimum MAWP Nozzles : 0.000 Nozzle : T3

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

Check the Spatial Relationship between the Nozzles

From Node	Nozzle Description	X Coordinate mm.	Layout Angle deg	Dia. Limit mm.
20	T2	210.000	90.000	150.862
20	T1	210.000	270.000	150.862
40	S2	661.175	90.000	150.862
40	S1	3195.175	90.000	150.862
40	S3	661.175	270.000	102.068
60	T4	3691.350	90.000	63.875
60	T3	3691.350	270.000	70.225

The nozzle spacing is computed by the following:

= Sqrt(ll^2 + lc^2) where
ll - Arc length along the inside vessel surface in the long. direction.
lc - Arc length along the inside vessel surface in the circ. direction

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

Input, Nozzle Desc: T2 From: 20

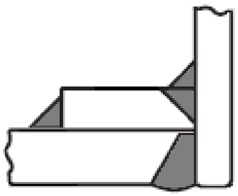
Pressure for Reinforcement Calculations	P	25.000	bars
Temperature for Internal Pressure	Temp	190	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	190	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm^2
Shell Allowable Stress At Ambient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

Type of Element Connected to the Shell : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		3.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.3344	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
Diameter of Pad along vessel surface	Dp	188.9000	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	8.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		50.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: T2

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

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

Nozzle input data check completed without errors.

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

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = (25.0*44.45)/(118*1.0+0.4*25.0)
  = 0.9346 mm.
```

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

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl   150.8618  mm.
 Parallel to Vessel Wall, opening length              d    75.4309  mm.
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp    20.2812  mm.
```

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

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

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

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

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	3.135	0.507	NA
Area in Shell	A1	2.984	5.106	NA
Area in Nozzle Wall	A2	2.353	2.564	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	6.196	6.196	NA
TOTAL AREA AVAILABLE	Atot	12.173	14.506	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

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

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

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 75.431( 1.0 * 8.1125 - 1.0 * 4.156 ) - 2 * 6.735
    ( 1.0 * 8.1125 - 1.0 * 4.156 ) * ( 1 - 1.0 )
  = 2.984 cm^2
```

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

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

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

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures        ta = 3.9346 mm.
 Wall Thickness per UG16(b),                         tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure        trb1 = 7.1560 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 7.1560 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                         tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[7.8, max(7.156, 4.5)]
= 7.1560 mm.

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

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

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

Sustained :	55.1,	Allowable :	117.9 N./mm^2	Passed
Expansion :	0.0,	Allowable :	239.7 N./mm^2	Passed
Occasional :	6.4,	Allowable :	156.8 N./mm^2	Passed
Shear :	27.3,	Allowable :	82.5 N./mm^2	Passed

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 25.00/51.10 = 0.489

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

Weld Size Calculations, Description: T2

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

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
Nozzle Weld           4.7142 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
Pad Weld              4.8500 = 0.5*TminPad  5.6560 = 0.7 * Wp mm.
```

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (3.1349 - 2.9844 + 2 * 6.7345 * 1.0 *
    (1.0 * 8.1125 - 4.156 ) )118)
  = 8.06 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 2.3526 + 6.1962 + 0.64 - 0.0 * 1.0 ) * 118
  = 108.33 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 2.3526 + 0.0 + 0.64 + ( 1.0927 ) ) * 118
  = 48.16 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 2.3526 + 0.0 + 0.64 + 6.1962 + ( 1.0927 ) ) * 118
  = 121.21 kN
```

Strength of Connection Elements for Failure Path Analysis

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

Shear, Pad Element Weld [Spew]:
```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 188.9 * 8.0 * 0.49 * 118
  = 137. kN
```

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

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

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

Strength of Failure Paths:

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

Summary of Failure Path Calculations:
```
 Path 1-1 = 208 kN , must exceed W = 8 kN  or W1 = 108 kN
 Path 2-2 = 272 kN , must exceed W = 8 kN  or W2 = 48 kN
 Path 3-3 = 202 kN , must exceed W = 8 kN  or W3 = 121 kN

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

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

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

```
 Diameter Basis for Vessel                    Vbasis      ID
 Cylindrical or Spherical Vessel              Cylsph      Cylindrical
 Internal Corrosion Allowance                    Cas      3.0000  mm.
 Vessel Diameter                                  Dv    381.000  mm.
 Vessel Thickness                                 Tv      11.113  mm.

 Design Temperature                               T1       190.0  °C
 Vessel Material                                        SA-106 B
 Vessel UNS Number                                        K03006
 Vessel Cold S.I. Allowable                      Smc      117.90  N./mm^2
 Vessel Hot  S.I. Allowable                      Smh      117.90  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-106 B

```
 Attachment Type                                Type      Round
```

```
 Diameter Basis for Nozzle                     Nbasis       OD
 Corrosion Allowance for Nozzle                   Can       3.0000  mm.
 Nozzle Diameter                                   Dn       88.900  mm.
 Nozzle Thickness                                  Tn        9.735  mm.
 Nozzle Material                                          SA-106 B
 Nozzle 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      188.900  mm.

 Design Internal Pressure                          Dp       25.000  bars
 Include Pressure Thrust                                        No
```

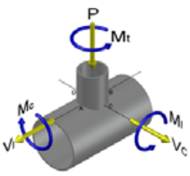
External Forces and Moments in WRC 107/537 Convention:

```
 Radial Load             (SUS)                      P          3.2  kN
 Longitudinal Shear      (SUS)                     Vl          3.2  kN
 Circumferential Shear   (SUS)                     Vc          3.2  kN
 Circumferential Moment  (SUS)                     Mc       1100.0  N-m
 Longitudinal Moment     (SUS)                     Ml       1100.0  N-m
 Torsional Moment        (SUS)                     Mt       1300.0  N-m


 Use Interactive Control                                 No
 WRC107 Version                               Version  March   1979

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

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



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

```
   = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
   = 88.9 + 2 * 1.65 * sqrt( 197.556 ( 11.113 - 3.0 ) )
   = 221.010 mm.
```

WRC 107 Stress Calculation for SUStained loads:

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

 Dimensionless Parameters used :    Gamma =    11.18
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

```
 -------------------------------------------------------------------
```

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.192	4C	1.931	(A,B)
N(PHI) / (P/Rm)	0.192	3C	1.667	(C,D)
M(PHI) / (P)	0.192	2C1	0.083	(A,B)
M(PHI) / (P)	0.192	1C	0.111	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.192	3A	0.339	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.192	1A	0.096	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.192	3B	1.207	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.192	1B	0.046	(A,B,C,D)
N(x) / (P/Rm)	0.192	3C	1.667	(A,B)
N(x) / (P/Rm)	0.192	4C	1.931	(C,D)
M(x) / (P)	0.192	1C1	0.113	(A,B)
M(x) / (P)	0.192	2C	0.081	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.192	4A	0.535	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.192	2A	0.055	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.192	4B	0.342	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.192	2B	0.074	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.5	-1.5	-1.5	-1.5
Circ. Bend. P	-4.8	4.8	-4.8	4.8	-6.5	6.5	-6.5	6.5
Circ. Memb. MC	0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Circ. Memb. MC	0.0	0.0	0.0	0.0	-49.7	49.7	49.7	-49.7
Circ. Memb. ML	-9.3	-9.3	9.3	9.3	0.0	0.0	0.0	0.0
Circ. Bend. ML	-23.9	23.9	23.9	-23.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-39.7	17.7	26.6	-11.4	-60.3	52.1	44.3	-42.0
Long. Memb. P	-1.5	-1.5	-1.5	-1.5	-1.7	-1.7	-1.7	-1.7
Long. Bend. P	-6.6	6.6	-6.6	6.6	-4.8	4.8	-4.8	4.8
Long. Memb. MC	0.0	0.0	0.0	0.0	-4.1	-4.1	4.1	4.1
Long. Bend. MC	0.0	0.0	0.0	0.0	-28.3	28.3	28.3	-28.3
Long. Memb. ML	-2.6	-2.6	2.6	2.6	0.0	0.0	0.0	0.0
Long. Bend. ML	-38.0	38.0	38.0	-38.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-48.7	40.6	32.6	-30.2	-38.9	27.3	26.0	-21.1
Shear VC	1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.3	-1.3	1.3	1.3
Shear MT	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Tot. Shear	7.0	7.0	4.5	4.5	4.5	4.5	7.0	7.0
Str. Int.	52.6	42.6	35.0	31.2	61.2	52.9	46.7	44.2

Dimensionless Parameters used : Gamma = 24.35

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.418	4C	2.460	(A,B)

```
N(PHI) / ( P/Rm )                 0.418   3C        1.198   (C,D)
M(PHI) / ( P )                    0.418   2C1       0.014   (A,B)
M(PHI) / ( P )                    0.418   1C  !     0.059   (C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )    0.418   3A        0.869   (A,B,C,D)
M(PHI) / ( MC/(Rm    * Beta) )    0.418   1A        0.068   (A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )    0.418   3B        1.572   (A,B,C,D)
M(PHI) / ( ML/(Rm    * Beta) )    0.418   1B        0.012   (A,B,C,D)

N(x)   / ( P/Rm )                 0.418   3C        1.198   (A,B)
N(x)   / ( P/Rm )                 0.418   4C        2.460   (C,D)
M(x)   / ( P )                    0.418   1C1       0.030   (A,B)
M(x)   / ( P )                    0.418   2C  !     0.030   (C,D)
N(x)   / ( MC/(Rm**2 * Beta) )    0.418   4A        2.422   (A,B,C,D)
M(x)   / ( MC/(Rm    * Beta) )    0.418   2A        0.029   (A,B,C,D)
N(x)   / ( ML/(Rm**2 * Beta) )    0.418   4B        0.816   (A,B,C,D)
M(x)   / ( ML/(Rm    * Beta) )    0.418   2B        0.020   (A,B,C,D)
```

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
		Stress Intensity Values at							
Circ. Memb.	P	-4.9	-4.9	-4.9	-4.9	-2.4	-2.4	-2.4	-2.4
Circ. Bend.	P	-4.0	4.0	-4.0	4.0	-17.2	17.2	-17.2	17.2
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-7.2	-7.2	7.2	7.2
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-82.6	82.6	82.6	-82.6
Circ. Memb.	ML	-13.1	-13.1	13.1	13.1	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-14.9	14.9	14.9	-14.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-36.8	0.9	19.1	-2.8	-109.5	90.2	70.2	-60.5
Long. Memb.	P	-2.4	-2.4	-2.4	-2.4	-4.9	-4.9	-4.9	-4.9
Long. Bend.	P	-8.7	8.7	-8.7	8.7	-8.7	8.7	-8.7	8.7
Long. Memb.	MC	0.0	0.0	0.0	0.0	-20.1	-20.1	20.1	20.1
Long. Bend.	MC	0.0	0.0	0.0	0.0	-35.5	35.5	35.5	-35.5
Long. Memb.	ML	-6.8	-6.8	6.8	6.8	0.0	0.0	0.0	0.0
Long. Bend.	ML	-24.4	24.4	24.4	-24.4	0.0	0.0	0.0	0.0
Tot. Long. Str.		-42.3	24.0	20.1	-11.4	-69.2	19.2	41.9	-11.5
Shear	VC	1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-1.3	-1.3	1.3	1.3
Shear	MT	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Tot. Shear		4.2	4.2	1.5	1.5	1.5	1.5	4.2	4.2
Str. Int.		44.6	24.7	21.2	11.6	109.5	90.3	70.8	60.9

WRC 107/537 Stress Summations:

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

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
		Stress Intensity Values at							
Circ. Pm	(SUS)	25.5	28.0	25.5	28.0	25.5	28.0	25.5	28.0
Circ. Pl	(SUS)	-11.0	-11.0	7.6	7.6	-4.1	-4.1	1.2	1.2
Circ. Q	(SUS)	-28.7	28.7	19.0	-19.0	-56.2	56.2	43.2	-43.2
Long. Pm	(SUS)	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8
Long. Pl	(SUS)	-4.1	-4.1	1.2	1.2	-5.8	-5.8	2.4	2.4
Long. Q	(SUS)	-44.7	44.7	31.4	-31.4	-33.1	33.1	23.5	-23.5
Shear Pm	(SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl	(SUS)	1.3	1.3	-1.3	-1.3	-1.3	-1.3	1.3	1.3
Shear Q	(SUS)	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Pm (SUS)		25.5	28.0	25.5	28.0	25.5	28.0	25.5	28.0
Pm+Pl (SUS)		14.8	17.2	33.2	35.7	21.6	24.0	26.8	29.3
Pm+Pl+Q (Total)		38.1	57.5	54.4	35.2	36.7	80.7	71.4	18.8

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	28.02	117.90	Passed
Pm+Pl (SUS)	35.71	176.86	Passed
Pm+Pl+Q (TOTAL)	80.66	353.71	Passed

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

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

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

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

Input, Nozzle Desc: T1 From: 20

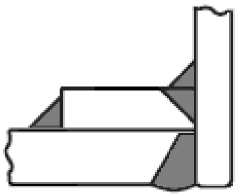
Pressure for Reinforcement Calculations	P	25.037	bars
Temperature for Internal Pressure	Temp	190	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	190	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm^2
Shell Allowable Stress At Ambient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

Type of Element Connected to the Shell : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
Diameter Basis (for tr calc only)		OD	
Layout Angle		270.00	deg
Diameter		3.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.3344	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
Diameter of Pad along vessel surface	Dp	214.3000	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	8.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		62.7000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: T1

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

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

Nozzle input data check completed without errors.

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

```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (25.04*193.5)/(118*1.0-0.6*25.04)
  = 4.1623 mm.
```

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

```
  = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = (25.04*44.45)/(118*1.0+0.4*25.04)
  = 0.9360 mm.
```

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

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

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

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

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 117.9/117.9 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 117.9/117.9 )
  = 1.000
```

Weld Strength Reduction Factor [fr4]:

```
  = min( 1, Sp/Sv )
  = min( 1, 137.9/117.9 )
  = 1.000
```

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	3.140	0.507	NA
Area in Shell	A1	2.980	5.106	NA
Area in Nozzle Wall	A2	2.352	2.564	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	4.647	4.647	NA
TOTAL AREA AVAILABLE	Atot	10.619	12.957	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

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

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

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 75.431( 1.0 * 8.1125 - 1.0 * 4.162 ) - 2 * 6.735
    ( 1.0 * 8.1125 - 1.0 * 4.1623 ) * ( 1 - 1.0 )
  = 2.980 cm^2
```

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

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

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

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 3.9360 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 7.1623 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 7.1623 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 7.1623, 4.5 ) ]
  = 7.1623 mm.
```

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

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

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):
```
 Sustained   :     55.1,  Allowable :    117.9 N./mm^2  Passed
 Expansion   :      0.0,  Allowable :    239.7 N./mm^2  Passed
 Occasional  :      6.4,  Allowable :    156.8 N./mm^2  Passed
 Shear       :     27.3,  Allowable :     82.5 N./mm^2  Passed
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

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

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

Weld Size Calculations, Description: T1

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

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	4.7142 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm.
Pad Weld	4.8500 = 0.5*TminPad	5.6560 = 0.7 * Wp mm.

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (3.1397 - 2.9797 + 2 * 6.7345 * 1.0 *
    (1.0 * 8.1125 - 4.1623 ) )118)
  = 8.16 kN
```

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

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

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

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

Strength of Connection Elements for Failure Path Analysis

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

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

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

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

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

Strength of Failure Paths:

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

Summary of Failure Path Calculations:
```
 Path 1-1 = 227 kN , must exceed W = 8 kN  or W1 = 90 kN
 Path 2-2 = 272 kN , must exceed W = 8 kN  or W2 = 48 kN
 Path 3-3 = 220 kN , must exceed W = 8 kN  or W3 = 102 kN

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

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

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

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	381.000	mm.
Vessel Thickness	Tv	11.113	mm.
Design Temperature	T1	190.0	°C
Vessel Material		SA-106 B	
Vessel UNS Number		K03006	
Vessel Cold S.I. Allowable	Smc	117.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	117.90	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-106 B

Attachment Type	Type	Round

```
 Diameter Basis for Nozzle                    Nbasis      OD
 Corrosion Allowance for Nozzle                  Can      3.0000  mm.
 Nozzle Diameter                                  Dn      88.900  mm.
 Nozzle Thickness                                 Tn       9.735  mm.
 Nozzle Material                                        SA-106 B
 Nozzle 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     214.300  mm.

 Design Internal Pressure                         Dp      25.037  bars
 Include Pressure Thrust                                      No
```

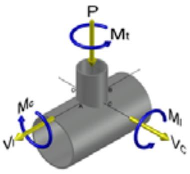
External Forces and Moments in WRC 107/537 Convention:

```
 Radial Load              (SUS)                    P         3.2  kN
 Longitudinal Shear       (SUS)                   Vl         3.2  kN
 Circumferential Shear    (SUS)                   Vc         3.2  kN
 Circumferential Moment   (SUS)                   Mc      1100.0  N-m
 Longitudinal Moment      (SUS)                   Ml      1100.0  N-m
 Torsional Moment         (SUS)                   Mt      1300.0  N-m


 Use Interactive Control                                No
 WRC107 Version                              Version    March  1979

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

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



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

```
   = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
   = 88.9 + 2 * 1.65 * sqrt( 197.556 ( 11.113 - 3.0 ) )
   = 221.010 mm.
```

WRC 107 Stress Calculation for SUStained loads:

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

 Dimensionless Parameters used :    Gamma =    11.18
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

```
 -------------------------------------------------------------------
```

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.192	4C	1.931	(A,B)
N(PHI) / (P/Rm)	0.192	3C	1.667	(C,D)
M(PHI) / (P)	0.192	2C1	0.083	(A,B)
M(PHI) / (P)	0.192	1C	0.111	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.192	3A	0.339	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.192	1A	0.096	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.192	3B	1.207	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.192	1B	0.046	(A,B,C,D)
N(x) / (P/Rm)	0.192	3C	1.667	(A,B)
N(x) / (P/Rm)	0.192	4C	1.931	(C,D)
M(x) / (P)	0.192	1C1	0.113	(A,B)
M(x) / (P)	0.192	2C	0.081	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.192	4A	0.535	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.192	2A	0.055	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.192	4B	0.342	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.192	2B	0.074	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.5	-1.5	-1.5	-1.5
Circ. Bend. P	-4.8	4.8	-4.8	4.8	-6.5	6.5	-6.5	6.5
Circ. Memb. MC	0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Circ. Memb. MC	0.0	0.0	0.0	0.0	-49.7	49.7	49.7	-49.7
Circ. Memb. ML	-9.3	-9.3	9.3	9.3	0.0	0.0	0.0	0.0
Circ. Bend. ML	-23.9	23.9	23.9	-23.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-39.7	17.7	26.6	-11.4	-60.3	52.1	44.3	-42.0
Long. Memb. P	-1.5	-1.5	-1.5	-1.5	-1.7	-1.7	-1.7	-1.7
Long. Bend. P	-6.6	6.6	-6.6	6.6	-4.8	4.8	-4.8	4.8
Long. Memb. MC	0.0	0.0	0.0	0.0	-4.1	-4.1	4.1	4.1
Long. Bend. MC	0.0	0.0	0.0	0.0	-28.3	28.3	28.3	-28.3
Long. Memb. ML	-2.6	-2.6	2.6	2.6	0.0	0.0	0.0	0.0
Long. Bend. ML	-38.0	38.0	38.0	-38.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-48.7	40.6	32.6	-30.2	-38.9	27.3	26.0	-21.1
Shear VC	1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.3	-1.3	1.3	1.3
Shear MT	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Tot. Shear	7.0	7.0	4.5	4.5	4.5	4.5	7.0	7.0
Str. Int.	52.6	42.6	35.0	31.2	61.2	52.9	46.7	44.2

Dimensionless Parameters used : Gamma = 24.35

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.475	4C	2.209	(A,B)

```
 N(PHI) / ( P/Rm )                  0.475   3C        1.004   (C,D)
 M(PHI) / ( P )                     0.475   2C1       0.010   (A,B)
 M(PHI) / ( P )                     0.475   1C   !    0.059   (C,D)
 N(PHI) / ( MC/(Rm**2 * Beta) )     0.475   3A        0.764   (A,B,C,D)
 M(PHI) / ( MC/(Rm    * Beta) )     0.475   1A        0.065   (A,B,C,D)
 N(PHI) / ( ML/(Rm**2 * Beta) )     0.475   3B        1.311   (A,B,C,D)
 M(PHI) / ( ML/(Rm    * Beta) )     0.475   1B        0.010   (A,B,C,D)

 N(x)   / ( P/Rm )                  0.475   3C        1.004   (A,B)
 N(x)   / ( P/Rm )                  0.475   4C        2.209   (C,D)
 M(x)   / ( P )                     0.475   1C1       0.023   (A,B)
 M(x)   / ( P )                     0.475   2C   !    0.030   (C,D)
 N(x)   / ( MC/(Rm**2 * Beta) )     0.475   4A        2.479   (A,B,C,D)
 M(x)   / ( MC/(Rm    * Beta) )     0.475   2A        0.028   (A,B,C,D)
 N(x)   / ( ML/(Rm**2 * Beta) )     0.475   4B        0.698   (A,B,C,D)
 M(x)   / ( ML/(Rm    * Beta) )     0.475   2B        0.016   (A,B,C,D)
```

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-4.4	-4.4	-4.4	-4.4	-2.0	-2.0	-2.0	-2.0
Circ. Bend.	P	-3.0	3.0	-3.0	3.0	-17.2	17.2	-17.2	17.2
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-5.6	-5.6	5.6	5.6
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-69.6	69.6	69.6	-69.6
Circ. Memb.	ML	-9.6	-9.6	9.6	9.6	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-10.7	10.7	10.7	-10.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-27.7	-0.3	12.9	-2.5	-94.5	79.3	56.0	-48.8
Long. Memb.	P	-2.0	-2.0	-2.0	-2.0	-4.4	-4.4	-4.4	-4.4
Long. Bend.	P	-6.8	6.8	-6.8	6.8	-8.7	8.7	-8.7	8.7
Long. Memb.	MC	0.0	0.0	0.0	0.0	-18.1	-18.1	18.1	18.1
Long. Bend.	MC	0.0	0.0	0.0	0.0	-30.1	30.1	30.1	-30.1
Long. Memb.	ML	-5.1	-5.1	5.1	5.1	0.0	0.0	0.0	0.0
Long. Bend.	ML	-17.4	17.4	17.4	-17.4	0.0	0.0	0.0	0.0
Tot. Long. Str.		-31.3	17.1	13.8	-7.5	-61.4	16.3	35.2	-7.7
Shear	VC	1.2	1.2	-1.2	-1.2	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-1.2	-1.2	1.2	1.2
Shear	MT	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Tot. Shear		3.4	3.4	1.0	1.0	1.0	1.0	3.4	3.4
Str. Int.		33.4	18.7	14.5	7.8	94.5	79.3	56.5	49.1

WRC 107/537 Stress Summations:

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

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-1 AB OIL COOLER
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for OIL COOLER E-PK6101-1AB --
Nozzle Calcs.: T1 Nozl: 9 8:06am Dec 23,2021

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
		Stress Intensity Values at							
Circ. Pm	(SUS)	25.6	28.1	25.6	28.1	25.6	28.1	25.6	28.1
Circ. Pl	(SUS)	-11.0	-11.0	7.6	7.6	-4.1	-4.1	1.2	1.2
Circ. Q	(SUS)	-28.7	28.7	19.0	-19.0	-56.2	56.2	43.2	-43.2
Long. Pm	(SUS)	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8
Long. Pl	(SUS)	-4.1	-4.1	1.2	1.2	-5.8	-5.8	2.4	2.4
Long. Q	(SUS)	-44.7	44.7	31.4	-31.4	-33.1	33.1	23.5	-23.5
Shear Pm	(SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl	(SUS)	1.3	1.3	-1.3	-1.3	-1.3	-1.3	1.3	1.3
Shear Q	(SUS)	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Pm (SUS)		25.6	28.1	25.6	28.1	25.6	28.1	25.6	28.1
Pm+Pl (SUS)		14.8	17.3	33.3	35.8	21.6	24.1	26.9	29.3
Pm+Pl+Q (Total)		38.0	57.6	54.4	35.2	36.7	80.7	71.4	18.7

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	28.06	117.90	Passed
Pm+Pl (SUS)	35.75	176.86	Passed
Pm+Pl+Q (TOTAL)	80.71	353.71	Passed

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

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

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

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

Input, Nozzle Desc: S2 From: 40

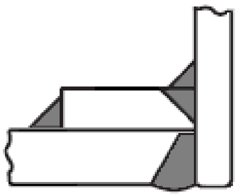
Pressure for Reinforcement Calculations	P	25.000	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	120	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	117.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	381.00	mm.
Design Length of Section	L	2908.0000	mm.
Shell Finished (Minimum) Thickness	t	11.1125	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		661.17	mm.
User Entered Minimum Design Metal Temperature		-10.00	°C

Type of Element Connected to the Shell : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		3.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.3344	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
Diameter of Pad along vessel surface	Dp	214.3000	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	8.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		62.7000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: S2

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

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

Nozzle input data check completed without errors.

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

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = (25.0*44.45)/(118*1.0+0.4*25.0)
  = 0.9346 mm.
```

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

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl   150.8618  mm.
 Parallel to Vessel Wall, opening length              d    75.4309  mm.
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp    20.2812  mm.
```

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

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

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

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

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	3.135	1.161	NA
Area in Shell	A1	2.984	3.798	NA
Area in Nozzle Wall	A2	2.353	2.566	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	6.196	6.196	NA
TOTAL AREA AVAILABLE	Atot	12.173	13.200	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

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

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

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 75.431(1.0 * 8.1125 - 1.0 * 4.156) - 2 * 6.735
(1.0 * 8.1125 - 1.0 * 4.156) * (1 - 1.0)
= 2.984 cm^2

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

Area Available in Welds [A41 + A42 + A43]:
= Wo^2 * fr3 + $(Wi\text{-}can/0.707)^2$ * fr2 + Wp^2 * fr4
= 8.0^2 * 1.0 + $(0.0)^2$ * 1.0 + 0.0^2 * 1.0
= 0.640 cm^2

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

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

Wall Thickness for Internal/External pressures	ta =	3.9346 mm.
Wall Thickness per UG16(b),	tr16b =	4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 =	7.1560 mm.
Wall Thickness	tb1 = max(trb1, tr16b) =	7.1560 mm.
Wall Thickness	tb2 = max(trb2, tr16b) =	4.5000 mm.
Wall Thickness per table UG-45	tb3 =	7.8000 mm.

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 7.156, 4.5 ) ]
  = 7.1560 mm.
```

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

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

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):
```
 Sustained  :     55.1,  Allowable :    117.9 N./mm^2  Passed
 Expansion  :      0.0,  Allowable :    239.7 N./mm^2  Passed
 Occasional :      6.4,  Allowable :    156.8 N./mm^2  Passed
 Shear      :     27.1,  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, Curve: B

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 25.00/51.10 = 0.489

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

Weld Size Calculations, Description: S2

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

Results Per UW-16.1:

```
                        Required Thickness    Actual Thickness
Nozzle Weld            4.7142 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
Pad Weld               4.8500 = 0.5*TminPad  5.6560 = 0.7 * Wp mm.
```

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (3.1349 - 2.9844 + 2 * 6.7345 * 1.0 *
    (1.0 * 8.1125 - 4.156 ) )118)
  = 8.06 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 2.3526 + 6.1962 + 0.64 - 0.0 * 1.0 ) * 118
  = 108.33 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 2.3526 + 0.0 + 0.64 + ( 1.0927 ) ) * 118
  = 48.16 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 2.3526 + 0.0 + 0.64 + 6.1962 + ( 1.0927 ) ) * 118
  = 121.21 kN
```

Strength of Connection Elements for Failure Path Analysis

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

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

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

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

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

Strength of Failure Paths:

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

Summary of Failure Path Calculations:

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

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

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

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

```
 Diameter Basis for Vessel                      Vbasis      ID
 Cylindrical or Spherical Vessel                Cylsph      Cylindrical
 Internal Corrosion Allowance                      Cas      3.0000  mm.
 Vessel Diameter                                    Dv     381.000  mm.
 Vessel Thickness                                   Tv      11.113  mm.

 Design Temperature                                 T1       120.0  °C
 Vessel Material                                         SA-106 B
 Vessel UNS Number                                          K03006
 Vessel Cold S.I. Allowable                        Smc      117.90  N./mm^2
 Vessel Hot  S.I. Allowable                        Smh      117.90  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-106 B

```
 Attachment Type                                  Type      Round
```

Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	88.900	mm.
Nozzle Thickness	Tn	9.735	mm.
Nozzle Material		SA-106 B	
Nozzle 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	214.300	mm.
Design Internal Pressure	Dp	25.000	bars
Include Pressure Thrust		No	

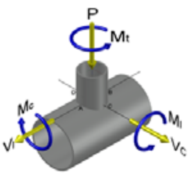
External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	3.2	kN
Longitudinal Shear	(SUS)	Vl	~~3.0~~	kN 3.2
Circumferential Shear	(SUS)	Vc	3.2	kN
Circumferential Moment	(SUS)	Mc	1100.0	N-m
Longitudinal Moment	(SUS)	Ml	1100.0	N-m
Torsional Moment	(SUS)	Mt	1300.0	N-m

Use Interactive Control		No	
WRC107 Version	Version	March	1979

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

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



Stress Attenuation Diameter (for Insert Plates) per WRC 297:
= NozzleOD + 2 * 1.65 * sqrt(Rmean(t - ca))
= 88.9 + 2 * 1.65 * sqrt(197.556 (11.113 - 3.0))
= 221.010 mm.

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	3.2	kN
Circumferential Shear	VC	3.2	kN
Longitudinal Shear	VL	3.0	kN
Circumferential Moment	MC	1100.0	N-m
Longitudinal Moment	ML	1100.0	N-m
Torsional Moment	MT	1300.0	N-m

Dimensionless Parameters used : Gamma = 11.18

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.192	4C	1.931	(A,B)
N(PHI) / (P/Rm)	0.192	3C	1.667	(C,D)
M(PHI) / (P)	0.192	2C1	0.083	(A,B)
M(PHI) / (P)	0.192	1C	0.111	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.192	3A	0.339	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.192	1A	0.096	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.192	3B	1.207	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.192	1B	0.046	(A,B,C,D)
N(x) / (P/Rm)	0.192	3C	1.667	(A,B)
N(x) / (P/Rm)	0.192	4C	1.931	(C,D)
M(x) / (P)	0.192	1C1	0.113	(A,B)
M(x) / (P)	0.192	2C	0.081	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.192	4A	0.535	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.192	2A	0.055	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.192	4B	0.342	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.192	2B	0.074	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.5	-1.5	-1.5	-1.5
Circ. Bend. P	-4.8	4.8	-4.8	4.8	-6.5	6.5	-6.5	6.5
Circ. Memb. MC	0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Circ. Memb. MC	0.0	0.0	0.0	0.0	-49.7	49.7	49.7	-49.7
Circ. Memb. ML	-9.3	-9.3	9.3	9.3	0.0	0.0	0.0	0.0
Circ. Bend. ML	-23.9	23.9	23.9	-23.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-39.7	17.7	26.6	-11.4	-60.3	52.1	44.3	-42.0
Long. Memb. P	-1.5	-1.5	-1.5	-1.5	-1.7	-1.7	-1.7	-1.7
Long. Bend. P	-6.6	6.6	-6.6	6.6	-4.8	4.8	-4.8	4.8
Long. Memb. MC	0.0	0.0	0.0	0.0	-4.1	-4.1	4.1	4.1
Long. Bend. MC	0.0	0.0	0.0	0.0	-28.3	28.3	28.3	-28.3
Long. Memb. ML	-2.6	-2.6	2.6	2.6	0.0	0.0	0.0	0.0
Long. Bend. ML	-38.0	38.0	38.0	-38.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-48.7	40.6	32.6	-30.2	-38.9	27.3	26.0	-21.1
Shear VC	1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.2	-1.2	1.2	1.2
Shear MT	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Tot. Shear	7.0	7.0	4.5	4.5	4.6	4.6	7.0	7.0
Str. Int.	52.6	42.6	35.0	31.2	61.2	53.0	46.7	44.1

Dimensionless Parameters used : Gamma = 24.35

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.475	4C	2.209	(A,B)

```
 N(PHI) / ( P/Rm )                  0.475   3C       1.004   (C,D)
 M(PHI) / ( P )                     0.475   2C1      0.010   (A,B)
 M(PHI) / ( P )                     0.475   1C   !   0.059   (C,D)
 N(PHI) / ( MC/(Rm**2 * Beta) )     0.475   3A       0.764   (A,B,C,D)
 M(PHI) / ( MC/(Rm    * Beta) )     0.475   1A       0.065   (A,B,C,D)
 N(PHI) / ( ML/(Rm**2 * Beta) )     0.475   3B       1.311   (A,B,C,D)
 M(PHI) / ( ML/(Rm    * Beta) )     0.475   1B       0.010   (A,B,C,D)

 N(x)   / ( P/Rm )                  0.475   3C       1.004   (A,B)
 N(x)   / ( P/Rm )                  0.475   4C       2.209   (C,D)
 M(x)   / ( P )                     0.475   1C1      0.023   (A,B)
 M(x)   / ( P )                     0.475   2C   !   0.030   (C,D)
 N(x)   / ( MC/(Rm**2 * Beta) )     0.475   4A       2.479   (A,B,C,D)
 M(x)   / ( MC/(Rm    * Beta) )     0.475   2A       0.028   (A,B,C,D)
 N(x)   / ( ML/(Rm**2 * Beta) )     0.475   4B       0.698   (A,B,C,D)
 M(x)   / ( ML/(Rm    * Beta) )     0.475   2B       0.016   (A,B,C,D)
```

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-4.4	-4.4	-4.4	-4.4	-2.0	-2.0	-2.0	-2.0
Circ. Bend.	P	-3.0	3.0	-3.0	3.0	-17.2	17.2	-17.2	17.2
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-5.6	-5.6	5.6	5.6
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-69.6	69.6	69.6	-69.6
Circ. Memb.	ML	-9.6	-9.6	9.6	9.6	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-10.7	10.7	10.7	-10.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-27.7	-0.3	12.9	-2.5	-94.5	79.3	56.0	-48.8
Long. Memb.	P	-2.0	-2.0	-2.0	-2.0	-4.4	-4.4	-4.4	-4.4
Long. Bend.	P	-6.8	6.8	-6.8	6.8	-8.7	8.7	-8.7	8.7
Long. Memb.	MC	0.0	0.0	0.0	0.0	-18.1	-18.1	18.1	18.1
Long. Bend.	MC	0.0	0.0	0.0	0.0	-30.1	30.1	30.1	-30.1
Long. Memb.	ML	-5.1	-5.1	5.1	5.1	0.0	0.0	0.0	0.0
Long. Bend.	ML	-17.4	17.4	17.4	-17.4	0.0	0.0	0.0	0.0
Tot. Long. Str.		-31.3	17.1	13.8	-7.5	-61.4	16.3	35.2	-7.7
Shear	VC	1.2	1.2	-1.2	-1.2	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-1.1	-1.1	1.1	1.1
Shear	MT	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Tot. Shear		3.4	3.4	1.0	1.0	1.1	1.1	3.3	3.3
Str. Int.		33.4	18.7	14.5	7.8	94.5	79.3	56.5	49.1

WRC 107/537 Stress Summations:

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

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
		Stress Intensity Values at							
Circ. Pm	(SUS)	25.5	28.0	25.5	28.0	25.5	28.0	25.5	28.0
Circ. Pl	(SUS)	-11.0	-11.0	7.6	7.6	-4.1	-4.1	1.2	1.2
Circ. Q	(SUS)	-28.7	28.7	19.0	-19.0	-56.2	56.2	43.2	-43.2
Long. Pm	(SUS)	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8
Long. Pl	(SUS)	-4.1	-4.1	1.2	1.2	-5.8	-5.8	2.4	2.4
Long. Q	(SUS)	-44.7	44.7	31.4	-31.4	-33.1	33.1	23.5	-23.5
Shear Pm	(SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl	(SUS)	1.3	1.3	-1.3	-1.3	-1.2	-1.2	1.2	1.2
Shear Q	(SUS)	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Pm (SUS)		25.5	28.0	25.5	28.0	25.5	28.0	25.5	28.0
Pm+Pl (SUS)		14.8	17.2	33.2	35.7	21.5	24.0	26.8	29.3
Pm+Pl+Q (Total)		38.1	57.5	54.4	35.2	36.8	80.7	71.3	18.7

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	28.02	117.90	Passed
Pm+Pl (SUS)	35.71	176.86	Passed
Pm+Pl+Q (TOTAL)	80.68	353.71	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)	58.4	60.9	58.4	60.9	58.4	60.9	58.4	60.9
Circ. Pl	(SUS)	-14.0	-14.0	5.2	5.2	-7.6	-7.6	3.6	3.6
Circ. Q	(SUS)	-13.7	13.7	7.7	-7.7	-86.9	86.9	52.4	-52.4
Long. Pm	(SUS)	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2
Long. Pl	(SUS)	-7.1	-7.1	3.1	3.1	-22.6	-22.6	13.7	13.7
Long. Q	(SUS)	-24.2	24.2	10.6	-10.6	-38.8	38.8	21.4	-21.4
Shear Pm	(SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl	(SUS)	1.2	1.2	-1.2	-1.2	-1.1	-1.1	1.1	1.1
Shear Q	(SUS)	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Pm (SUS)		58.4	60.9	58.4	60.9	58.4	60.9	58.4	60.9
Pm+Pl (SUS)		44.5	47.0	63.6	66.1	50.8	53.3	62.1	64.6
Pm+Pl+Q (Total)		33.5	61.3	71.3	58.4	36.4	140.2	114.6	22.6

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

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

*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      25.000  bars
Temperature for Internal Pressure            Temp        120  °C
Design External Pressure                     Pext       1.10  bars
Temperature for External Pressure          Tempex        120  °C

Shell Material                                      SA-106 B
Shell Allowable Stress at Temperature          Sv     117.90  N./mm^2
Shell Allowable Stress At Ambient             Sva     117.90  N./mm^2

Inside Diameter of Cylindrical Shell           D      381.00  mm.
Design Length of Section                       L   2908.0000  mm.
Shell Finished (Minimum) Thickness             t     11.1125  mm.
Shell Internal Corrosion Allowance             c      3.0000  mm.
Shell External Corrosion Allowance            co      0.0000  mm.

Distance from Bottom/Left Tangent                    3195.17  mm.

User Entered Minimum Design Metal Temperature         -10.00  °C
```

Type of Element Connected to the Shell : Nozzle

```
Material                                            SA-106 B
Material UNS Number                                   K03006
Material Specification/Type                       Smls. pipe
Allowable Stress at Temperature               Sn      117.90  N./mm^2
Allowable Stress At Ambient                  Sna      117.90  N./mm^2

Diameter Basis (for tr calc only)                       OD
Layout Angle                                           90.00  deg
Diameter                                              3.0000  in.

Size and Thickness Basis                              Minimum
Nominal Thickness                             tn      160

Flange Material                                       SA-105
Flange Type                                  Weld Neck Flange

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

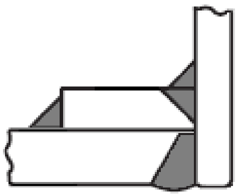
Outside Projection                            ho    200.0000  mm.
Weld leg size between Nozzle and Pad/Shell    Wo      8.0000  mm.
Groove weld depth between Nozzle and Vessel Wgnv      8.3344  mm.
Inside Projection                              h      0.0000  mm.
Weld leg size, Inside Element to Shell        Wi      0.0000  mm.

Pad Material                                        SA-516 70
Pad Allowable Stress at Temperature           Sp      137.90  N./mm^2
Pad Allowable Stress At Ambient              Spa      137.90  N./mm^2
Diameter of Pad along vessel surface          Dp    214.3000  mm.
Thickness of Pad                              te     10.0000  mm.
Weld leg size between Pad and Shell           Wp      8.0000  mm.
Groove weld depth between Pad and Nozzle    Wgpn     10.0000  mm.
Reinforcing Pad Width                                62.7000  mm.

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

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: S1

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

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

Nozzle input data check completed without errors.

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

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = (25.0*44.45)/(118*1.0+0.4*25.0)
  = 0.9346 mm.
```

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

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl   150.8618  mm.
Parallel to Vessel Wall, opening length              d    75.4309  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp    20.2812  mm.
```

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

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

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

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

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	3.135	1.161	NA
Area in Shell	A1	2.984	3.798	NA
Area in Nozzle Wall	A2	2.353	2.566	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	6.196	6.196	NA
TOTAL AREA AVAILABLE	Atot	12.173	13.200	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

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

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

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 75.431(1.0 * 8.1125 - 1.0 * 4.156) - 2 * 6.735
(1.0 * 8.1125 - 1.0 * 4.156) * (1 - 1.0)
= 2.984 cm^2

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

Area Available in Welds [A41 + A42 + A43]:
= Wo^2 * fr3 + $(Wi-can/0.707)^2$ * fr2 + Wp^2 * fr4
= 8.0^2 * 1.0 + $(0.0)^2$ * 1.0 + 0.0^2 * 1.0
= 0.640 cm^2

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

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

Wall Thickness for Internal/External pressures	ta =	3.9346 mm.
Wall Thickness per UG16(b),	tr16b =	4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 =	7.1560 mm.
Wall Thickness	tb1 = max(trb1, tr16b) =	7.1560 mm.
Wall Thickness	tb2 = max(trb2, tr16b) =	4.5000 mm.
Wall Thickness per table UG-45	tb3 =	7.8000 mm.

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 7.156, 4.5 ) ]
  = 7.1560 mm.
```

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

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

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):
```
 Sustained  :    55.1,  Allowable :    117.9 N./mm^2  Passed
 Expansion  :     0.0,  Allowable :    239.7 N./mm^2  Passed
 Occasional :     6.4,  Allowable :    156.8 N./mm^2  Passed
 Shear      :    27.3,  Allowable :     82.5 N./mm^2  Passed
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

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

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

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

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

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

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

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

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

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

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

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

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

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


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

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 25.00/51.10 = 0.489

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

Weld Size Calculations, Description: S1

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

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
Nozzle Weld          4.7142 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm.
Pad Weld             4.8500 = 0.5*TminPad  5.6560 = 0.7 * Wp mm.
```

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (3.1349 - 2.9844 + 2 * 6.7345 * 1.0 *
    (1.0 * 8.1125 - 4.156 ) )118)
  = 8.06 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 2.3526 + 6.1962 + 0.64 - 0.0 * 1.0 ) * 118
  = 108.33 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 2.3526 + 0.0 + 0.64 + ( 1.0927 ) ) * 118
  = 48.16 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 2.3526 + 0.0 + 0.64 + 6.1962 + ( 1.0927 ) ) * 118
  = 121.21 kN
```

Strength of Connection Elements for Failure Path Analysis

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

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

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

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

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

Strength of Failure Paths:

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

Summary of Failure Path Calculations:
```
 Path 1-1 = 227 kN , must exceed W = 8 kN  or W1 = 108 kN
 Path 2-2 = 272 kN , must exceed W = 8 kN  or W2 = 48 kN
 Path 3-3 = 220 kN , must exceed W = 8 kN  or W3 = 121 kN

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

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

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

```
 Diameter Basis for Vessel                    Vbasis      ID
 Cylindrical or Spherical Vessel              Cylsph      Cylindrical
 Internal Corrosion Allowance                    Cas      3.0000  mm.
 Vessel Diameter                                  Dv    381.000  mm.
 Vessel Thickness                                 Tv      11.113  mm.

 Design Temperature                               T1       120.0  °C
 Vessel Material                                        SA-106 B
 Vessel UNS Number                                        K03006
 Vessel Cold S.I. Allowable                      Smc      117.90  N./mm^2
 Vessel Hot  S.I. Allowable                      Smh      117.90  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-106 B

```
 Attachment Type                                Type       Round
```

```
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-1 AB    OIL COOLER
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for OIL COOLER E-PK6101-1AB    --
Nozzle Calcs.: S1                        Nozl:    11    8:06am  Dec 23,2021

 Diameter Basis for Nozzle                       Nbasis       OD
 Corrosion Allowance for Nozzle                     Can      3.0000  mm.
 Nozzle Diameter                                     Dn      88.900  mm.
 Nozzle Thickness                                    Tn       9.735  mm.
 Nozzle Material                                            SA-106 B
 Nozzle 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     214.300  mm.

 Design Internal Pressure                            Dp      25.000  bars
 Include Pressure Thrust                                         No
```

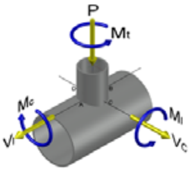
External Forces and Moments in WRC 107/537 Convention:

```
 Radial Load             (SUS)                        P         3.2  kN
 Longitudinal Shear      (SUS)                       Vl         3.2  kN
 Circumferential Shear   (SUS)                       Vc         3.2  kN
 Circumferential Moment  (SUS)                       Mc      1100.0  N-m
 Longitudinal Moment     (SUS)                       Ml      1100.0  N-m
 Torsional Moment        (SUS)                       Mt      1300.0  N-m


 Use Interactive Control                                   No
 WRC107 Version                                 Version   March  1979

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

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



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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 88.9 + 2 * 1.65 * sqrt( 197.556 ( 11.113 - 3.0 ) )
  = 221.010 mm.
```

WRC 107 Stress Calculation for SUStained loads:

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

 Dimensionless Parameters used :    Gamma =    11.18
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.192	4C	1.931	(A,B)
N(PHI) / (P/Rm)	0.192	3C	1.667	(C,D)
M(PHI) / (P)	0.192	2C1	0.083	(A,B)
M(PHI) / (P)	0.192	1C	0.111	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.192	3A	0.339	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.192	1A	0.096	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.192	3B	1.207	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.192	1B	0.046	(A,B,C,D)
N(x) / (P/Rm)	0.192	3C	1.667	(A,B)
N(x) / (P/Rm)	0.192	4C	1.931	(C,D)
M(x) / (P)	0.192	1C1	0.113	(A,B)
M(x) / (P)	0.192	2C	0.081	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.192	4A	0.535	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.192	2A	0.055	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.192	4B	0.342	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.192	2B	0.074	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.5	-1.5	-1.5	-1.5
Circ. Bend. P	-4.8	4.8	-4.8	4.8	-6.5	6.5	-6.5	6.5
Circ. Memb. MC	0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Circ. Memb. MC	0.0	0.0	0.0	0.0	-49.7	49.7	49.7	-49.7
Circ. Memb. ML	-9.3	-9.3	9.3	9.3	0.0	0.0	0.0	0.0
Circ. Bend. ML	-23.9	23.9	23.9	-23.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-39.7	17.7	26.6	-11.4	-60.3	52.1	44.3	-42.0
Long. Memb. P	-1.5	-1.5	-1.5	-1.5	-1.7	-1.7	-1.7	-1.7
Long. Bend. P	-6.6	6.6	-6.6	6.6	-4.8	4.8	-4.8	4.8
Long. Memb. MC	0.0	0.0	0.0	0.0	-4.1	-4.1	4.1	4.1
Long. Bend. MC	0.0	0.0	0.0	0.0	-28.3	28.3	28.3	-28.3
Long. Memb. ML	-2.6	-2.6	2.6	2.6	0.0	0.0	0.0	0.0
Long. Bend. ML	-38.0	38.0	38.0	-38.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-48.7	40.6	32.6	-30.2	-38.9	27.3	26.0	-21.1
Shear VC	1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.3	-1.3	1.3	1.3
Shear MT	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Tot. Shear	7.0	7.0	4.5	4.5	4.5	4.5	7.0	7.0
Str. Int.	52.6	42.6	35.0	31.2	61.2	52.9	46.7	44.2

Dimensionless Parameters used : Gamma = 24.35

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.475	4C	2.209	(A,B)

N(PHI) / (P/Rm)	0.475	3C		1.004	(C,D)
M(PHI) / (P)	0.475	2C1		0.010	(A,B)
M(PHI) / (P)	0.475	1C	!	0.059	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.475	3A		0.764	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.475	1A		0.065	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.475	3B		1.311	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.475	1B		0.010	(A,B,C,D)
N(x) / (P/Rm)	0.475	3C		1.004	(A,B)
N(x) / (P/Rm)	0.475	4C		2.209	(C,D)
M(x) / (P)	0.475	1C1		0.023	(A,B)
M(x) / (P)	0.475	2C	!	0.030	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.475	4A		2.479	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.475	2A		0.028	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.475	4B		0.698	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.475	2B		0.016	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
Circ. Memb. P	-4.4	-4.4	-4.4	-4.4	-2.0	-2.0	-2.0	-2.0
Circ. Bend. P	-3.0	3.0	-3.0	3.0	-17.2	17.2	-17.2	17.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	-5.6	-5.6	5.6	5.6
Circ. Memb. MC	0.0	0.0	0.0	0.0	-69.6	69.6	69.6	-69.6
Circ. Memb. ML	-9.6	-9.6	9.6	9.6	0.0	0.0	0.0	0.0
Circ. Bend. ML	-10.7	10.7	10.7	-10.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-27.7	-0.3	12.9	-2.5	-94.5	79.3	56.0	-48.8
Long. Memb. P	-2.0	-2.0	-2.0	-2.0	-4.4	-4.4	-4.4	-4.4
Long. Bend. P	-6.8	6.8	-6.8	6.8	-8.7	8.7	-8.7	8.7
Long. Memb. MC	0.0	0.0	0.0	0.0	-18.1	-18.1	18.1	18.1
Long. Bend. MC	0.0	0.0	0.0	0.0	-30.1	30.1	30.1	-30.1
Long. Memb. ML	-5.1	-5.1	5.1	5.1	0.0	0.0	0.0	0.0
Long. Bend. ML	-17.4	17.4	17.4	-17.4	0.0	0.0	0.0	0.0
Tot. Long. Str.	-31.3	17.1	13.8	-7.5	-61.4	16.3	35.2	-7.7
Shear VC	1.2	1.2	-1.2	-1.2	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.2	-1.2	1.2	1.2
Shear MT	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Tot. Shear	3.4	3.4	1.0	1.0	1.0	1.0	3.4	3.4
Str. Int.	33.4	18.7	14.5	7.8	94.5	79.3	56.5	49.1

WRC 107/537 Stress Summations:

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

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

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	28.02	117.90	Passed
Pm+Pl (SUS)	35.71	176.86	Passed
Pm+Pl+Q (TOTAL)	80.66	353.71	Passed

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

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

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

*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	25.033	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	120	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	117.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	381.00	mm.
Design Length of Section	L	2908.0000	mm.
Shell Finished (Minimum) Thickness	t	11.1125	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		661.17	mm.
User Entered Minimum Design Metal Temperature		-10.00	°C

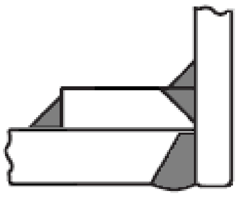
Type of Element Connected to the Shell : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
Diameter Basis (for tr calc only)		OD	
Layout Angle		270.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	8.3344	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
Diameter of Pad along vessel surface	Dp	160.3250	mm.
Thickness of Pad	te	10.0000	mm.
Weld leg size between Pad and Shell	Wp	8.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		50.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

flanged connections 2” N.D. and lesser shall be long welding-neck type.

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)
  = (25.03*193.5)/(118*1.0-0.6*25.03)
  = 4.1615 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = (25.03*30.1625)/(118*1.0+0.4*25.03)
  = 0.6350 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    20.2812  mm.
```

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

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

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

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

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	2.124	0.785	NA
Area in Shell	A1	2.016	2.570	NA
Area in Nozzle Wall	A2	1.627	1.752	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.640	0.640	NA
Area in Element	A5	4.174	4.174	NA
TOTAL AREA AVAILABLE	Atot	8.457	9.136	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

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

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (51.0342*4.1615*1.0+2*4.6454*4.1615*1.0*(1-1.0))
  = 2.124 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 * 8.1125 - 1.0 * 4.162 ) - 2 * 4.645
    ( 1.0 * 8.1125 - 1.0 * 4.1615 ) * ( 1 - 1.0 )
  = 2.016 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 20.28 ) * ( 4.65 - 0.64 ) * 1.0
  = 1.627 cm^2
```

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

Area Available in Element [A5]:
```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 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 = 3.6350 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 7.1615 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 7.1615 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 6.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[6.42, max(7.1615, 4.5)]
= 6.4200 mm.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(3.635, 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 :	62.6,	Allowable :	117.9 N./mm^2	Passed
Expansion :	0.0,	Allowable :	232.2 N./mm^2	Passed
Occasional :	6.3,	Allowable :	156.8 N./mm^2	Passed
Shear :	33.9,	Allowable :	82.5 N./mm^2	Passed

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 7.645, tr = 0.635, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.137, Temp. Reduction = 78 °C

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

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

Govrn. thk, tg = 7.645, tr = 0.635, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.137, Temp. Reduction = 78 °C

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

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

Govrn. thk, tg = 7.645, tr = 0.635, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.137, Temp. Reduction = 78 °C

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

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

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

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

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

Govrn. thk, tg = 7.645, tr = 0.635, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.137, Temp. Reduction = 78 °C

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

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

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

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

Weld Size Calculations, Description: S3

```
Intermediate Calc. for nozzle/shell Welds   Tmin       4.6454  mm.
Intermediate Calc. for pad/shell Welds   TminPad       9.7000  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             4.8500 = 0.5*TminPad  5.6560 = 0.7 * Wp mm.
```

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

Weld Load [W]:
```
= max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
= max( 0, (2.1238 - 2.0164 + 2 * 4.6454 * 1.0 *
  (1.0 * 8.1125 - 4.1615 ) )118)
= 5.59 kN
```

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

Weld Load [W1]:
```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 1.6267 + 4.1743 + 0.64 - 0.0 * 1.0 ) * 118
= 75.94 kN
```

Weld Load [W2]:
```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 1.6267 + 0.0 + 0.64 + ( 0.7537 ) ) * 118
= 35.61 kN
```

Weld Load [W3]:
```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 1.6267 + 0.0 + 0.64 + 4.1743 + ( 0.7537 ) ) * 118
= 84.82 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 ) * 160.325 * 8.0 * 0.49 * 118
  = 116. 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 * ( 8.3344 - 3.0 ) * 0.74 * 118
  = 44. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 116 + 34 ) = 150 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 44 + 97 + 44 + 0 ) = 185 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 116 + 44 + 0 ) = 160 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 149 kN , must exceed W = 5 kN  or W1 = 75 kN
 Path 2-2 = 184 kN , must exceed W = 5 kN  or W2 = 35 kN
 Path 3-3 = 160 kN , must exceed W = 5 kN  or W3 = 84 kN

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

The Drop for this Nozzle is : 2.4030 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 213.5155 mm.

Input Echo, WRC107/537 Item 1, Description: S3 :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	381.000	mm.
Vessel Thickness	Tv	11.113	mm.
Design Temperature	T1	120.0	°C
Vessel Material		SA-106 B	
Vessel UNS Number		K03006	
Vessel Cold S.I. Allowable	Smc	117.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	117.90	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-106 B

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-106 B	
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	160.325	mm.
Design Internal Pressure	Dp	25.033	bars
Include Pressure Thrust		No	

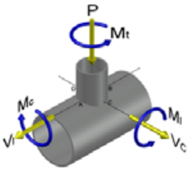
External Forces and Moments in WRC 107/537 Convention:

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

Use Interactive Control		No	
WRC107 Version	Version	March	1979

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

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



Stress Attenuation Diameter (for Insert Plates) per WRC 297:
= NozzleOD + 2 * 1.65 * sqrt(Rmean(t - ca))
= 60.325 + 2 * 1.65 * sqrt(197.556 (11.113 - 3.0))
= 192.435 mm.

WRC 107 Stress Calculation for SUStained loads:

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

Dimensionless Parameters used : Gamma = 11.18

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.130	4C	2.080	(A,B)
N(PHI) / (P/Rm)	0.130	3C	1.966	(C,D)
M(PHI) / (P)	0.130	2C1	0.117	(A,B)
M(PHI) / (P)	0.130	1C	0.148	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.130	3A	0.236	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.130	1A	0.101	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.130	3B	0.907	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.130	1B	0.054	(A,B,C,D)
N(x) / (P/Rm)	0.130	3C	1.966	(A,B)
N(x) / (P/Rm)	0.130	4C	2.080	(C,D)
M(x) / (P)	0.130	1C1	0.154	(A,B)
M(x) / (P)	0.130	2C	0.118	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.130	4A	0.337	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.130	2A	0.059	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.130	4B	0.236	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.130	2B	0.088	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
Circ. Memb. P	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1
Circ. Bend. P	-4.3	4.3	-4.3	4.3	-5.4	5.4	-5.4	5.4
Circ. Memb. MC	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	-28.0	28.0	28.0	-28.0
Circ. Memb. ML	-3.7	-3.7	3.7	3.7	0.0	0.0	0.0	0.0
Circ. Bend. ML	-15.0	15.0	15.0	-15.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-24.1	14.4	13.3	-8.0	-35.5	31.4	22.5	-22.7
Long. Memb. P	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1
Long. Bend. P	-5.6	5.6	-5.6	5.6	-4.3	4.3	-4.3	4.3
Long. Memb. MC	0.0	0.0	0.0	0.0	-1.4	-1.4	1.4	1.4
Long. Bend. MC	0.0	0.0	0.0	0.0	-16.3	16.3	16.3	-16.3
Long. Memb. ML	-1.0	-1.0	1.0	1.0	0.0	0.0	0.0	0.0
Long. Bend. ML	-24.4	24.4	24.4	-24.4	0.0	0.0	0.0	0.0
Tot. Long. Str.	-32.1	28.0	18.7	-18.9	-23.1	18.1	12.2	-11.7
Shear VC	1.2	1.2	-1.2	-1.2	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.2	-1.2	1.2	1.2
Shear MT	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Tot. Shear	6.0	6.0	3.7	3.7	3.7	3.7	6.0	6.0
Str. Int.	35.3	30.2	20.5	20.0	36.5	32.3	25.3	25.3

Dimensionless Parameters used : Gamma = 24.35

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.355	4C	2.777	(A,B)

```
 N(PHI) / ( P/Rm )                 0.355   3C        1.477   (C,D)
 M(PHI) / ( P )                    0.355   2C1       0.018   (A,B)
 M(PHI) / ( P )                    0.355   1C   !    0.059   (C,D)
 N(PHI) / ( MC/(Rm**2 * Beta) )    0.355   3A        0.979   (A,B,C,D)
 M(PHI) / ( MC/(Rm    * Beta) )    0.355   1A        0.073   (A,B,C,D)
 N(PHI) / ( ML/(Rm**2 * Beta) )    0.355   3B        1.919   (A,B,C,D)
 M(PHI) / ( ML/(Rm    * Beta) )    0.355   1B        0.016   (A,B,C,D)

 N(x)   / ( P/Rm )                 0.355   3C        1.477   (A,B)
 N(x)   / ( P/Rm )                 0.355   4C        2.777   (C,D)
 M(x)   / ( P )                    0.355   1C1       0.039   (A,B)
 M(x)   / ( P )                    0.355   2C   !    0.030   (C,D)
 N(x)   / ( MC/(Rm**2 * Beta) )    0.355   4A        2.259   (A,B,C,D)
 M(x)   / ( MC/(Rm    * Beta) )    0.355   2A        0.031   (A,B,C,D)
 N(x)   / ( ML/(Rm**2 * Beta) )    0.355   4B        0.924   (A,B,C,D)
 M(x)   / ( ML/(Rm    * Beta) )    0.355   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	-3.5	-3.5	-3.5	-3.5	-1.8	-1.8	-1.8	-1.8
Circ. Bend. P	-3.3	3.3	-3.3	3.3	-10.8	10.8	-10.8	10.8
Circ. Memb. MC	0.0	0.0	0.0	0.0	-3.5	-3.5	3.5	3.5
Circ. Memb. MC	0.0	0.0	0.0	0.0	-37.8	37.8	37.8	-37.8
Circ. Memb. ML	-6.8	-6.8	6.8	6.8	0.0	0.0	0.0	0.0
Circ. Bend. ML	-8.2	8.2	8.2	-8.2	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-21.8	1.3	8.3	-1.5	-53.9	43.2	28.6	-25.3
Long. Memb. P	-1.8	-1.8	-1.8	-1.8	-3.5	-3.5	-3.5	-3.5
Long. Bend. P	-7.1	7.1	-7.1	7.1	-5.4	5.4	-5.4	5.4
Long. Memb. MC	0.0	0.0	0.0	0.0	-8.0	-8.0	8.0	8.0
Long. Bend. MC	0.0	0.0	0.0	0.0	-15.9	15.9	15.9	-15.9
Long. Memb. ML	-3.3	-3.3	3.3	3.3	0.0	0.0	0.0	0.0
Long. Bend. ML	-13.7	13.7	13.7	-13.7	0.0	0.0	0.0	0.0
Tot. Long. Str.	-26.0	15.7	8.0	-5.1	-32.8	9.8	15.0	-5.9
Shear VC	1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear MT	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Tot. Shear	2.5	2.5	0.5	0.5	0.5	0.5	2.5	2.5
Str. Int.	27.1	16.1	8.7	5.2	53.9	43.2	29.1	25.7

WRC 107/537 Stress Summations:

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

Type of Stress	Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm	(SUS)	25.5	28.1	25.5	28.1	25.5	28.1	25.5	28.1
Circ. Pl	(SUS)	-4.9	-4.9	2.6	2.6	-2.0	-2.0	-0.1	-0.1
Circ. Q	(SUS)	-19.3	19.3	10.7	-10.7	-33.5	33.5	22.6	-22.6
Long. Pm	(SUS)	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8
Long. Pl	(SUS)	-2.0	-2.0	-0.1	-0.1	-2.5	-2.5	0.3	0.3
Long. Q	(SUS)	-30.0	30.0	18.8	-18.8	-20.6	20.6	11.9	-11.9
Shear Pm	(SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl	(SUS)	1.2	1.2	-1.2	-1.2	-1.2	-1.2	1.2	1.2
Shear Q	(SUS)	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Pm	(SUS)	25.5	28.1	25.5	28.1	25.5	28.1	25.5	28.1
Pm+Pl	(SUS)	20.8	23.3	28.2	30.7	23.6	26.1	25.6	28.0
Pm+Pl+Q	(Total)	23.9	47.6	40.3	27.1	13.8	59.9	49.5	12.7

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	28.05	117.90	Passed
Pm+Pl (SUS)	30.74	176.86	Passed
Pm+Pl+Q (TOTAL)	59.92	353.71	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)	58.5	61.0	58.5	61.0	58.5	61.0	58.5	61.0
Circ. Pl	(SUS)	-10.3	-10.3	3.4	3.4	-5.3	-5.3	1.6	1.6
Circ. Q	(SUS)	-11.6	11.6	4.9	-4.9	-48.5	48.5	27.0	-27.0
Long. Pm	(SUS)	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2
Long. Pl	(SUS)	-5.1	-5.1	1.4	1.4	-11.5	-11.5	4.6	4.6
Long. Q	(SUS)	-20.8	20.8	6.5	-6.5	-21.3	21.3	10.4	-10.4
Shear Pm	(SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl	(SUS)	1.0	1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q	(SUS)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Pm	(SUS)	58.5	61.0	58.5	61.0	58.5	61.0	58.5	61.0
Pm+Pl	(SUS)	48.2	50.7	61.9	64.4	53.2	55.7	60.2	62.7
Pm+Pl+Q	(Total)	36.8	62.6	66.8	59.5	8.3	104.2	87.3	36.1

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	60.99	117.90	Passed
Pm+Pl (SUS)	64.38	176.86	Passed
Pm+Pl+Q (TOTAL)	104.20	353.71	Passed

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

Input, Nozzle Desc: T4 From: 60

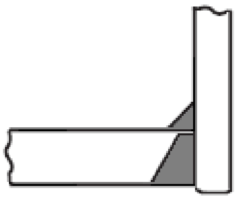
Pressure for Reinforcement Calculations	P	25.000	bars
Temperature for Internal Pressure	Temp	190	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	190	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	117.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	381.00	mm.
Design Length of Section	L	402.7500	mm.
Shell Finished (Minimum) Thickness	t	11.1125	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3691.35	mm.
User Entered Minimum Design Metal Temperature		-10.00	°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	14.3000	mm.
Flange Material	SA-105	~~SA-350 LF2~~	LWN to be considered
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	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: T4

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

```
 Actual Inside Diameter Used in Calculation              0.750  in.
 Actual Thickness Used in Calculation                    0.563  in.
```

Nozzle input data check completed without errors.

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

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 12.525(exp([25.0/(137.9*1.0]-1)
  = 0.2292 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2879 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl    63.8750  mm.
 Parallel to Vessel Wall                        Rn+tn+t    31.9375  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    20.2812  mm.
```

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

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

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.041	0.168	NA
Area in Shell	A1	1.536	2.628	NA

Area in Nozzle Wall	A2	4.491	4.467	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.964	0.964	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	6.991	8.059	NA

The Internal Pressure Case Governs the Analysis.

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

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (25.05*4.156*1.0+2*11.3*4.156*1.0*(1-1.0))
  = 1.041 cm^2
```

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 38.825( 1.0 * 8.1125 - 1.0 * 4.156 ) - 2 * 11.3
    ( 1.0 * 8.1125 - 1.0 * 4.156 ) * ( 1 - 1.0 )
  = 1.536 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 20.28 )( 11.3 - 0.23 )1.0
  = 4.491 cm^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = ( Wo² - Area Lost )*fr2 + ( (Wi-can/0.707)² - Area Lost)*fr2
  = ( 10.0² - 0.0356 ) * 1.0 + ( 0.0² -0.0 ) * 1.0
  = 0.964 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 3.2879 mm.
 Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 7.1560 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 7.1560 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                     tb3 = 6.2200 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 6.22, max( 7.156, 4.5 ) ]
  = 6.2200 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.2879, 6.22 )
  = 6.2200 mm.
```

Available Nozzle Neck Thickness = 14.3000 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle 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: B

Govrn. thk, tg = 11.113, tr = 4.156, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.512, Temp. Reduction = 31 °C

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

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ANSI B16.5/47 flange per Matl. Specification       -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)           -79 °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 = 25.00/51.10 = 0.489

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      9.7000  mm.
```

Results Per UW-16.1:

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

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (1.0411 - 1.5361 + 2 * 11.3 * 1.0 *
    (1.0 * 8.1125 - 4.156 ) )118)
  = 4.71 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.4906 + 0.0 + 0.9644 - 0.0 * 1.0 ) * 118
  = 64.31 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.4906 + 0.0 + 0.9644 + ( 1.8334 ) ) * 118
  = 85.93 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.4906 + 0.0 + 0.9644 + 0.0 + ( 1.8334 ) ) * 118
  = 85.93 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 47.65 * 10.0 * 0.49 * 118
  = 43. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 18.175) * ( 14.3 - 3.0 ) * 0.7 * 138
  = 62. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 47.65 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 53. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 43 + 62 ) = 106 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 43 + 0 + 53 + 0 ) = 97 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 43 + 53 + 0 ) = 97 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 105 kN , must exceed W = 4 kN  or W1 = 64 kN
 Path 2-2 = 96 kN , must exceed W = 4 kN  or W2 = 85 kN
 Path 3-3 = 96 kN , must exceed W = 4 kN  or W3 = 85 kN

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

The Drop for this Nozzle is : 1.4957 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 212.6082 mm.

Input, Nozzle Desc: T3 From: 60

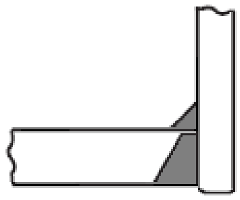
Pressure for Reinforcement Calculations	P	25.037	bars
Temperature for Internal Pressure	Temp	190	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	190	°C
Shell Material		SA-106 B	
Shell Allowable Stress at Temperature	Sv	117.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	117.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	381.00	mm.
Design Length of Section	L	402.7500	mm.
Shell Finished (Minimum) Thickness	t	11.1125	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3691.35	mm.
User Entered Minimum Design Metal Temperature		-10.00	°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-105	~~SA-350 LF2~~	
Flange Type		~~Slip on~~	LWN to be considered
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	10.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: T3

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

```
 Actual Inside Diameter Used in Calculation              1.000  in.
 Actual Thickness Used in Calculation                    0.563  in.
```

Nozzle input data check completed without errors.

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

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 15.7(exp([25.04/(137.9*1.0]-1)
  = 0.2877 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3088 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl    70.2250  mm.
 Parallel to Vessel Wall                         Rn+tn+t    35.1125  mm.
 Normal to Vessel Wall (Thickness Limit), no pad    Tlnp    20.2812  mm.
```

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

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

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.307	0.211	NA
Area in Shell	A1	1.534	2.628	NA

Area in Nozzle Wall	A2	4.467	4.458	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.964	0.964	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	6.965	8.051	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (31.4*4.1623*1.0+2*11.3*4.1623*1.0*(1-1.0))
  = 1.307 cm^2
```

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 38.825( 1.0 * 8.1125 - 1.0 * 4.162 ) - 2 * 11.3
    ( 1.0 * 8.1125 - 1.0 * 4.1623 ) * ( 1 - 1.0 )
  = 1.534 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 20.28 )( 11.3 - 0.29 )1.0
  = 4.467 cm^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = ( Wo² - Area Lost )*fr2 + ( (Wi-can/0.707)² - Area Lost)*fr2
  = ( 10.0² - 0.0356 ) * 1.0 + ( 0.0² -0.0 ) * 1.0
  = 0.964 cm^2
```

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

```
 Wall Thickness for Internal/External pressures      ta = 3.3088 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 7.1623 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 7.1623 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 6.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 6.42, max( 7.1623, 4.5 ) ]
  = 6.4200 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.3088, 6.42 )
  = 6.4200 mm.
```

Available Nozzle Neck Thickness = 14.3000 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle 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: B

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

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

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
 MDMT of ANSI B16.5/47 flange per Matl. Specification      -46 °C
 Flange MDMT with Temp reduction per UCS-66(i)(2)          -79 °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 = 25.04/51.10 = 0.490

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      9.7000  mm.
```

Results Per UW-16.1:

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

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (1.307 - 1.5337 + 2 * 11.3 * 1.0 *
    (1.0 * 8.1125 - 4.1623 ) )118)
  = 7.85 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.4669 + 0.0 + 0.9644 - 0.0 * 1.0 ) * 118
  = 64.03 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.4669 + 0.0 + 0.9644 + ( 1.8334 ) ) * 118
  = 85.65 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.4669 + 0.0 + 0.9644 + 0.0 + ( 1.8334 ) ) * 118
  = 85.65 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 54.0 * 10.0 * 0.49 * 118
  = 49. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 21.35) * ( 14.3 - 3.0 ) * 0.7 * 138
  = 73. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 54.0 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 61. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 49 + 73 ) = 122 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 49 + 0 + 61 + 0 ) = 110 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 49 + 61 + 0 ) = 110 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 122 kN , must exceed W = 7 kN  or W1 = 64 kN
 Path 2-2 = 109 kN , must exceed W = 7 kN  or W2 = 85 kN
 Path 3-3 = 109 kN , must exceed W = 7 kN  or W3 = 85 kN

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

The Drop for this Nozzle is : 1.9231 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 213.0356 mm.

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-1 AB OIL COOLER
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for OIL COOLER E-PK6101-1AB --
Nozzle Schedule: Step: 21 8:06am Dec 23,2021

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	1.876	14.300	...	...	212.61	300
T3	1.000 in	Actual	SlipOn	2.126	14.300	...	...	213.04	300
S3	2.000 in	160	WNF	2.375	8.738	160.32	10.00	213.52	300
T2	3.000 in	160	WNF	3.500	11.125	188.90	10.00	216.37	300
T1	3.000 in	160	WNF	3.500	11.125	214.30	10.00	216.37	300
S2	3.000 in	160	WNF	3.500	11.125	214.30	10.00	216.37	300
S1	3.000 in	160	WNF	3.500	11.125	214.30	10.00	216.37	300

General Notes for the above table:

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

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

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

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

Description	Material	Shl Grve Weld	Noz Shl/Pad Weld	Pad OD Weld	Pad Grve Weld	Inside Weld
T4	SA-350 LF2	10.000	10.000	...	...	...
T3	SA-350 LF2	10.000	10.000	...	...	...
S3	SA-106 B	8.334	8.000	8.000	10.000	...
T2	SA-106 B	8.334	8.000	8.000	10.000	...
T1	SA-106 B	8.334	8.000	8.000	10.000	...
S2	SA-106 B	8.334	8.000	8.000	10.000	...
S1	SA-106 B	8.334	8.000	8.000	10.000	...

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

Nozzle Miscellaneous Data:

Description	Elev/Distance From Datum mm.	Layout Angle deg	Proj Outside mm.	Proj Inside mm.	Installed in Component
T4	3641.350	90.0	200.00	0.00	CHANNEL 002

T3	3641.350	270.0	200.00	0.00	CHANNEL 002
S3	611.175	270.0	200.00	0.00	SHELL
T2	160.000	90.0	200.00	0.00	CHANNEL 01
T1	160.000	270.0	200.00	0.00	CHANNEL 01
S2	611.175	90.0	200.00	0.00	SHELL
S1	3145.175	90.0	200.00	0.00	SHELL

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	1.876	11.300	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	25.00	bars
Shell Maximum Operating Pressure	Psox,max	25.00	bars
Shell Minimum Operating Pressure	Psox,min	0.00	bars
Shell Thickness	ts	12.7000	mm.
Shell Internal Corrosion Allowance	cas	3.0000	mm.
Shell External Corrosion Allowance	caext	0.0000	mm.
Inside Diameter of Shell	Ds	381.000	mm.
Shell Circumferential Joint Efficiency	Esw	1.000	
Shell Temperature for Internal Pressure	Ts	190.00	°C
Shell Material		SA-106 B	

Note:
Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-106 B

Shell Material UNS Number		K03006	
Shell Allowable Stress at Temperature	Ss	117.90	N./mm^2
Shell Allowable Stress at Ambient		117.90	N./mm^2

Channel Description: CHANNEL 01

Channel Type:		Cylinder	
Channel Maximum Design Pressure	Ptd,max	25.00	bars
Channel Maximum Operating Pressure	Ptox,max	25.00	bars
Channel Minimum Operating Pressure	Ptox,min	0.00	bars
Channel Thickness	tc	12.7000	mm.
Channel Corrosion Allowance	cac	3.0000	mm.
Inside Diameter of Channel	Dc	381.000	mm.
Channel Design Temperature	TEMPC	190.00	°C
Channel Material		SA-106 B	

Note:
Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-106 B

Channel Material UNS Number		K03006	
Channel Allowable Stress at Temperature	Sc	117.90	N./mm^2
Channel Allowable Stress at Ambient		117.90	N./mm^2

Tube Data:

Number of Tube Holes	Nt	166	
Tube Wall Thickness	et	2.1080	mm.
Tube Outside Diameter	D	19.0500	mm.
Total Straight Tube Length	Lt	3000.00	mm.
Straight Tube Length (bet. inner tubsht faces)	L	2908.00	mm.
Design Temperature of the Tubes		190.00	°C
Tube Material		SA-179	
Tube Material UNS Number		K01200	
Is this a Welded Tube		No	
Tube Material Specification used		Smls. tube	
Tube Allowable Stress at Temperature		92.39	N./mm^2
Tube Allowable Stress At Ambient		92.39	N./mm^2
Tube Yield Stress At design Temperature	Syt	154.50	N./mm^2
Tube Pitch (Center to Center Spacing)	P	24.0000	mm.
Tube Layout Pattern		Triangular	

Fillet Weld Leg	af	1.5000	mm.
Groove Weld Leg	ag	1.5000	mm.
Tube-Tubesheet Joint Weld Type		Full Strength	
Method for Tube-Tubesheet Jt. Allow.		UW-20	
Tube-Tubesheet Joint Classification		b-1	f
Radius to Outermost Tube Hole Center	ro	173.770	mm.
Largest Center-to-Center Tube Distance	Ul	34.9000	mm.
Length of Expanded Portion of Tube	ltx	~~35.0000~~	~~mm.~~ 0
Tube-side pass partition groove depth	hg	5.0000	mm.

Tubesheet Data:

tubesheet extended as flange shall be considered and relevant thickness to be considered

Tubesheet TYPE: Fixed Tubesheet Exchanger, Conf B

Tubesheet Design Metal Temperature	T	190.00	°C
Tubesheet Material		SA-266 2	

Note:
Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
Make sure that material properties at this temperature are not time-dependent for Material: SA-266 2

Tubesheet Material UNS Number		K03506	
Tubesheet Allowable Stress at Temperature	S	137.90	N./mm^2
Tubesheet Allowable Stress at Ambient	Tt	137.90	N./mm^2
Thickness of Tubesheet	h	46.0000	mm.
Tubesheet Corr. Allowance (Shell side)	Cats	3.0000	mm.
Tubesheet Corr. Allowance (Channel side)	Catc	3.0000	mm.
Tubesheet Outside Diameter	A	515.000	mm.

Additional Data for Stepped Tubesheets:

Is the Tubesheet Stepped?		YES	
Is the Tubesheet Flat on Tubeside?		NO	
Step 1 Diameter on the Tubeside	dt1	444.00	mm.
Step 1 Depth on the Tubeside	ht1	6.00	mm.
Step 2 Diameter on the Tubeside	dt2	378.00	mm.
Step 2 Depth on the Tubeside	ht2	5.00	mm.
Is the Tubesheet Flat on Shellside?		NO	
Step 1 Diameter on the Shellside	ds1	0.00	mm.
Step 1 Depth on the Shellside	hs1	0.00	mm.
Step 2 Diameter on the Shellside	ds2	378.00	mm.
Step 2 Depth on the Shellside	hs2	5.00	mm.
Calculated Tubesheet Diameter as per UHX-10(b)		378.00	mm.

Note: Tubesheet diameter is now: 378.000 mm. per UHX-10(b).

Area of the Untubed Lanes	AL	128.0	cm^2

Additional Data for Fixed/Floating Tubesheet Exchangers:

Unsupported Tube Span under consideration	l	571.000	mm.
Tube End condition corresponding to Span (l)	k	0.80	
Ignore Radial Thermal Exp. effects (UHX-13.8/14.6)		YES	

Note: The Metal temperatures at the Rim are set to ambient (21 °C)

Tubesheet Metal Temp. at Rim	T'	21.11	°C
Shell Metal Temp. at Tubesheet	T'S	21.11	°C
Channel Metal Temp. at Tubesheet	T'C	21.11	°C
Perform Differential Pressure Design		N	

Run Multiple Load Cases		YES	
Shell Side Min. Design Pressure	Psd,min	1.0342	bars
Channel Side Min. Design Pressure	Ptd,min	1.0314	bars
Mean Shell Metal Temp. along Shell len.	Tsm	56.96	°C
Mean Tube Metal Temp. along Tube length	Ttm	49.96	°C
Junction Stress Reduction option	Perform Plastic Calculation		

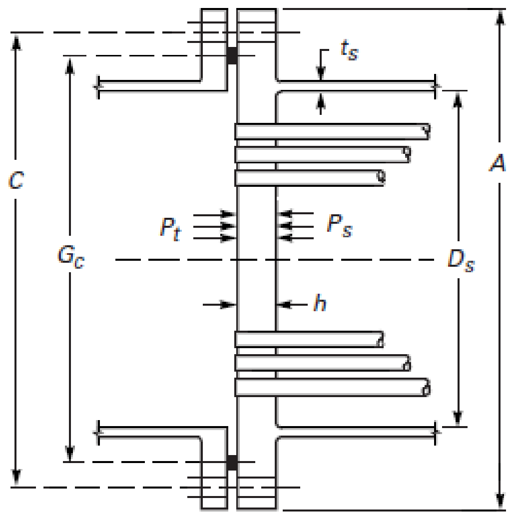
Additional Data for Gasketed Tubesheets:

Tubesheet Gasket on which Side		Channel	
Flange Outside Diameter	A	515.000	mm.
Flange Inside Diameter	B	381.000	mm.
Flange Face Outside Diameter	Fod	447.000	mm.
Flange Face Inside Diameter	Fid	381.000	mm.
Gasket Outside Diameter	Go	444.000	mm.
Gasket Inside Diameter	Gi	404.000	mm.
Small end Hub thk.	g0	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	473.000	mm.
Nominal Bolt Diameter	dB	19.0500	mm.
Type of Thread Series	UNC Thread Series		
Number of Bolts	n	28	

Tubesheet Integral With Shell and Gasketed
With Channel, Extended as a Flange



Configuration b:

```
                                         Bolt Material                                   SA-
193 B7
 Bolt Allowable Stress At Temperature         Sb       172.38  N./mm^2
 Bolt Allowable Stress At Ambient             Sa       172.38  N./mm^2
 Weld between Flange and Shell/Channel                 0.0000  mm.

 Tubesheet Integral with                                Shell
 Tubesheet Extended as Flange                             Yes
 Thickness of Extended Portion of Tubesheet   Tf      30.0000  mm.
 Is Bolt Load Transferred to the Tubesheet                Yes

 Is Exchanger in Creep range (skip EP, Use 3S for Sps)     NO
```

ASME TubeSheet Results per Part UHX, 2017

Elasticity/Expansion Material Properties:

Shell - TE-1 Carbon & Low Alloy Steels, Group 1
Shell - TM-1 Carbon Steels with C<= 0.3%

```
 -----------------------------------------------------------------
 Th. Exp. Coeff. Metal Temp. along Len    57.0 °C    0.0000118233 /°C
 Elastic Mod. at Design Temperature      190.0 °C      0.19308E+09 KPa.
 Th. Exp. Coeff. Metal Temp. at Tubsht    21.1 °C    0.0000115190 /°C
 Elastic Mod. at Metal Temp. along Len    57.0 °C      0.20065E+09 KPa.
 Elastic Mod. at Ambient Temperature      21.1 °C      0.20270E+09 KPa.
```

Channel - TE-1 Carbon & Low Alloy Steels, Group 1
Channel - TM-1 Carbon Steels with C<= 0.3%

```
 -----------------------------------------------------------------
 Th. Exp. Coeff. Metal Temp. at Tubsht    21.1 °C    0.0000115190 /°C
 Elastic Mod. at Design Temperature      190.0 °C      0.19308E+09 KPa.
 Elastic Mod. at Ambient Temperature      21.1 °C      0.20270E+09 KPa.
```

Tubes - TE-1 Carbon & Low Alloy Steels, Group 1

Tubes - TM-1 Carbon Steels with C<= 0.3%

```
 ---------------------------------------------------------------
 Th. Exp. Coeff. Metal Temp. along Len    50.0 °C    0.0000117780 /°C
 Elastic Mod. at Design Temperature      190.0 °C      0.19308E+09 KPa.
 Elastic Mod. at Metal Temp. along Len    50.0 °C      0.20105E+09 KPa.
 Elastic Mod. at Tubsht. Design Temp.    190.0 °C      0.19308E+09 KPa.
 Elastic Mod. at Ambient Temperature      21.1 °C      0.20270E+09 KPa.
```

TubeSheet - TE-1 Carbon & Low Alloy Steels, Group 1
TubeSheet - TM-1 Carbon Steels with C<= 0.3%

```
 ---------------------------------------------------------------
 Th. Exp. Coeff. Metal Temp. at Rim       21.1 °C    0.0000115190 /°C
 Elastic Mod. at Design Temperature      190.0 °C      0.19308E+09 KPa.
 Elastic Mod. at Metal Temp. at Rim       21.1 °C      0.20270E+09 KPa.
 Elastic Mod. at Ambient Temperature      21.1 °C      0.20270E+09 KPa.
```

Note:
The Elasticity and Alpha values are taken from Tables in ASME II D.
Please insure these properties are consistent with the
type of Material for the tubes, shell, channel etc.

Tube Required Thickness under Internal Pressure (Tubeside pressure):

Thickness Due to Internal Pressure:

```
  = (P*(D/2-CAE)) / (S*E+0.4*P) per Appendix 1-1 (a)(1)
  = (26.03*(19.05/2-0.0)/(92.39*1.0+0.4*26.03)
  = 0.2654 + 0.0000 = 0.2654 mm.
```

Tube Required Thickness under External Pressure (Shellside pressure) :

```
 External Pressure Chart     CS-1             at       190.00   °C
 Elastic Modulus for Material                    194843456.00  KPa.
```

Results for Max. Allowable External Pressure (Emawp):

```
     TCA        ODCA      SLEN        D/T        L/D    Factor A         B
   2.1080     19.05    2908.00      9.04    50.0000  0.0134693         93.80
 EMAWP = (2.167/(D/T)-0.0833)*B = 146.7815 bars
```

Results for Reqd Thickness for Ext. Pressure (Tca):

```
     TCA        ODCA      SLEN        D/T        L/D    Factor A         B
   0.5486     19.05    2908.00     34.73    50.0000  0.0009121         67.81
 EMAWP = (4*B)/(3*(D/T)) = ( 4 *67.811 )/( 3 *34.7278 ) = 26.0338 bars
```

Summary of Tube Required Thickness Results:

```
 Total Required Thickness including Corrosion all.          0.5486  mm.
 Allowable Internal Pressure at Corroded thickness          224.32  bars
 Required Internal Design Pressure                           26.03  bars
 Allowable External Pressure at Corroded thickness          146.78  bars
 Required External Design Pressure                           26.03  bars
 Required Thickness due to Shell Side pressure              0.5486  mm.
```

Detailed Results for load Case D3 un-corr. (Psd,max + Ptd,max)

Intermediate Calculations For Tubesheets Extended As Flanges:

ASME Code, Section VIII Division 1, 2017

```
 Gasket Contact Width,       N = (Goc-Gic) / 2            20.000  mm.
 Basic Gasket Width,        b0 = N / 2.0                  10.000  mm.
```

```
Effective Gasket Width,     b = SQRT(b0) * 2.5           7.966  mm.
Gasket Reaction Diameter,   G = Go-2.0*b               428.068  mm.
```

Bolting Information for UNC Thread Series (Non Mandatory):

```
Distance Across Corners for Nuts                     35.128  mm.
Circular Wrench End Diameter                   a     52.388  mm.
```

	Minimum	Actual	Maximum
Bolt Area, cm^2	50.206	54.555	
Radial Distance between Hub and Bolts:	20.637	33.300	
Radial Distance between Bolts and Edge:	20.637	21.000	
Circ. Spacing between the Bolts:	44.450	52.959	68.100

```
Flange Design Bolt Load, Seating Condition    W  :      902.83  kN
Flange Design Bolt Load, Operating Condition  Wm1:      622.88  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 )
  = 35.0/46.0 = 0.7609 ( must be 0 <= rho <= 1 )
```

Compute the Effective Tube Hole Diameter [d*]:
```
  = Max( dt - 2tt*( Et/E )( StT/S )( rho ), dt - 2tt)
  = Max( 19.05 -2*2.108 *(.19308E+09/.19308E+09)*
    ( 92/137 )*( 0.761 ), 19.05 -2*2.108 )
  = 16.9008 mm.
```

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
```
  = 2 * ro + dt = 2 * 173.77 + 19.05 = 366.59 mm.
```

Determine the Basic Ligament Efficiency for Shear [mu]:
```
  = (p - dt)/p = (24.0 - 19.05 )/24.0 = 0.2063
```

Compute the Equivalent Outer Tube Limit Radius [ao]:
```
  = Do/2 = 366.59/2 = 183.295 mm.
```

Compute the Effective Tube Pitch [p*]:
```
  = p / sqrt( 1 - 4 * min( AL * CNV_factor, 4*Do*p)/(Pi * Do²) )
  = 24.0/sqrt( 1 - 4 * min( 128.0 *100.0, 4*366.59 *24.0 )/( 3.141 * 366.59²) )
  = 25.6026 mm.
```

Compute the Effective Ligament Efficiency for Bending [mu*]:
```
  = (p* - d*)/p* = (25.6026 - 16.9008 )/25.6026 = 0.3399
```

Compute the Ratio [Rhos]:
```
  = as/ao = 190.5/183.295 = 1.039308
```

Compute the Ratio [Rhoc]:
```
  = ac/ao = 214.0342/183.295 = 1.167704
```

Compute Parameter [xt]:
```
  = 1 - Nt * (( dt - 2 * tt )/( 2 * ao ))²
```

```
  = 1 - 166 * ((19.05 - 2 * 2.108 )/(2 * 183.295 ))^2 = 0.7282
```

Determine Parameter [xs]:
```
  = 1 - Nt*( dt/(2*ao) )^2
  = 1 - 166 *( 19.05/(2*183.295 ) )^2 = 0.5517
```

Determine the Value [h'g]:
```
  = Max(( hg - CATC ), 0 )  (For pressure only cases)
  = Max(( 5.0 - 0.0 ), 0 ) = 5.0 mm.
```

UHX-13.5.2 Step 2:

Determine the Axial Shell Stiffness [Ks]:
```
  = pi * ts( Ds + ts )Es/L
  = 3.1416 * 12.7 ( 381.0 + 12.7 ).19308E+09/2908.0
  = 1042931072.0000 KPa. * mm.
```

Determine the Axial Tube Stiffness [Kt]:
```
  = pi * tt( Dt - tt )Et/L
  = 3.1416 * 2.108 ( 19.05 - 2.108 ).19308E+09/2908.0
  = 7449408.0000 KPa. * mm.
```

Compute the Stiffness Factor [Ks,t]:
```
  = Ks/( Nt * Kt ) = 0.10429E+1/( 166 * 7449408 ) = 0.84338
```

Rigidty Ratio [J]:
```
  = 1 / ( 1 + Ks/Kj )
  = 1/(1 + 0.10429E+1/0.0 ) = 1. (= 1 if No Exp. Jt.)
```

Compute Shell Coefficient [betas]:
```
  = (( 12 * (1-nus^2))^0.25 )/((Ds + ts) * ts )^0.5
  = (( 12 * (1 - 0.3^2) )^0.25 )/(( 381.0 + 12.7 ) * 12.7 )^0.5
  = 0.0257 1/mm.
```

Determine Shell Coefficient [ks]:
```
  = betas * Es * ts^3 / ( 6 * (1 - nus^2) )
  = 0.026 * 0.19308E+09 * 12.7^3/( 6 * (1 - 0.3^2) )
  = 18621754.0000 bars*mm.^2
```

Determine Shell Coefficient [Lambdas]:
```
  = (6*Ds*ks)/(h^3) * (1 + h*betas + 0.5*(h*betas)^2)
  = 6*381.0 *18621754/(46.0^3) * ( 1 + 46.0 * 0.026 + 0.699 )
  = 1260346.6250 bars
```

Determine Shell Coefficient [deltaS]:
```
  = Ds^2/(4 * Es * Ts) * ( 1 - nus/2 )
  = 381.0^2/( 4 * 0.19308E+09 * 12.7 ) * ( 1 - 0.3/2 )
  = 0.0125790816 mm./N./mm^2
```

Intermediate parameters for Tubesheet Gasketed on the Channel Side:
betac, kc, deltaC, Lambdac = 0

UHX-13.5.3 Step 3:

E*/E and nu* for Triangular pattern from Fig. UHX-11.3.
```
   h/p =   1.916667 ;  mu* =   0.339881
  E*/E =   0.336955 ;  nu* =   0.328482 ;  E* = 65058264. KPa.
```

Compute the Tube Bundle Stiffness Factor [Xa]:
```
  = ((24 *(1 - nu*^2)*Nt * Et* tt* (dt - tt)* ao^2) /
    ( E* * L * H^3 ) )^0.25
```

```
  = ((24 *(1 - 0.328²)*166 *.19308E+09*2.108 *
    (19.05 - 2.108 )*183.295²)/( 65058264 *
    2908.0 * 46.0³ ))^0.25
  = 2.5859
```

Values from Table UHX-13.1
```
  Zd =       0.083130 ;  Zv =       0.131082 ;  Zm =       0.580632
  Za =   0.137874E+01 ;  Zw =       0.131082
```

UHX-13.5.4 Step 4:

Compute the Diameter Ratio [K]:
```
  = A/Do = 378.0/366.59 = 1.0311
```

Compute Coefficient [F]:
```
  = (1 - nu*) / (E*) * ( Lambdas + Lambdac + E * ln(K) )
  = (1 - 0.33 )/(65058264 ) * ( 1260346 + 0.0 +
    0.19308E+09 * ln(1.03 ) )
  = 1.3620
```

Compute Parameter [Phi]:
```
  = (1 + nu*) * F = (1 + 0.3285 ) * 1.362 = 1.8094
```

Compute Parameter [Q1]:
```
  = (Rhos - 1 - Phi * Zv)/(1 + Phi * Zm)
  = (1.0393 - 1 - 1.8094 * 0.1311 )/(1 + 1.8094 * 0.5806 )
  = -0.096494138
```

Compute Parameter [Qz1]:
```
  = (Zd + Q1*Zw)/2 *Xa⁴
  = ( 0.08313 + -0.09649 * 0.13108 )/2 *2.58587⁴ = 1.5757
```

Compute Parameter [Qz2]:
```
  = (Zv + Q1*Zm)/2 *Xa⁴
  = ( 0.13108 + -0.09649 * 0.58063 )/2 *2.58587⁴ = 1.6779
```

Compute Parameter [U]:
```
  = (Zw + (Rhos - 1)*Zm)*Xa⁴ / (1 + Phi*Zm)
  = ( 0.1311 + (1.0393 - 1)* 0.5806 )*2.58587⁴/(1 + 1.8094 * 0.5806 )
  = 3.3559
```

UHX-13.5.5 Step 5:

Determine factor [gamab]:
```
  = ( Gc - C ) / Do (config b)
  = (428.0685 - 473.0 )/366.59 = -0.12257
```

Compute Parameter [gamma]:
```
  = 0.000 mm. (For Pressure only cases)
```

Calculate Parameter [OmegaS]:
```
  = rhos * ks * Betas * deltaS( 1 + h * Betas )
  = 1.0393 * 18621754 * 0.0257 * 0.012579 ( 1 + 46.0 * 0.0257 )
  = 1366.0907 mm.²
```

Calculate Parameter [Omega*S]:
```
  = Ao² * ( Rhos² - 1 ) * ( Rhos - 1 ) / 4 - OmegaS
  = 183.295² * ( 1.039² - 1 ) * ( 1.039 - 1 )/4 - 1366.091
  = -1339.6246 mm.²
```

Calculate Parameter [OmegaC]:

```
  = rhoc * kc * Betac * deltaC( 1 + h * Betac )
  = 1.1677 * 0.0 * 0.0 * 0. ( 1 + 46.0 * 0.0 )
  = 0.0000 mm.²
```

Calculate Parameter [Omega*C]:

```
  = ao²[( Rhoc²+1 )*( Rhoc-1 )/4 -(Rhos-1)/2]- OmegaC
  = 183.295²[( 1.1677²+1 )*( 1.1677 -1 )/4 -(1.03931 -1)/2]- 0.
  = 2668.9180 mm.²
```

Compute the Pressure [P*S]:
 = 0 For Pressure only cases or Configurations d,e,f,A,B,C,D

Compute the Pressure [P*C]:
 = 0 For Pressure only cases or Configurations b,c,d,B,C,D

UHX-13.5.6 Step 6:

Compute the Pressure [P's]:

```
  = Ps * {xs + 2( 1 - xs )nut + [2/Kst(Ds/Do)²]nus -
    [(rhos²-1)/(J*Kst)]-[(1-J)/(2J*Kst)][(Dj²-(Ds)²)/Do²]}
  = 25.0 * { 0.552 + 2( 1 - 0.552 ) 0.3 +
    [2/0.843 (381.0/366.59 )²] 0.3 -
    [(1.039²-1)/( 1.0 * 0.843 )] -
    [(1 - 1.0 )/(2 * 1.0 * 0.843 )][(0.0²-(381.0 )²)/366.59²]}
  = 37.3523 bars
```

Compute the Pressure [P't]:

```
  = [ xt + 2(1 - xt)nut + 1/(J * Kst) ]*Pt
  = [ 0.728 + 2(1 - 0.728 ) 0.3 +
    1/(1. * 0.843 ) ]* 25.0
  = 51.9244 bars
```

Compute the Pressure [Pgama]:

```
  = Nt * Kt * gama / ( pi * ao² )
  = 166 * 7449408 * 0.0/(3.142 * 183.295²) = 0.0 bars
```

Compute the Pressure [Pw]:

```
  = -gamab * U * W* / (2 * pi * ao²)
  = --0.123 * 3.356 * 622.88/(2 * 3.142 * 183.295²)
  = 12.1371 bars
```

Calculate the Pressure [Prim]:

```
  = -( U/ao²)(Omega*S * Ps - Omega*C * Pt )
  = -( 3.356/183.295²)(-2.076 * 25.0 - 4.137 * 25.0 )
  = 10.0100 bars
```

Calculate the Pressure [POmega]:

```
  = U/ao²(OmegaS * P*s - OmegaC * P*c )
  = 3.356/183.295²( 2.1174 * 0.0 - 0.0 * 0.0 )
  = 0.0000 bars
```

Determine the Effective Pressure [Pe]:

```
  = J * Kst / (1 + J * Kst *(Qz1 + (Rhos - 1) * Qz2)) *
    (P's - P't + Pgama + Pw + Prim )
  = 0.1000E+01 * 0.843/(1 + 1.0 * 0.843 *(1.576 + (1.039 -
    1) * 1.678 )) * (37.352 - 51.924 + 0.0 + 12.137 + 10.01 )
  = 2.6792 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)
  = [( ( -1339.625 * 25.0 - 2668.918 * 25.0 ) -
    ( 1366.091 * 0.0 - 0.0 * 0.0 )) * 0. +
    622.9 * -0.123/(2*3.141)]/(1 + 1.80937 * 0.58063 )
  = -10.812397003 kN
```

Calculate Factor [Q3]:

```
  = Q1 + 2 * Q2 / ( Pe * ao² )
  = -0.096 + 2 * -10.812/( 2.679 * 183.295² )
  = -2.498946
```

Fm Value from Table UHX-13.1 = 1.249473

The Tubesheet Bending Stress - Original Thickness [Sigma]:

```
  = (1.5 * Fm / mu* ) * (2 * ao/(H - h'g)² * Pe
  = (1.5 * 1.2495/0.3399 ) * (2 * 183.295/(46.0 - 5.0 ))² * 2.68
  = 118.1185 N./mm^2
```

The Allowable Tubesheet Bending Stress [Sigma allowed]:

```
  = 1.5 * S = 1.5 * 137.9 = 206.85 N./mm^2
```

The Tubesheet Bending Stress - Final Thickness [Sigmaf]:

```
  = (1.5 * Fm/mu*) * (2 * ao/( h - h'g)² * Pe
  = (1.5 * 0.5146/0.3399 ) * (2 * 183.295/(32.983 - 5.0 ))² * 5.31
  = 206.8425 N./mm^2
```

Reqd Tubesheet Thickness, for Bending Stress (Including CA) [HReqB]:

```
  = h + Cats + Catc = 32.9827 + 0.0 + 0.0 = 32.9827 mm.
```

UHX-13.5.8 Step 8:

Shear Stress check [Tau_limit]:

```
  = 1.6 * S * MU * h / ao
  = 1.6 * 137.9 * 0.206 * 46.0/183.29
  = 11.4205 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.)= 3.8684 mm.
  Tubesheet Shear Stress           = 29.7726 N./mm^2
```

Reqd Tubesheet Thickness for Given Loadings (Including CA) [Hreqd] :

```
  = Max( HreqB, HreqS ) = Max( 32.9827, 3.8684 ) = 32.9827 mm.
```

UHX-13.5.9 Step 9:

The Ftmin and Ftmax Coefficients from Table UHX-13.2:

```
  Ftmin = -5.4647, Ftmax = 6.3486
```

First Extreme Tube Axial Stress from among all the tubes [Sigmat1]:

```
  = ( (Ps * xs - Pt * xt) - Pe * Ftmin ) / ( Xt - Xs )
  = ( (25.0 * 0.5517 - 25.0 * 0.7282 ) - (2.679 ) * -5.465 )/
    ( 0.7282 - 0.5517 ) )
  = 5.7976 N./mm^2
```

Second Extreme value of Tube Axial Stress from among all the tubes [Sigmat2]:

```
  = ( (Ps * xs - Pt * xt) - Pe * Ftmax ) / ( Xt - Xs )
  = ( (25.0 * 0.5517 - 25.0 * 0.7282 ) - (2.679 ) * 6.349 )/
```

```
    ( 0.7282 - 0.5517 ) )
  = -12.1399 N./mm^2
```

Maximum Tube Axial Stress [Sigmat,max]:

```
  = MAX( abs(Sigmat1), abs(Sigmat2) ) = 12.14 N./mm^2
```

The Allowable Tube Stress, [SigmatA]:

```
  = Sot = 92.3930 N./mm^2
```

Check for Buckling as some of the Tubes are in Compression

Determine the Factor of Safety [Fs]:

```
  = Max( (3.25 - 0.25*(Zd + Q3*Zw)*Xa^4 ), 1.25 )
  = Max((3.25 - 0.25*( 0.083 + -2.499 * 0.131 )*2.586^4), 1.25 )
  = 2.0000 (Should be <= 2 )
```

Determine the Factor [rt]:

$= ((dt^2 + (dt - 2*tt)^2)^{.5})/4$

$= ((19.05^2 + (19.05 - 2*2.108)^2)^{.5})/4 = 6.0361$ mm.

Determine the Factor [Ct]:

$= (2 * PI^2 * Et/Syt)^{0.5}$

$= (2 * 3.14^2 * 0.19308E+09/154)^{0.5} = 157.0623$

Determine the Factor [Ft]:

```
  = k * L/r = 0.8 * 571.0/6.036 = 75.6781
```

The Buckling Allowable Stress [Stb]:

```
  = Sy,t/Fs*( 1 - Ft/(2*Ct) )
  = 154/2.0 *( 1 - 75.678/(2*157.062 ) )
  = 58.641 N./mm^2    (Never greater than Sot)
```

Note: The Axial Compressive stress in Tubes is within limits.

The Largest tube-to-tubesheet Joint Load [Wt]:

```
  = Sigmat,max * Tube Area = 12.14 * 1.122 = 1.36 kN
```

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:

```
  = 3.1415 * t * ( do - t ) * Sa
  = 3.1415 * 2.108 * ( 19.05 - 2.108 ) * 92.39 = 10.365 kN
```

Fillet Weld Strength [Ff]:

```
  = 0.55 * 3.1415 * af * (do + 0.67*af) * Sw (but not > Ft)
  = 0.55 * 3.1415 * 1.5 * (19.05 + 0.67*1.5 ) * 92.39
  = 4.8021  kN
```

Groove Weld Strength [Fg]:

```
  = 0.85 * 3.1415 * ag * (do + 0.67*ag) * Sw (but not > Ft)
  = 0.85 * 3.1415 * 1.5 * (19.05 + 0.67*1.5 ) * 92.39
  = 7.4214  kN
```

```
 Max. Allow. Tube-Tubesheet Joint load, Lmax
  = Ft = 10.3654 kN
```

Design Strength Ratio [fd]:

```
  = 1.0000
```

Weld Strength Factor [fw]:

```
  = Sot / ( Min(Sot, S) ) = 1.0000
```

Min Weld Length [ar]:
```
  = 2 *( ( (0.75 * do)² + 1.07*t*(do - t)* fw * fd ) )½ - 0.75 * do)
  = 2.5600  mm.

 Minimum Required Fillet Weld Leg            afr      1.2800  mm.
 Minimum Required Groove Weld Leg            agr      1.2800  mm.

 Tube-Tubesheet Jt allowable, 10.37 is >= tube strength 10.37 kN
```
Note: This tube-tubesheet joint is a Full Strength joint

UHX-13.5.10 Step 10:

Shell Axial Membrane Allowable Stress:
```
  = Ss * Esw = 117.9 * 1.0 = 117.9 N./mm^2
```

Axial Membrane Stress in Shell [Sigmas,m]:
```
  = ao²/((Ds+ts)*ts)* [Pe + (Rhos²-1)(Ps-Pt)]+ as²*Pt/((Ds+ts)*ts)
  = 183.295²/((381.0 +12.7 )*12.7 )* [2.68 + (1.039²-1)
    (25.0 -25.0 )] + 190.5²*25.0/((381.0 +12.7 )
    * 12.7 )
  = 19.9466 N./mm^2
```

UHX-13.5.11 Step 11:

Note:
For a given Shell thickness of 12.7 mm., the minimum Shell
length adjacent to the tubesheet should be 125.209 mm.

The Shell Membrane Stress due to Joint Interaction [Sigmas,m]:
```
  = ao²/((Ds+ts)*ts)[Pe + (Rhos²-1)(Ps-Pt)]+ as²*Pt/((Ds+ts)*ts)
  = 183.295²/((381.0 +12.7 )*12.7 )[2.68 + (1.039²-1)
    (25.0 -25.0 )] + 190.5²*25.0/((381.0 +12.7 )
    * 12.7 )
  = 19.9466 N./mm^2
```

The Shell Bending Stress due to Joint Interaction [Sigmasb]:
```
  = 6*ks/ts² {betas[deltaS*Ps + as²*PstarS/(Es*ts)] +
    6(1 - nu*²)/(E*)(ao/h)³(1 + h*betas/2)[Pe(Zv + Zm*Q1) +
    2/ao² * Zm * Q2 ]}
  = 6 * 18621754/12.7² { 0.026 [ 0.013 * 25.0 + 190.5²
    * 0.0/(.24521E+1 ) ] +
    6(1 - 0.33²)/(65058264 )(183.29/46.0 )³(1 + 46.0 *
    0.03/2)[ 2.7 ( 0.131 + 0.581 * -0.096 ) +
    2/183.29² * 0.581 * -10.812 ] }
  = -146.9078 N./mm^2
```

Shell Stress Summation vs. Allowable
```
  abs(Sigmasm) + abs(Sigmasb) <= 1.5 * Ss
  abs(19.9 ) + abs(-146.9 ) <= 176.86 N./mm^2
  166.85 must be < or = 176.86 N./mm^2
```

Computations Completed for ASME Tubesheet Configuration b

Stress/Force Summary for Loadcase D3 un-corr. (Psd,max + Ptd,max):

Stress Description	Actual		Allowable	Pass/Fail
Tubesheet Bend. Stress	118.1	<=	206.9 N./mm^2	Ok
Tubesheet Shear Stress	2.6	<=	110.3 N./mm^2	Ok

Maximum Tube Stress	12.1	<=	92.4 N./mm^2	Ok
Minimum Tube Stress (Buckling)	-12.1	<=	-58.6 N./mm^2	Ok
Maximum Force on any one Tube	1.4	<=	10.4 kN	Ok
Axial Membrane Stress in Shell	19.9	<=	117.9 N./mm^2	Ok
Shell Stress (jt. inter.)	166.9	<=	176.9 N./mm^2	Ok

Thickness Results for Loadcase D3 un-corr. (Psd,max + Ptd,max):

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	32.983	46.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.280	1.500	Ok
Tube-Tubesheet Groove Weld Leg :	1.280	1.500	Ok

Fixed Tubesheet results per ASME UHX-13 2017

Results for 16 Load Cases:

Case#	--Reqd. Thk. + CA Tbsht	Extnsn	---- Tubesheet Stresses Bend	Allwd	Shear	Allwd	Case Type		Pass/ Fail
D1uc	26.909	25.552	106	207	12	110	Ps+Pt-Th	D1	Ok
D2uc	19.550	...	43	207	15	110	Ps+Pt-Th	D2	Ok
D3uc	32.983	...	118	207	3	110	Ps+Pt-Th	D3	Ok
D4uc	5.925	...	2	207	...	110	Ps+Pt-Th	D4	Ok
O1uc	8.512	...	113	428	19	110	Ps+Pt+Th	O1	Ok
O2uc	12.554	...	99	428	10	110	Ps+Pt+Th	O2	Ok
O3uc	6.688	...	110	428	5	110	Ps+Pt+Th	O3	Ok
O4uc	7.403	...	70	428	4	110	Ps+Pt+Th	O4	Ok
D1c	36.730	25.552	141	207	10	110	Ps+Pt-Th-c	D1	Ok
D2c	19.386	...	41	207	15	110	Ps+Pt-Th-c	D2	Ok
D3c	38.937	...	150	207	5	110	Ps+Pt-Th-c	D3	Ok
D4c	9.810	...	2	207	...	110	Ps+Pt-Th-c	D4	Ok
O1c	21.418	...	157	428	16	110	Ps+Pt+Th-c	O1	Ok
O2c	24.361	...	142	428	14	110	Ps+Pt+Th-c	O2	Ok
O3c	25.812	...	165	428	1	110	Ps+Pt+Th-c	O3	Ok
O4c	20.018	...	112	428	...	110	Ps+Pt+Th-c	O4	Ok
Max:	38.9374	25.552	mm.	0.726		0.174	(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	8	117	...	...	...	...	...	...	Ok
D2uc	11	117	...	...	...	...	...	...	Ok
D3uc	20	117	...	...	...	...	...	...	Ok
D4uc	1	117	-1	-114	...	...	...	...	Ok
O1uc	3	416	...	...	...	...	...	...	Ok
O2uc	8	416	...	...	...	...	...	...	Ok
O3uc	14	416	...	...	...	...	...	...	Ok
O4uc	3	416	-3	-114	...	...	...	...	Ok
D1c	14	117	...	...	...	...	...	...	Ok
D2c	13	117	...	...	...	...	...	...	Ok
D3c	28	117	...	...	...	...	...	...	Ok
D4c	1	117	-1	-111	...	...	...	...	Ok
O1c	9	416	...	...	...	...	...	...	Ok
O2c	14	416	...	...	...	...	...	...	Ok
O3c	23	416	...	...	...	...	...	...	Ok
O4c	...	416	...	...	...	...	...	...	Ok
Max RATIO		0.238		0.023		...		...	

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	16	92	-16	-64	2	10	245	416	...	...	Ok
D2uc	4	92	-4	-58	...	10	102	176	...	...	Ok
D3uc	12	92	-12	-58	1	10	167	176	...	...	Ok
D4uc	...	92	...	-92	...	10	3	176	...	...	Ok
O1uc	19	184	-17	-60	2	20	324	416	...	...	Ok
O2uc	9	184	-3	-58	1	20	110	416	...	...	Ok
O3uc	16	184	-13	-92	2	20	249	416	...	...	Ok
O4uc	12	184	-7	-92	1	20	190	416	...	...	Ok
D1c	21	92	-21	-92	2	10	317	416	...	...	Ok
D2c	7	92	-4	-58	1	10	141	176	...	...	Ok
D3c	15	92	-15	-58	2	10	206	416	...	...	Ok
D4c	...	92	...	-92	...	10	3	176	...	...	Ok
O1c	24	184	-24	-92	3	20	416	416	...	...	Ok
O2c	9	184	-4	-58	1	20	131	416	...	...	Ok
O3c	18	184	-18	-92	2	20	310	416	...	...	Ok
O4c	13	184	-10	-58	1	20	237	416	...	...	Ok
Max RATIO	0.231			0.282		0.231		1.000		...	

Summary of Thickness Comparisons for 16 Load Cases:

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	38.937	46.000	Ok
Tubesheet Thickness Flanged Extension :	25.552	30.000	Ok
Tube Thickness :	0.549	2.108	Ok
Tube-Tubesheet Fillet Weld Leg :	1.280	1.500	Ok
Tube-Tubesheet Groove Weld Leg :	1.280	1.500	Ok

Min Shell length of thk, (12.700) adj. to tubesheet: 125.209 mm.

Note: This is a full strength Tube to Tubesheet Joint.

Summary of Axial Differential Expansion between Shell and Tubes :

Due to Thermal Expansion Shell Compresses by : -0.245 mm.
Due to Pressure Shell Compresses by : -0.045 mm.
Due to Pressure + Thermal Shell Compresses by : -0.290 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	39.548	1.000	124.138	1.000
Tubesheet Shear Stress	193.537	1.000	191.922	1.000
Tube Tensile Stress	109.468	1.000	369.622	1.000
Tube Compressive Stress	100.151	1.000	367.600	1.000
Tube-Tubesheet Joint load	109.468	1.000	369.623	1.000
Shell Stress (Axial, Junction)	24.791	0.996	77.604	1.000
Tube Pressure Stress	224.322	1.000	146.781	1.000
Tubesheet Extension Stress	37.739	...	No Calc	No Calc
Minimum MAWP	24.791		77.604	

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	50.222	1.000	124.861	0.988
Tubesheet Shear Stress	243.700	1.000	198.340	1.000
Tube Tensile Stress	142.986	1.000	575.419	1.000
Tube Compressive Stress	116.473	1.000	488.954	1.000
Tube-Tubesheet Joint load	142.986	1.000	575.419	1.000
Shell Stress (Axial, Junction)	43.960	1.000	124.861	1.000
Tube Pressure Stress	224.322	1.000	149.973	1.000
Tubesheet Extension Stress	37.739	...	No Calc	No Calc
Minimum MAPnc	37.739		124.861	

(*) 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(46.0/4, min(46.0, 12.7))
= 12.700 mm.

Thickness Ratio = 0.662, Temperature Reduction per Fig. UCS 66.1 = 19 °C

Min Metal Temp. w/o impact per UCS-66, Curve B -21 °C
Min Metal Temp. at Required thickness (UCS 66.1) -40 °C

```
 Min Metal Temp. w/o impact per UG-20(f)                    -29 °C
```

Channel Side MDMT calculation:

Governing thickness for the channel side:

```
  = tubesheet thickness/4
  = 46.0/4
  = 11.500 mm.
```

Thickness Ratio = 0.662, Temperature Reduction per Fig. UCS 66.1 = 19 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B             -24 °C
 Min Metal Temp. at Required thickness (UCS 66.1)           -43 °C
 Min Metal Temp. w/o impact per UG-20(f)                    -29 °C
```

where the MDMT reduction ratio per UCS 66 (b)(1)(b) is:

```
  = max( pt/Tubeside MAPnc, ps/Shellside MAPnc ), must be <= 1
  = max( 25.0/37.74, 25.0/124.86 )
  = 0.662
```

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-1 AB OIL COOLER
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for OIL COOLER E-PK6101-1AB --
MDMT Summary: Step: 23 8:06am Dec 23,2021

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]	B	-26	-48	-29	0.513	11.113	1.00	No
S2	[1]	B	-29	-48	-29	0.512	10.000	1.00	No
Nozzle Flg	[4]	B	-29	-104					
S1	[1]	B	-29	-48	-29	0.512	10.000	1.00	No
Nozzle Flg	[4]	B	-29	-104					
S3	[1]	B	-29	-48	-29	0.513	10.000	1.00	No
Nozzle Flg	[4]	B	-29	-104					
Tubesheet: SS	[13]	B	-21	-40	-29	0.662	12.700	1.00	No
Warmest MDMT:			-21	-40					
BODY FLANGE 0	[11]	B	-29	-48	-29	0.436	10.000	1.00	No
BODY FLANGE 0	[11]	B	-26	-48	-29	0.436	11.113	1.00	No
HEAD 1	[10]	D	-48	-48	-29	0.425	11.113	1.00	No
HEAD 1	[7]	D	-48	-104	-29	0.323	14.000	1.00	No
CHANNEL 01	[8]	B	-26	-47	-29	0.622	11.113	1.00	No
CHANNEL 002	[8]	B	-26	-48	-29	0.513	11.113	1.00	No
HEAD 002	[10]	D	-48	-48	-29	0.425	11.113	1.00	No
HEAD 002	[7]	D	-48	-104	-29	0.323	14.000	1.00	No
T2	[1]	B	-29	-48	-29	0.512	10.000	1.00	No
Nozzle Flg	[4]	B	-29	-104					
T1	[1]	B	-29	-48	-29	0.513	10.000	1.00	No
Nozzle Flg	[4]	B	-29	-104					
T4	[1]	B	-26	-48	-29	0.512	11.113	1.00	No
Nozzle Flg	[4]	!	-46	-104					
T3	[1]	B	-26	-48	-29	0.513	11.113	1.00	No
Nozzle Flg	[4]	!	-46	-104					
Tubesheet: CS	[14]	B	-24	-43	-29	0.662	11.500	1.00	No
Bolting	[21]		-48						
Bolting	[21]		-48						
Warmest MDMT:			-24	-43					

Exchanger Side	Computed MDMT °C	Required MDMT °C	Pass/Fail
Shell	-40.0	-10.0	Pass
Channel/Tube	-43.0	-10.0	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-PK6101-1 AB   OIL COOLER
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for OIL COOLER E-PK6101-1AB   --
Vessel Design Summary: Step: 24 8:06am Dec 23,2021

ASME Code, Section VIII Division 1, 2017

```
Diameter Spec : 381.000 mm. ID
Vessel Design Length, Tangent to Tangent          3902.35  mm.

Specified Datum Line Distance                       50.00  mm.

Shell  Side  Design Temperature                       120  °C
Channel Side Design Temperature                       190  °C

Shell  Side  Design Pressure                       25.000  bars
Channel Side Design Pressure                       25.000  bars

Wind Design Code                               ASCE-2010
Earthquake Design Code                       ASCE 7-2010
```

Materials of Construction:

Component Type	Material	Class	Thickness	UNS #	Normalized	Impact Tested
Shell	SA-106 B	...	...	K03006	No	No
Head	SA-516 70	...	...	K02700	Yes	No
Flange	SA-266 2	...	...	K03506	No	No
Nozzle	SA-106 B	...	...	K03006	No	No
Nozzle	SA-350 LF2	1	...	K03011	No	Yes
Re-Pad	SA-516 70	...	...	K02700	No	No
Nozzle Flg	SA-105	...	...	K03504	No	No
Nozzle Flg	SA-350 LF2	1	...	K03011	No	Yes
Tubes	SA-179	...	...	K01200	No	No
Tubesheet	SA-266 2	...	...	K03506	No	No
Flg Bolting	SA-193 B7	...	<= 2 1/2	G41400	No	No
Hrz Bolting	SA-193 B7	...	2 1/2 < t <= 4	G41400	No	No

Normalized is determined based on the UCS-66 material curve selection and Figure UCS-66.
Impact Tested is based on material selection and material data properties.

Element Pressures and MAWP (bars & mm.):

Element Description or Type	Design Pressure + Stat. head	Ext. Press.	Element M.A.W.P	Corrosion Allowance	Str. Flg. Gov.	In Creep Range
HEAD 1	25.038	1.10	No Calc	3.0000	No	No
CHANNEL 01	25.038	1.10	No Calc	3.0000	N/A	No
BODY FLANGE 01	25.037	1.10	No Calc	3.0000	N/A	No
SHELL	25.033	1.10	No Calc	3.0000	N/A	No
BODY FLANGE 002	25.037	1.10	No Calc	3.0000	N/A	No
CHANNEL 002	25.038	1.10	No Calc	3.0000	N/A	No
HEAD 002	25.038	1.10	No Calc	3.0000	No	No

Liquid Level: 381.00 mm. Dens.: 0.001 kg./cm^3   Sp. Gr.: 1.000

Element Types and Properties:

Element Type	"To" Elev mm.	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	14.0	11.1	6.4	4.5	1.00	0.85

Cylinder	321.0	321.0	12.7	11.1	7.2	4.3	1.00	1.00
Body Flg	395.0	74.0	79.0	48.0	45.1	45.1	1.00	1.00
Cylinder	3355.2	2908.0	12.7	11.1	7.2	6.1	1.00	1.00
Body Flg	3435.4	74.0	79.0	48.0	41.4	41.4	1.00	1.00
Cylinder	3802.4	321.0	12.7	11.1	7.2	4.3	1.00	1.00
Ellipse	3852.4	50.0	14.0	11.1	6.4	4.5	1.00	1.00

Saddle Parameters:

Saddle Width	140.000	mm.
Saddle Bearing Angle	120.000	deg.
Centerline Dimension	500.000	mm.
Wear Pad Width	200.000	mm.
Wear Pad Thickness	10.000	mm.
Wear Pad Bearing Angle	132.000	deg.
Distance from Saddle to Tangent	500.000	mm.
Baseplate Length	370.000	mm.
Baseplate Thickness	12.000	mm.
Baseplate Width	150.000	mm.
Number of Ribs (including outside ribs)	2	
Rib Thickness	10.000	mm.
Web Thickness	10.000	mm.
Height of Center Web	275.000	mm.
Number of Bolts in Baseplate	2	

Baseplate Sketch

```
|------------------- 370.000 mm. --------------------|
----------------------------------------------------- ---
|                                                    |
|                                                    | 150.000 mm.
|                                                    |
----------------------------------------------------- ---
```

Baseplate Plan View

```
----------------------------------------------------- ---
|                                                    | 12.000 mm.
----------------------------------------------------- ---
```

Baseplate Side View

Maximum Tensile Bolt Load	0.	kN

Summary of Maximum Saddle Loads, Operating Case :

Maximum Vertical Saddle Load	16.96	kN
Maximum Transverse Saddle Shear Load	2.03	kN
Maximum Longitudinal Saddle Shear Load	4.06	kN

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

Maximum Vertical Saddle Load	20.52	kN
Maximum Transverse Saddle Shear Load	8.30	kN
Maximum Longitudinal Saddle Shear Load	5.79	kN

Summary of Maximum Saddle Loads, Hydrotest Case :

Maximum Vertical Saddle Load	10.56	kN
Maximum Transverse Saddle Shear Load	0.29	kN
Maximum Longitudinal Saddle Shear Load	0.09	kN

Local Stress Analysis Results:

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:E-PK6101-1 AB   OIL COOLER
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for OIL COOLER E-PK6101-1AB   --
Vessel Design Summary: Step: 24   8:06am Dec 23,2021

Description	Analysis Type	Max Stress Ratio	Pass Fail
T2	WRC-107/537	0.517	Passed
T1	WRC-107/537	0.517	Passed
S2	WRC-107/537	0.517	Passed
S1	WRC-107/537	0.517	Passed
S3	WRC-107/537	0.517	Passed

Weights:

Fabricated	- Bare W/O Removable Internals	1437.2	kg.
Shop Test	- Fabricated + Water (Full)	1840.7	kg.
Shipping	- Fab. + Rem. Intls.+ Shipping App.	1437.2	kg.
Erected	- Fab. + Rem. Intls.+ Insul. (etc)	1437.2	kg.
Empty	- Fab. + Intls. + Details + Wghts.	1437.2	kg.
Operating	- Empty + Operating Liquid (No CA)	1816.4	kg.
Field Test	- Empty Weight + Water (Full)	1731.9	kg.