PPI / NARGAN	DEHDASHT PETROCHEMICAL INDUSTRY COMPANY DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT	PGPIC
	DOCUMENT TITLE: Mechanical Calculation for Condenser	POI: IFA
Contract No.: DPIC/98-12	DOCUMENT NUMBER: DPIC9812-000-VD-1002-ME-CLN-0093	Rev. No.: D0

DOCUMENT TITLE:

Mechanical Calculation for Condenser (E-PK6101-2)

PURCHASER'S COMMENT/APPROVAL STATUS		Purchaser: NARGAN
1	AP: Approved (Released for Manufacturing)	Requisition No.: DPIC98-12-001-000-ME-MR-4150-0001-D1
2	AN: Approved With Minor Comments (Fabrication may Proceed)	
3	NF: Approved With Comments (Fabrication not Proceed)	Item No. (Tag No.): PK-6101
4	RJ: Rejected	
5	NR: Not be Returned	Vendor Doc. No.: DPIC9812-000-VD-1002-ME-CLN-0093-D0
Date:	Signature:	

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

KASRAVAND Engineering & Construction

PPI / NARGAN	DEHDASHT PETROCHEMICAL INDUSTRY COMPANY DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT	PGPIC
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DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2

DESIGN CALCULATION

In Accordance with ASME Section VIII Division 1

```
ASME Code Version     : 2017

Analysis Performed by : SPLM Licensed User

Job File              :

Date of Analysis      : Dec 24,2021   7:41am

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 7:41am Dec 24,2021

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

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

There were no geometry errors or warnings.
```

PV Elite Vessel Analysis Program: Input Data

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2

Exchanger Design Pressures and Temperatures

Shell Side Design Pressure	23	bars
Channel Side Design Pressure	23	bars
Shell Side Design Temperature	125.0	°C
Channel Side Design Temperature	190.0	°C
Radiography, Shell Side	RT-1	
Radiography, Channel Side	RT-1	
Service Type, Shell Side	None	
Service Type, Channel Side	None	
MDMT (CET), Shell Side	-45.0	°C
MDMT (CET), Tube Side	-45.0	°C
User defined MAWP, Shell Side	0	bars
User defined MAWP, Channel Side	0	bars
User defined MAPnc, Shell Side	0	bars
User defined MAPnc, Channel Side	0	bars
User defined Test Pres., Shell Side	0	bars
User defined Test Pres., Channel Side	0	bars

Type of Hydrotest	UG-99(b) Note [36]	
Hydrotest Position	Horizontal	
Projection of Nozzle from Vessel Top	0	mm.
Projection of Nozzle from Vessel Bottom	0	mm.
Type of Construction	Welded	
Use Higher Longitudinal Stresses (Flag)	Y	
Select t for Internal Pressure (Flag)	N	
Select t for External Pressure (Flag)	N	
Select t for Axial Stress (Flag)	N	
Select Location for Stiff. Rings (Flag)	N	
Consider Vortex Shedding	N	
Perform a Corroded Hydrotest	Y	

Load Case 1	NP+EW+WI+FW+BW
Load Case 2	NP+EW+EE+FS+BS
Load Case 3	NP+OW+WI+FW+BW
Load Case 4	NP+OW+EQ+FS+BS
Load Case 5	NP+HW+HI
Load Case 6	NP+HW+HE
Load Case 7	IP+OW+WI+FW+BW
Load Case 8	IP+OW+EQ+FS+BS
Load Case 9	EP+OW+WI+FW+BW
Load Case 10	EP+OW+EQ+FS+BS
Load Case 11	HP+HW+HI
Load Case 12	HP+HW+HE
Load Case 13	IP+WE+EW
Load Case 14	IP+WF+CW
Load Case 15	IP+VO+OW
Load Case 16	IP+VE+EW
Load Case 17	NP+VO+OW
Load Case 18	FS+BS+IP+OW
Load Case 19	FS+BS+EP+OW

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

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

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

Material Database Year	Current w/Addenda or Code Year

Configuration Directives:

Do not use Nozzle MDMT Interpretation VIII-1 01-37	No
Use Table G instead of exact equation for "A"	Yes
Shell Head Joints are Tapered	Yes
Compute "K" in corroded condition	Yes
Use Code Case 2286	No
Use the MAWP to compute the MDMT	Yes
For thickness ratios <= 0.35, MDMT will be -155F (-104C)	Yes
For PWHT & P1 Materials the MDMT can be < -55F (-48C)	No
Using Metric Material Databases, ASME II D	No
Calculate B31.3 type stress for Nozzles with Loads	Yes
Reduce the MDMT due to lower membrane stress	Yes
Consider Longitudinal Stress in MDMT calcs. (Div. 1)	No

Complete Listing of Vessel Elements and Details:

Element From Node	10

```
Element To Node                                      20
Element Type                                 Elliptical
Description                                      HEAD 1
Distance "FROM" to "TO"                              50  mm.
Inside Diameter                                    1180  mm.
Element Thickness                                    13  mm.
Internal Corrosion Allowance                          3  mm.
Nominal Thickness                                    15  mm.
External Corrosion Allowance                          0  mm.
Design Internal Pressure                             23  bars
Design Temperature Internal Pressure                190  °C
Design External Pressure                            1.1  bars
Design Temperature External Pressure                190  °C
Effective Diameter Multiplier                       1.2
Material Name                                 SA-516 70 [Normalized]
    Allowable Stress, Ambient                     137.9  N./mm^2
    Allowable Stress, Operating                   137.9  N./mm^2
    Allowable Stress, Hydrotest                   235.8  N./mm^2
    Material Density                            0.00775  kg./cm^3
    P Number Thickness                           29.997  mm.
    Yield Stress, Operating                       226.1  N./mm^2
    UCS-66 Chart Curve Designation                    D
    External Pressure Chart Name                   CS-2
    UNS Number                                   K02700
    Product Form                                  Plate
Efficiency, Longitudinal Seam                       1.0
Efficiency, Circumferential Seam                   0.85
Elliptical Head Factor                              2.0
Weld is pre-Heated                                   No

    Element From Node                                10
    Detail Type                                  Liquid
    Detail ID                                         1
    Dist. from "FROM" Node / Offset dist              0  mm.
    Height/Length of Liquid                        1180  mm.
    Liquid Density                            0.0006998  kg./cm^3

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

Element From Node                                    20
Element To Node                                      30
Element Type                                   Cylinder
Description                                  CHANNEL 01
Distance "FROM" to "TO"                             749  mm.
Inside Diameter                                    1180  mm.
Element Thickness                                    15  mm.
Internal Corrosion Allowance                          3  mm.
Nominal Thickness                                    15  mm.
External Corrosion Allowance                          0  mm.
Design Internal Pressure                             23  bars
Design Temperature Internal Pressure                120  °C
Design External Pressure                            1.1  bars
Design Temperature External Pressure                120  °C
Effective Diameter Multiplier                       1.2
Material Name                                 SA-516 70 [Normalized]
Efficiency, Longitudinal Seam                      0.85
Efficiency, Circumferential Seam                   0.85
Weld is pre-Heated                                   No

    Element From Node                                20
    Detail Type                                  Liquid
```

```
     Detail ID                                            2
     Dist. from "FROM" Node / Offset dist                 0  mm.
     Height/Length of Liquid                           1180  mm.
     Liquid Density                               0.0006998  kg./cm^3

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

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

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

 Element From Node                                       30
 Element To Node                                         40
 Element Type                                        Flange
 Description                                 BODY FLANGE 01
 Distance "FROM" to "TO"                                146  mm.
 Flange Inside Diameter                                1180  mm.
 Element Thickness                                      110  mm.
 Internal Corrosion Allowance                             3  mm.
 Nominal Thickness                                       79  mm.
 External Corrosion Allowance                             0  mm.
 Design Internal Pressure                                23  bars
 Design Temperature Internal Pressure                   190  °C
 Design External Pressure                               1.1  bars
 Design Temperature External Pressure                   190  °C
 Effective Diameter Multiplier                          1.2
 Material Name                                 SA-350 LF2 [Impact Tested]
     Allowable Stress, Ambient                        137.9  N./mm^2
     Allowable Stress, Operating                      137.9  N./mm^2
     Allowable Stress, Hydrotest                      223.4  N./mm^2
     Material Density                               0.00775  kg./cm^3
     P Number Thickness                               31.75  mm.
     Yield Stress, Operating                         214.16  N./mm^2
     UCS-66 Chart Curve Designation           Impact Tested
     External Pressure Chart Name                      CS-2
     UNS Number                                      K03011
     Class / Thickness / Grade     1::
     Product Form                                  Forgings
 Perform Flange Stress Calculation (Y/N)                  Y
```

```
 Weight of ANSI B16.5/B16.47 Flange                    0  kN
 Class of ANSI B16.5/B16.47 Flange
 Grade of ANSI B16.5/B16.47 Flange
 Weld is pre-Heated                                   No

     Element From Node                                30
     Detail Type                                  Liquid
     Detail ID                                         3
     Dist. from "FROM" Node / Offset dist              0  mm.
     Height/Length of Liquid                        1180  mm.
     Liquid Density                            0.0006998  kg./cm^3

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

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

     Element From Node                                40
     Detail Type                                  Saddle
     Detail ID                              FIXED SADDLE
     Dist. from "FROM" Node / Offset dist            920  mm.
     Width of Saddle                                 172  mm.
     Height of Saddle at Bottom                      950  mm.
     Saddle Contact Angle                          120.0
     Height of Composite Ring Stiffener                0  mm.
     Width of Wear Plate                             225  mm.
     Thickness of Wear Plate                          15  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                                     New Sdl
Dist. from "FROM" Node / Offset dist             3924  mm.
Width of Saddle                                   172  mm.
Height of Saddle at Bottom                        950  mm.
Saddle Contact Angle                            120.0
Height of Composite Ring Stiffener                  0  mm.
Width of Wear Plate                               225  mm.
Thickness of Wear Plate                            15  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                                    Liquid
Detail ID                                           4
Dist. from "FROM" Node / Offset dist                0  mm.
Height/Length of Liquid                          1180  mm.
Liquid Density                              0.0009996  kg./cm^3

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

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

Element From Node                                  40
Detail Type                                    Nozzle
Detail ID                                          S3
Dist. from "FROM" Node / Offset dist              265  mm.
Nozzle Diameter                                     2  in.
Nozzle Schedule                                   160
Nozzle Class                                      300
Layout Angle                                     90.0
Blind Flange (Y/N)                                  N
```

```
     Weight of Nozzle ( Used if > 0 )                0.1162  kN
     Grade of Attached Flange                        GR 1.1
     Nozzle Matl                                   SA-333 6 [Impact Tested]

     Element From Node                                   40
     Detail Type                                     Weight
     Detail ID                                WEIGHT BAFFLE
     Dist. from "FROM" Node / Offset dist              2422  mm.
     Miscellaneous Weight                            2.9418  kN
     Offset from Element Centerline                       0  mm.

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

 Element From Node                                       50
 Element To Node                                         60
 Element Type                                       Flange
 Description                                BODY FLANGE 002
 Distance "FROM" to "TO"                                146  mm.
 Flange Inside Diameter                                1180  mm.
 Element Thickness                                      110  mm.
 Internal Corrosion Allowance                             3  mm.
 Nominal Thickness                                       79  mm.
 External Corrosion Allowance                             0  mm.
 Design Internal Pressure                                23  bars
 Design Temperature Internal Pressure                   190  °C
 Design External Pressure                               1.1  bars
 Design Temperature External Pressure                   190  °C
 Effective Diameter Multiplier                          1.2
 Material Name                                 SA-350 LF2 [Impact Tested]
     Allowable Stress, Ambient                        137.9  N./mm^2
     Allowable Stress, Operating                      137.9  N./mm^2
     Allowable Stress, Hydrotest                      223.4  N./mm^2
     Material Density                               0.00775  kg./cm^3
     P Number Thickness                               31.75  mm.
     Yield Stress, Operating                         214.16  N./mm^2
     UCS-66 Chart Curve Designation           Impact Tested
     External Pressure Chart Name                      CS-2
     UNS Number                                      K03011
     Class / Thickness / Grade     1::
     Product Form                                  Forgings
 Perform Flange Stress Calculation (Y/N)                  Y
 Weight of ANSI B16.5/B16.47 Flange                       0  kN
 Class of ANSI B16.5/B16.47 Flange
 Grade of ANSI B16.5/B16.47 Flange
 Weld is pre-Heated                                      No

     Element From Node                                   50
     Detail Type                                     Liquid
     Detail ID                                            5
     Dist. from "FROM" Node / Offset dist                 0  mm.
     Height/Length of Liquid                            540  mm.
     Liquid Density                               0.0006998  kg./cm^3

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

 Element From Node                                       60
 Element To Node                                         70
 Element Type                                      Cylinder
 Description                                    CHANNEL 002
 Distance "FROM" to "TO"                                299  mm.
 Inside Diameter                                       1180  mm.
```

```
Element Thickness                                      15  mm.
Internal Corrosion Allowance                            3  mm.
Nominal Thickness                                      15  mm.
External Corrosion Allowance                            0  mm.
Design Internal Pressure                               23  bars
Design Temperature Internal Pressure                  190  °C
Design External Pressure                              1.1  bars
Design Temperature External Pressure                  190  °C
Effective Diameter Multiplier                         1.2
Material Name                                 SA-516 70 [Normalized]
    Allowable Stress, Ambient                       137.9  N./mm^2
    Allowable Stress, Operating                     137.9  N./mm^2
    Allowable Stress, Hydrotest                     235.8  N./mm^2
    Material Density                              0.00775  kg./cm^3
    P Number Thickness                             29.997  mm.
    Yield Stress, Operating                         226.1  N./mm^2
    UCS-66 Chart Curve Designation                      D
    External Pressure Chart Name                     CS-2
    UNS Number                                     K02700
    Product Form                                    Plate
Efficiency, Longitudinal Seam                         1.0
Efficiency, Circumferential Seam                      1.0
Weld is pre-Heated                                     No

    Element From Node                                  60
    Detail Type                                    Liquid
    Detail ID                                           5
    Dist. from "FROM" Node / Offset dist                0  mm.
    Height/Length of Liquid                          1180  mm.
    Liquid Density                              0.0006998  kg./cm^3

    Element From Node                                  60
    Detail Type                                    Nozzle
    Detail ID                                          T4
    Dist. from "FROM" Node / Offset dist              150  mm.
    Nozzle Diameter                                  0.75  in.
    Nozzle Schedule                                  None
    Nozzle Class                                      300
    Layout Angle                                     90.0
    Blind Flange (Y/N)                                  N
    Weight of Nozzle ( Used if > 0 )              0.05845  kN
    Grade of Attached Flange                       GR 1.1
    Nozzle Matl                                SA-350 LF2 [Impact Tested]

    Element From Node                                  60
    Detail Type                                    Nozzle
    Detail ID                                          T3
    Dist. from "FROM" Node / Offset dist              150  mm.
    Nozzle Diameter                                     1  in.
    Nozzle Schedule                                  None
    Nozzle Class                                      300
    Layout Angle                                    270.0
    Blind Flange (Y/N)                                  N
    Weight of Nozzle ( Used if > 0 )              0.05845  kN
    Grade of Attached Flange                       GR 1.1
    Nozzle Matl                                SA-350 LF2 [Impact Tested]

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

Element From Node                                      70
Element To Node                                        80
```

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for CONDENSER E-PK6101-2 -----
Input Echo: Step: 1 7:41am Dec 24,2021

Element Type	Elliptical	
Description	HEAD 002	
Distance "FROM" to "TO"	50	mm.
Inside Diameter	1180	mm.
Element Thickness	13	mm.
Internal Corrosion Allowance	3	mm.
Nominal Thickness	15	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	23	bars
Design Temperature Internal Pressure	190	°C
Design External Pressure	1.1	bars
Design Temperature External Pressure	190	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	[Normalized]
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	0.85	
Elliptical Head Factor	2.0	
Weld is pre-Heated	No	

Element From Node	70	
Detail Type	Liquid	
Detail ID	6	
Dist. from "FROM" Node / Offset dist	0	mm.
Height/Length of Liquid	1180	mm.
Liquid Density	0.0006998	kg./cm^3

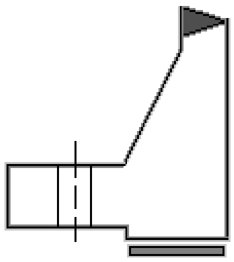
XY Coordinate Calculations:

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
	HEAD 1	50	...	50	...
	CHANNEL 01	799	...	749	...
	BODY FLANGE 01	945	...	146	...
	SHELL	5870.18	...	4844	...
	BODY FLANGE 002	6022.35	...	146	...
	CHANNEL 002	6396.35	...	299	...
	HEAD 002	6446.35	...	50	...

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

BODY FLANGE 01

```
Description of Flange Geometry (Type)          Integral Weld Neck
Design Pressure                          P              23.08  bars
Design Temperature                                        190  °C
Internal Corrosion Allowance             ci            3.0000  mm.
External Corrosion Allowance             ce            0.0000  mm.
Use Corrosion Allowance in Thickness Calcs.               Yes

Flange Inside Diameter                   B           1180.000  mm.
Flange Outside Diameter                  A           1350.000  mm.
Flange Thickness                         t           110.0000  mm.
Thickness of Hub at Small End            go           15.0000  mm.
Thickness of Hub at Large End            g1           27.0000  mm.
Length of Hub                            h            36.0000  mm.

Flange Material                                    SA-350 LF2
Flange Material UNS number                             K03011
Flange Allowable Stress At Temperature  Sfo            137.90  N./mm^2
Flange Allowable Stress At Ambient      Sfa            137.90  N./mm^2

Bolt Material                                       SA-320 L7
Bolt Allowable Stress At Temperature     Sb            172.38  N./mm^2
Bolt Allowable Stress At Ambient         Sa            172.38  N./mm^2

Diameter of Bolt Circle                  C           1298.000  mm.
Nominal Bolt Diameter                    a            22.2250  mm.
Type of Threads                          UNC Thread Series
Number of Bolts                                            76

Flange Face Outside Diameter            Fod          1266.000  mm.
Flange Face Inside Diameter             Fid          1180.000  mm.
Flange Facing Sketch                     1, Code Sketch 1a

Gasket Outside Diameter                  Go          1263.000  mm.
Gasket Inside Diameter                   Gi          1223.000  mm.
Gasket Factor                            m             3.7800
Gasket Design Seating Stress             y              62.05  N./mm^2

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

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



ASME Code, Section VIII Division 1, 2017

Hub Small End Required Thickness due to Internal Pressure:
```
  = (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
  = (23.08*(1180.0/2+3.0))/(137.9*1.0-0.6*23.08)+Ca
  = 13.0266 mm.
```

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

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

 Gasket Contact Width,       N = (Go - Gi) / 2            20.000  mm.
 Basic Gasket Width,        bo = N / 2                    10.000  mm.
 Effective Gasket Width,     b = Cb sqrt(bo)               7.969  mm.
 Gasket Reaction Diameter,   G = Go - 2 * b             1247.063  mm.
```

<u>Basic Flange and Bolt Loads:</u>

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.785 * 1247.0626² * 23.081
  = 2819.088 kN
```
Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * Pi * G * m * P + 2 * lp * bPart * mPart * P
  = 2 * 7.9687 * 3.1416 * 1247.0626 * 3.78 * 23.08
    + 2.0 * 1078.0 * 3.0 * 3.75 * 23.081
  = 600.721 kN
```
Hydrostatic End Load at Flange ID [Hd]:
```
  = Pi * Bcor² * P  / 4
  = 3.1416 * 1186.0² *23.081/4
  = 2549.773 kN
```
Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 2819 - 2550
  = 269.315 kN
```
Operating Bolt Load [Wm1]:
```
  = max( H + Hp + H'p, 0 )
  = max( 2819 + 601 + 0, 0 )
  = 3419.809 kN
```
Gasket Seating Bolt Load [Wm2]:
```
  = y * b * Pi * G  + yPart * bPart * lp
  = 62.05*7.9687*3.141*1247.063+62.05*3.0*1078.0
  = 2137.750 kN
```
Required Bolt Area [Am]:
```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 3420/172, 2138/172
  = 198.410 cm^2
```

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

Actual Circumferential Bolt Spacing [Bs]:

```
  = C * sin( pi / n )
  = 1298.0 * sin( 3.142/76 )
  = 53.640 mm.
```

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

Bolting Information for UNC Thread Series (Non Mandatory):

	Minimum	Actual	Maximum
Bolt Area, cm^2	198.410	205.445	
Radial Distance between Hub and Bolts:	31.750	32.000	
Radial Distance between Bolts and Edge:	23.812	26.000	
Circ. Spacing between the Bolts:	52.400	53.640	194.450

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

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

Flange Design Bolt Load, Gasket Seating [W]:
```
  = Sa * ( Am + Ab ) / 2
  = 172.38 * ( 198.4104 + 205.4447 )/2
  = 3480.43 kN
```
Gasket Load for the Operating Condition [HG]:
```
  = Wm1 - H
  = 3420 - 2819
  = 600.72 kN
```

Moment Arm Calculations:
Distance to Gasket Load Reaction [hg]:
```
  = (C - G ) / 2
  = ( 1298.0 - 1247.0626 )/2
  = 25.4687 mm.
```
Distance to Face Pressure Reaction [ht]:
```
  = ( R + g1 + hg ) / 2
  = ( 32.0 + 24.0 + 25.4687 )/2
  = 40.7344 mm.
```
Distance to End Pressure Reaction [hd]:
```
  = R + ( g1 / 2 )
  = 32.0 + ( 24.0/2.0 )
  = 44.0000 mm.
```

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

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	2550.	44.0000	1.0000	112236.
Face Pressure,	Mt	269.	40.7344	1.0000	10975.
Gasket Load,	Mg	601.	25.4687	1.0000	15306.
Gasket Seating,	Matm	3480.	25.4687	1.0000	88678.

```
Total Moment for Operation,      Mop                    138516. N-m
Total Moment for Gasket seating, Matm                    88678. N-m
```

```
 Effective Hub Length, ho = sqrt(Bcor*goCor)          119.298  mm.
 Hub Ratio,          h/h0 = HL / H0                     0.302
 Thickness Ratio,   g1/g0 = (g1Cor/goCor)               2.000
```

Flange Factors for Integral Flange:

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

Longitudinal Hub Stress, Operating [SHo]:

```
  = ( f * Mop / Bcor ) / ( L * g1² )
  = (2.0679*138516/1186.0)/(2.2585*24.0²)
  = 185.59 N./mm^2
```

Longitudinal Hub Stress, Seating [SHa]:

```
  = ( f * Matm / Bcor ) / ( L * g1² )
  = (2.0679*88678/1186.0)/(2.2585*24.0²)
  = 118.81 N./mm^2
```

Radial Flange Stress, Operating [SRo]:

```
  = ( Beta * Mop / Bcor ) / ( L * t² )
  = (2.0403*138516/1186.0)/(2.2585*107.0²)
  = 9.21 N./mm^2
```

Radial Flange Stress, Seating [SRa]:

```
  = ( Beta * Matm/Bcor ) / ( L * t² )
  = (2.0403*88678/1186.0)/(2.2585*107.0²)
  = 5.90 N./mm^2
```

Tangential Flange Stress, Operating [STo]:

```
  = ( Y * Mo / (t² * Bcor) ) - Z * SRo
  = (15.0244*138516/(107.0²*1186.0))-7.764*9
  = 81.69 N./mm^2
```

Tangential Flange Stress, Seating [STa]:

```
  = ( y * Matm / (t² * Bcor) ) - Z * SRa
  = (15.0244*88678/(107.0²*1186.0))-7.764*6
  = 52.30 N./mm^2
```

Average Flange Stress, Operating [SAo]:

```
  = ( SHo + max( SRo, STo ) ) / 2
  = (186+max(9,82))/2
  = 133.64 N./mm^2
```

Average Flange Stress, Seating [SAa]:

```
  = ( SHa + max( SRa, STa ) ) / 2
  = (119+max(6,52))/2
  = 85.56 N./mm^2
```

Bolt Stress, Operating [BSo]:

```
  = Wm1 / Ab
  = 3420/205.4447
  = 166.47 N./mm^2
```

Bolt Stress, Seating [BSa]:

```
  = ( Wm2 / Ab )
  = (2138/205.4447)
  = 104.06 N./mm^2
```

Flange Stress Analysis Results: N./mm^2

	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Longitudinal Hub	186.	207.	119.	207.
Radial Flange	9.	138.	6.	138.
Tangential Flange	82.	138.	52.	138.
Maximum Average	134.	138.	86.	138.
Bolting	166.	172.	104.	172.

```
Minimum Required Flange Thickness [Rigidity]          108.255  mm.
Estimated M.A.W.P. ( Operating )                        23.815  bars
Estimated Finished Weight of Flange at given Thk.       310.1  kg.
Estimated Unfinished Weight of Forging at given Thk     382.2  kg.
```

Flange Rigidity Based on Required Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
= 52.14 * Ma / Bsc * Cnv_fac * V / (Lambda * Eamb * go² * ho * Ki)
= 52.14 * 88678.0/1.0 * 999.68 * 0.302/(2.189 * 202713 * 12.0² * 119.298 * 0.3)
= 0.610 (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 * 138516.2/1.0 * 999.68 * 0.302/(2.189 * 193088 * 12.0² * 119.298 * 0.3)
= 1.000 (should be <= 1)

Flange Rigidity Based on Given Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
= 52.14 * Ma / Bsc * Cnv_fac * V / (Lambda * Eamb * go² * ho * Ki)
= 52.14 * 88678.0/1.0 * 999.68 * 0.302/(2.259 * 202713 * 12.0² * 119.298 * 0.3)
= 0.591 (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 * 138516.2/1.0 * 999.68 * 0.302/(2.259 * 193088 * 12.0² * 119.298 * 0.3)
= 0.969 (should be <= 1)

Minimum Design Metal Temperature Results:

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

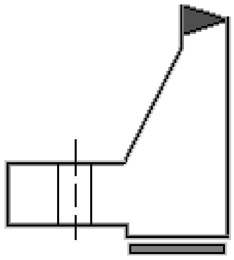
Impact Test Temperature provided per Specification -46 °C

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

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

BODY FLANGE 002

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	23.04	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	1180.000	mm.
Flange Outside Diameter	A	1346.000	mm.
Flange Thickness	t	110.0000	mm.
Thickness of Hub at Small End	go	15.0000	mm.
Thickness of Hub at Large End	g1	27.0000	mm.
Length of Hub	h	36.0000	mm.
Flange Material		SA-350 LF2	
Flange Material UNS number		K03011	
Flange Allowable Stress At Temperature	Sfo	137.90	N./mm^2
Flange Allowable Stress At Ambient	Sfa	137.90	N./mm^2
Bolt Material		SA-320 L7	
Bolt Allowable Stress At Temperature	Sb	172.38	N./mm^2
Bolt Allowable Stress At Ambient	Sa	172.38	N./mm^2
Diameter of Bolt Circle	C	1298.000	mm.
Nominal Bolt Diameter	a	22.2250	mm.
Type of Threads		UNC Thread Series	
Number of Bolts		76	
Flange Face Outside Diameter	Fod	1266.000	mm.
Flange Face Inside Diameter	Fid	1180.000	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	1263.000	mm.
Gasket Inside Diameter	Gi	1223.000	mm.
Gasket Factor	m	3.7800	
Gasket Design Seating Stress	y	62.05	N./mm^2
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	3.0000	mm.
Length of Partition Gasket	lp	1078.0000	mm.
Width of Partition Gasket	tp	6.0000	mm.
Partition Gasket Factor	mPart	3.7500	
Partition Gasket Design Seating Stress	yPart	62.05	N./mm^2



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Hub Small End Required Thickness due to Internal Pressure:
```
  = (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
  = (23.04*(1180.0/2+3.0))/(137.9*1.0-0.6*23.04)+Ca
  = 13.0073 mm.
```

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

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

 Gasket Contact Width,        N = (Go - Gi) / 2            20.000  mm.
 Basic Gasket Width,         bo = N / 2                    10.000  mm.
 Effective Gasket Width,      b = Cb sqrt(bo)               7.969  mm.
 Gasket Reaction Diameter,    G = Go - 2 * b             1247.063  mm.
```

<u>Basic Flange and Bolt Loads:</u>

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.785 * 1247.0626² * 23.037
  = 2813.725 kN
```
Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * Pi * G * m * P + 2 * lp * bPart * mPart * P
  = 2 * 7.9687 * 3.1416 * 1247.0626 * 3.78 * 23.04
    + 2.0 * 1078.0 * 3.0 * 3.75 * 23.0371
  = 599.578 kN
```
Hydrostatic End Load at Flange ID [Hd]:
```
  = Pi * Bcor² * P  / 4
  = 3.1416 * 1186.0² *23.0371/4
  = 2544.922 kN
```
Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 2814 - 2545
  = 268.803 kN
```
Operating Bolt Load [Wm1]:
```
  = max( H + Hp + H'p, 0 )
  = max( 2814 + 600 + 0, 0 )
  = 3413.303 kN
```
Gasket Seating Bolt Load [Wm2]:
```
  = y * b * Pi * G  + yPart * bPart * lp
  = 62.05*7.9687*3.141*1247.063+62.05*3.0*1078.0
  = 2137.750 kN
```
Required Bolt Area [Am]:
```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 3413/172, 2138/172
  = 198.033 cm^2
```

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

Actual Circumferential Bolt Spacing [Bs]:

```
  = C * sin( pi / n )
  = 1298.0 * sin( 3.142/76 )
  = 53.640 mm.
```

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

```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 53.64/( 2 * 22.225 + 107.0 )), 1 )
  = 1.0000
```

Bolting Information for UNC Thread Series (Non Mandatory):

	Minimum	Actual	Maximum
Bolt Area, cm^2	198.033	205.445	
Radial Distance between Hub and Bolts:	31.750	32.000	
Radial Distance between Bolts and Edge:	23.812	24.000	
Circ. Spacing between the Bolts:	52.400	53.640	194.450

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

```
  = Ab * Sa/( y * Pi * (Go + Gi) )
  = 205.445 * 172.38/(62.05 * 3.14 * (1263.0 + 1223.0) )
  = 7.307 mm.
```

Note: Recommended Min. Width for Sheet and Composite Gaskets per table 2-4 :

```
 = 32.000 mm.[Note: Exceeds actual gasket width, 20.000  ]
```

Flange Design Bolt Load, Gasket Seating [W]:

```
  = Sa * ( Am + Ab ) / 2
  = 172.38 * ( 198.033 + 205.4447 )/2
  = 3477.18 kN
```

Gasket Load for the Operating Condition [HG]:

```
  = Wm1 - H
  = 3413 - 2814
  = 599.58 kN
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
  = (C - G ) / 2
  = ( 1298.0 - 1247.0626 )/2
  = 25.4687 mm.
```

Distance to Face Pressure Reaction [ht]:

```
  = ( R + g1 + hg ) / 2
  = ( 32.0 + 24.0 + 25.4687 )/2
  = 40.7344 mm.
```

Distance to End Pressure Reaction [hd]:

```
  = R + ( g1 / 2 )
  = 32.0 + ( 24.0/2.0 )
  = 44.0000 mm.
```

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

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	2545.	44.0000	1.0000	112022.
Face Pressure,	Mt	269.	40.7344	1.0000	10954.
Gasket Load,	Mg	600.	25.4687	1.0000	15277.
Gasket Seating,	Matm	3477.	25.4687	1.0000	88595.

```
 Total Moment for Operation,       Mop                          138253. N-m
 Total Moment for Gasket seating,  Matm                          88595. N-m
```

```
 Effective Hub Length, ho = sqrt(Bcor*goCor)          119.298  mm.
 Hub Ratio,          h/h0 = HL / H0                      0.302
 Thickness Ratio,   g1/g0 = (g1Cor/goCor)                2.000
```

Flange Factors for Integral Flange:

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

Longitudinal Hub Stress, Operating [SHo]:
```
  = ( f * Mop / Bcor ) / ( L * g1² )
  = (2.0679*138253/1186.0)/(2.2286*24.0²)
  = 187.73 N./mm^2
```
Longitudinal Hub Stress, Seating [SHa]:
```
  = ( f * Matm / Bcor ) / ( L * g1² )
  = (2.0679*88595/1186.0)/(2.2286*24.0²)
  = 120.30 N./mm^2
```

Radial Flange Stress, Operating [SRo]:
```
  = ( Beta * Mop / Bcor ) / ( L * t² )
  = (2.0403*138253/1186.0)/(2.2286*107.0²)
  = 9.32 N./mm^2
```
Radial Flange Stress, Seating [SRa]:
```
  = ( Beta * Matm/Bcor ) / ( L * t² )
  = (2.0403*88595/1186.0)/(2.2286*107.0²)
  = 5.97 N./mm^2
```

Tangential Flange Stress, Operating [STo]:
```
  = ( Y * Mo / (t² * Bcor) ) - Z * SRo
  = (15.3704*138253/(107.0²*1186.0))-7.9441*9
  = 82.42 N./mm^2
```
Tangential Flange Stress, Seating [STa]:
```
  = ( y * Matm / (t² * Bcor) ) - Z * SRa
  = (15.3704*88595/(107.0²*1186.0))-7.9441*6
  = 52.82 N./mm^2
```

Average Flange Stress, Operating [SAo]:
```
  = ( SHo + max( SRo, STo ) ) / 2
  = (188+max(9,82))/2
  = 135.07 N./mm^2
```
Average Flange Stress, Seating [SAa]:
```
  = ( SHa + max( SRa, STa ) ) / 2
  = (120+max(6,53))/2
  = 86.56 N./mm^2
```

Bolt Stress, Operating [BSo]:
```
  = Wm1 / Ab
  = 3413/205.4447
  = 166.16 N./mm^2
```
Bolt Stress, Seating [BSa]:
```
  = ( Wm2 / Ab )
  = (2138/205.4447)
  = 104.06 N./mm^2
```


Flange Stress Analysis Results: N./mm^2

	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Longitudinal Hub	188.	207.	120.	207.
Radial Flange	9.	138.	6.	138.
Tangential Flange	82.	138.	53.	138.
Maximum Average	135.	138.	87.	138.
Bolting	166.	172.	104.	172.

```
Minimum Required Flange Thickness [Rigidity]         108.890  mm.
Estimated M.A.W.P. ( Operating )                      23.499  bars
Estimated Finished Weight of Flange at given Thk.      302.9  kg.
Estimated Unfinished Weight of Forging at given Thk    372.7  kg.
```

Flange Rigidity Based on Required Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
```
  = 52.14 * Ma / Bsc * Cnv_fac * V / ( Lambda * Eamb * go² * ho * Ki )
  = 52.14 * 88595.1/1.0 * 999.68 * 0.302/( 2.185 * 202713 *
    12.0² * 119.298 * 0.3 )
  = 0.610  (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 * 138252.6/1.0 * 999.68 * 0.302/( 2.185 * 193088
    * 12.0² * 119.298 * 0.3 )
  = 1.000  (should be <= 1)
```

Flange Rigidity Based on Given Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
```
  = 52.14 * Ma / Bsc * Cnv_fac * V / ( Lambda * Eamb * go² * ho * Ki )
  = 52.14 * 88595.1/1.0 * 999.68 * 0.302/( 2.229 * 202713 *
    12.0² * 119.298 * 0.3 )
  = 0.598  (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 * 138252.6/1.0 * 999.68 * 0.302/( 2.229 * 193088
    * 12.0² * 119.298 * 0.3 )
  = 0.980  (should be <= 1)
```

Minimum Design Metal Temperature Results:

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

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

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

Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd bars	Nominal Thickness mm.	Total Corr Allowance mm.	Element Diameter mm.	Allowable Stress(SE) N./mm^2
HEAD 1		23.081	15	3	1180	137.9
CHANNEL 01		23.081	15	3	1180	117.21
BODY FLANGE 01		23.081	79	3	1180	137.9
SHELL		23.116	15	3	1180	137.9
BODY FLANGE 002		23.037	79	3	1180	137.9
CHANNEL 002		23.081	15	3	1180	137.9
HEAD 002		23.081	15	3	1180	137.9

Element Required Thickness and MAWP :

From	To	Design Pressure bars	M.A.W.P. Corroded bars	M.A.P. New & Cold bars	Minimum Thickness mm.	Required Thickness mm.
HEAD 1		23	No Calc	No Calc	13	12.8761
CHANNEL 01		23	No Calc	No Calc	15	14.8173
BODY FLANGE 01		23	No Calc	No Calc	110	108.255
SHELL		23	No Calc	No Calc	15	13.0419
BODY FLANGE 002		23	No Calc	No Calc	110	108.89
CHANNEL 002		23	No Calc	No Calc	15	13.0267
HEAD 002		23	No Calc	No Calc	13	12.8761

Internal Pressure Calculation Results :

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

HEAD 1

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
```
  = (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
  = (23.081*1186.0*0.993)/(2*137.9*1.0-0.2*23.081)
  = 9.8761 + 3.0000 = 12.8761 mm.
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(Kcor*D+0.2*t))/(2*E*t)
  = (23.081*(0.993*1186.0+0.2*10.0))/(2*1.0*10.0)
  = 136.194 N./mm^2
```

Straight Flange Required Thickness:
```
  = (P*R)/(S*E-0.6*P) + c    per UG-27 (c)(1)
  = (23.081*593.0)/(137.9*1.0-0.6*23.081)+3.0
  = 13.027 mm.
```

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.081 bars
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9 * 1.0 * 12.0)/(593.0 + 0.6 * 12.0 )
```

= 27.569 - 0.081 = 27.488 bars

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

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

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 13.0, tr = 9.876, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.988, Temp. Reduction = 1 °C

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

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 15.0, tr = 10.027, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.836, Temp. Reduction = 9 °C

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

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

CHANNEL 01

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
= (23.081*593.0)/(137.9*0.85-0.6*23.081)
= 11.8173 + 3.0000 = 14.8173 mm.

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(R+0.6*t))/(E*t)
= (23.081*(593.0+0.6*12.0))/(0.85*12.0)
= 135.825 N./mm^2

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

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 15.0, tr = 11.817, c = 3.0 mm., E* = 0.85
Thickness Ratio = tr * (E*)/(tg - c) = 0.837, Temp. Reduction = 9 °C

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

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

SHELL

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (23.116*593.0)/(137.9*1.0-0.6*23.116)
  = 10.0419 + 3.0000 = 13.0419 mm.
```

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

```
  = (P*(R+0.6*t))/(E*t)
  = (23.116*(593.0+0.6*12.0))/(1.0*12.0)
  = 115.625 N./mm^2
```

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

Minimum Design Metal Temperature Results:

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

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

CHANNEL 002

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (23.081*593.0)/(137.9*1.0-0.6*23.081)
  = 10.0267 + 3.0000 = 13.0267 mm.
```

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

```
  = (P*(R+0.6*t))/(E*t)
  = (23.081*(593.0+0.6*12.0))/(1.0*12.0)
  = 115.451 N./mm^2
```

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

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 15.0, tr = 10.027, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.836, Temp. Reduction = 9 °C

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

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

HEAD 002

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
  = (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
  = (23.081*1186.0*0.993)/(2*137.9*1.0-0.2*23.081)
  = 9.8761 + 3.0000 = 12.8761 mm.
```

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

```
  = (P*(Kcor*D+0.2*t))/(2*E*t)
  = (23.081*(0.993*1186.0+0.2*10.0))/(2*1.0*10.0)
  = 136.194 N./mm^2
```

Straight Flange Required Thickness:
```
  = (P*R)/(S*E-0.6*P) + c    per UG-27 (c)(1)
  = (23.081*593.0)/(137.9*1.0-0.6*23.081)+3.0
  = 13.027 mm.
```

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.081 bars
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9 * 1.0 * 12.0)/(593.0 + 0.6 * 12.0 )
  = 27.569 - 0.081 = 27.488  bars
```

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

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

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 13.0, tr = 9.876, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.988, Temp. Reduction = 1 °C

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

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 15.0, tr = 10.027, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.836, Temp. Reduction = 9 °C

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

Hydrostatic Test Pressure Results:

Exchanger Shell Side Hydrostatic Test Pressures:

```
 Pressure per UG99b[36] = 1.30 * Design Pres * Sa/S      29.900  bars
 Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)    32.890  bars
 Pressure per App 27-4  = M.A.W.P.                       40.217  bars
```

Exchanger Channel Side Hydrostatic Test Pressures:

```
 Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S         30.970  bars
 Pressure per UG99b[36] = 1.30 * Design Pres * Sa/S      29.900  bars
 Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)      30.954  bars
 Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S         26.205  bars
 Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)    32.890  bars
 Pressure per App 27-4  = M.A.W.P.                       23.823  bars
```

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

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

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

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

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

From To	Stress	Allowable	Ratio	Pressure
HEAD 1	177.1	235.8	0.751	30.02
CHANNEL 01	176.6	235.8	0.749	30.02
SHELL	150.1	235.8	0.637	30.02
CHANNEL 002	150.1	235.8	0.637	30.02
HEAD 002	177.1	235.8	0.751	30.02

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

Description	Pad/Nozzle	Ambient	Operating	Ratio
T1	Nozzle	117.90	117.90	1.000
T1	Pad	137.90	137.90	1.000
T2	Nozzle	117.90	117.90	1.000
T2	Pad	137.90	137.90	1.000
S2	Nozzle	117.90	117.90	1.000
S2	Pad	137.90	137.90	1.000
S1	Nozzle	117.90	117.90	1.000
S1	Pad	137.90	137.90	1.000
S3	Nozzle	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	137.90	137.90	1.000
BODY FLANGE 01	137.90	137.90	1.000
SHELL	137.90	137.90	1.000
BODY FLANGE 002	137.90	137.90	1.000
CHANNEL 002	137.90	137.90	1.000
HEAD 002	137.90	137.90	1.000
Minimum			1.000

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

Description	Ambient	Operating	Ratio
Tube Material	117.90	117.90	1.000
Tubesheet Material	137.90	137.90	1.000
Minimum			1.000

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

Description	Ambient	Operating	Ratio

T1	38.42	217.19	0.177
T2	38.42	217.19	0.177
S2	39.33	217.19	0.181
S1	38.42	217.19	0.177
S3	18.29	217.19	0.084
T4	5.14	223.40	0.023
T3	5.97	223.40	0.027

Elements Suitable for Internal Pressure.

External Pressure Calculation Results :

External Pressure Calculations:

From	To	Section Length mm.	Outside Diameter mm.	Corroded Thickness mm.	Factor A	Factor B N./mm^2
10	20	No Calc	1206	10	0.0011516	82.603
20	30	897.333	1210	12	0.0018252	101.647
30	40	No Calc	...	107	No Calc	No Calc
40	50	4844	1210	12	0.00030147	30.1399
50	60	No Calc	...	107	No Calc	No Calc
60	70	447.333	1210	12	0.0039525	106.227
70	80	No Calc	1206	10	0.0011516	82.603

External Pressure Calculations:

From	To	External Actual T. mm.	External Required T. mm.	External Design Pressure bars	External M.A.W.P. bars
10	20	13	6.26226	1.1	7.60993
20	30	15	6.49927	1.1	13.4402
30	40	110	68.3514	1.1	No Calc
40	50	15	10.0794	1.1	3.98521
50	60	110	68.7578	1.1	No Calc
60	70	15	5.65111	1.1	14.0457
70	80	13	6.26226	1.1	7.60993
Minimum					3.985

External Pressure Calculations:

From	To	Actual Length Bet. Stiffeners mm.	Allowable Length Bet. Stiffeners mm.	Ring Inertia Required cm**4	Ring Inertia Available cm**4
10	20	No Calc	No Calc	No Calc	No Calc
20	30	897.333	19354.8	No Calc	No Calc
30	40	No Calc	No Calc	No Calc	No Calc
40	50	4844	102403	No Calc	No Calc
50	60	No Calc	No Calc	No Calc	No Calc
60	70	447.333	9164.93	No Calc	No Calc
70	80	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

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

HEAD 1

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

Results for Maximum Allowable External Pressure (MAEP):

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

```
  10.000     1206.00      120.60    0.0011516       82.60
 EMAP = B/(K0*D/t) = 82.603/( 0.9 *120.6 ) = 7.6099 bars
```

Results for Required Thickness (Tca):

```
     Tca          OD          D/t     Factor A            B
   3.262     1206.00      369.68    0.0003757       36.60
 EMAP = B/(K0*D/t) = 36.6032/( 0.9 *369.6828 ) = 1.1001 bars
```

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

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
  = (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
  = (1.837*1186.0*0.993)/(2*137.9*1.0-0.2*1.837)
  = 0.7848 + 3.0000 = 3.7848 mm.
```

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

```
  = ((2*S*E*t)/(Kcor*D+0.2*t))/1.67 per Appendix 1-4 (c)
  = ((2*137.9*1.0*10.0)/(0.993*1186.0+0.2*10.0))/1.67
  = 13.994 bars
```

Maximum Allowable External Pressure [MAEP]:

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

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

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

CHANNEL 01

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

Results for Maximum Allowable External Pressure (MAEP):

```
     Tca          OD        SLEN        D/t        L/D    Factor A        B
  12.000     1210.00      897.33     100.83     0.7416  0.0018252   101.65
 EMAP = (4*B)/(3*(D/t)) = (4*101.6474)/(3*100.8333) = 13.4402 bars
```

Results for Required Thickness (Tca):

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

Results for Maximum Stiffened Length (Slen):

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

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

SHELL

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

Results for Maximum Allowable External Pressure (MAEP):

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

```
  12.000     1210.00     4844.00    100.83    4.0033  0.0003015    30.14
 EMAP = (4*B)/(3*(D/t)) = (4*30.1399)/(3*100.8333) = 3.9852 bars
```

Results for Required Thickness (Tca):

```
     Tca          OD         SLEN        D/t        L/D   Factor A        B
   7.079     1210.00     4844.00    170.92    4.0033  0.0001411    14.10
 EMAP = (4*B)/(3*(D/t)) = (4*14.1022)/(3*170.9189) = 1.1 bars
```

Results for Maximum Stiffened Length (Slen):

```
     Tca          OD         SLEN        D/t        L/D   Factor A        B
  12.000     1210.00   102403.33    100.83   50.0000  0.0001084    10.84
 EMAP = (4*B)/(3*(D/t)) = (4*10.841)/(3*100.8333) = 1.4334 bars
```

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

CHANNEL 002

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

Results for Maximum Allowable External Pressure (MAEP):

```
     Tca          OD         SLEN        D/t        L/D   Factor A        B
  12.000     1210.00      447.33    100.83    0.3697  0.0039525   106.23
 EMAP = (4*B)/(3*(D/t)) = (4*106.2269)/(3*100.8333) = 14.0457 bars
```

Results for Required Thickness (Tca):

```
     Tca          OD         SLEN        D/t        L/D   Factor A        B
   2.651     1210.00      447.33    456.41    0.3697  0.0003865    37.66
 EMAP = (4*B)/(3*(D/t)) = (4*37.658)/(3*456.4122) = 1.1001 bars
```

Results for Maximum Stiffened Length (Slen):

```
     Tca          OD         SLEN        D/t        L/D   Factor A        B
  12.000     1210.00     9164.93    100.83    7.5743  0.0001492    14.54
 EMAP = (4*B)/(3*(D/t)) = (4*14.5391)/(3*100.8333) = 1.9224 bars
```

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

HEAD 002

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

Results for Maximum Allowable External Pressure (MAEP):

```
     Tca          OD          D/t     Factor A          B
  10.000     1206.00      120.60   0.0011516        82.60
 EMAP = B/(K0*D/t) = 82.603/( 0.9 *120.6 ) = 7.6099 bars
```

Results for Required Thickness (Tca):

```
     Tca          OD          D/t     Factor A          B
   3.262     1206.00      369.68   0.0003757        36.60
 EMAP = B/(K0*D/t) = 36.6032/( 0.9 *369.6828 ) = 1.1001 bars
```

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

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
  = (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
  = (1.837*1186.0*0.993)/(2*137.9*1.0-0.2*1.837)
  = 0.7848 + 3.0000 = 3.7848 mm.
```

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

```
  = ((2*S*E*t)/(Kcor*D+0.2*t))/1.67 per Appendix 1-4 (c)
  = ((2*137.9*1.0*10.0)/(0.993*1186.0+0.2*10.0))/1.67
  = 13.994 bars
```

Maximum Allowable External Pressure [MAEP]:

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

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

Element and Detail Weights:

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

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

Weight of Details:

From	Type	Weight of Detail kg.	X Offset, Dtl. Cent. mm.	Y Offset, Dtl. Cent. mm.	Description
10	Liqd	188.745	-98.3333	0.36335E-04	1
20	Liqd	573.121	374.5	...	2
20	Nozl	172.777	375	751.925	T1
20	Nozl	172.777	375	751.925	T2
30	Liqd	112.575	73	...	3
40	Sadl	160.346	920	755	FIXED SADDLE
40	Sadl	160.346	3924	755	New Sdl
40	Liqd	2808.2	2422	...	4
40	Nozl	93.335	265	699.537	S2
40	Nozl	173.514	4480	751.925	S1
40	Nozl	12.4379	265	620.162	S3
40	Wght	300	2422	...	WEIGHT BAFFLE
50	Liqd	50.2212	73	320	5
60	Liqd	228.79	149.5	...	5
60	Nozl	6.25877	150	599.525	T4
60	Nozl	6.25877	150	602.7	T3
70	Liqd	188.745	148.333	0.36335E-04	6
30	FTsh	560.167	188.5	...	TUBE SHEET
30	Tube	8226.77	2651	...	
30	RTsh	560.167	5113.5	...	

Total Weight of Each Detail Type:

Saddles	320.7
Liquid	4150.4
Nozzles	637.4
Weights	300.0
Exchanger Components	9347.1
Liquid in Tubes	1089.5
Sum of the Detail Weights	15845.1 kg.

Weight Summation Results: (kg.)

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for CONDENSER E-PK6101-2 -----
Element and Detail Weights: Step: 7 7:41am Dec 24,2021

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	3806.9	3806.9	3806.9	3806.9	3806.9	3806.9
Saddles	320.7	320.7	320.7	320.7	320.7	320.7
Nozzles	637.4	637.4	637.4	637.4	637.4	637.4
Wld Weights	300.0	300.0	300.0	300.0	300.0	300.0
Exchanger	9347.1	9347.1	9347.1	9347.1	9347.1	9347.1
Ope. Liquid	...	...	...	...	...	4150.4
Tube Ope Lqd	...	...	...	...	...	1089.5
Test Liquid	...	4814.7	...	...	...	...
Tube Tst Lqd	...	1556.5	...	...	...	...
Totals	14412.0	20783.2	14412.0	14412.0	14412.0	19652.0

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	14412.0 kg.
Shop Test Wt.	- Fabricated Weight + Water (Full)	20783.2 kg.
Shipping Wt.	- Fab. Weight + removable Intls.+ Shipping App.	14412.0 kg.
Erected Wt.	- Fab. Wt + or - loose items (trays,platforms etc.)	14412.0 kg.
Ope. Wt. no Liq	- Fab. Weight + Internals. + Details + Weights	14412.0 kg.
Operating Wt.	- Empty Weight + Operating Liq. Uncorroded	19652.0 kg.
Oper. Wt. + CA	- Corr Wt. + Operating Liquid	18998.2 kg.
Field Test Wt.	- Empty Weight + Water (Full)	20203.7 kg.

Exchanger Tube Data

Volume of Exchanger tubes :	1557431.8 Cm3
Weight of Ope Liq in tubes :	1089.5 kg.
Weight of Water in tubes :	1556.5 kg.

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

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

Outside Surface Areas of Elements:

From	To	Surface Area cm^2
10	20	17771.3
20	30	28471.9
30	40	9438.89
40	50	184136
50	60	9340.36
60	70	11366
70	80	17771.3

Total 278296.031 cm^2

Nozzle Flange MAWP Results:

Nozzle Description	Flange Rating Ope. bars	Flange Rating Ambient bars	Design Temp °C	Class	Grade/ Group	Equiv. Press	Max Pressure PVP	Max Pressure 50%	Max Pressure DNV bars
T1	46.00	51.10	120	300	GR 1.1	...	...	...	...
T2	46.00	51.10	120	300	GR 1.1	...	...	...	...
S2	45.85	51.10	125	300	GR 1.1	...	...	...	...
S1	45.85	51.10	125	300	GR 1.1	...	...	...	...
S3	45.85	51.10	125	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]: 45.850 bars
Lowest Flange Pressure Rating was (Amb)[ShellSide]: 51.100 bars

Channelside Flange Rating

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

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

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

```
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for CONDENSER E-PK6101-2    -----
Wind Load Calculation:                      Step:    9   7:41am  Dec 24,2021
```

Input Values:

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

Wind Analysis Results

Static Gust-Effect Factor, Operating Case [G]:

```
  = min(0.85, 0.925((1 + 1.7 * gQ * Izbar * Q )/( 1 + 1.7 * gV * Izbar)))
  = min(0.85,0.925((1+1.7*3.4*0.143*0.836)/(1+1.7*3.4*0.143)))
  = min(0.85, 0.856 )
  = 0.850

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

 Force Coefficient                                        [Cf] 0.580
 Structure Height to Diameter ratio                            5.785
```

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

Sample Calculation for the First Element

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

Value of [Alpha] and [Zg]:

```
  Exposure Category: C from Table 26.9.1
  Alpha = 9.5: Zg = 274320. mm.
```

Effective Height [z]:

```
  = Centroid Height + Vessel Base Elevation
  = 950.0 + 123000. = 123950. mm.
  = 406.66 ft. Imperial Units
```

Velocity Pressure coefficient evaluated at height z [Kz]:

  Because z (406.66 ft.) > 15 ft.
  $= 2.01 * (z / Zg)^{2 / Alpha}$
  $= 2.01 * (406.66/900.0)^{2/9.5}$
  = 1.7

Type of Hill: No Hill

Wind Directionality Factor [Kd]:

  = 0.95 per Table 26.6-1

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

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

Velocity Pressure evaluated at height z, Imperial Units [qz]:
= max(16, 0.00256 * Kz * Kzt * Kd * V(mph)²)
= max(16, 0.00256 * 1.7 * 1.0 * 0.95 * 121.171²)
= 60.7 psf [296.458] Kgs/m^2

Force on the first element [F]:
= qz * G * Cf * WindArea
= 60.718 * 0.85 * 0.58 * 3.919
= 117.3 lbs. [0.5] kN

Element	Hgt (z) mm.	K1	K2	K3	Kz	Kzt	qz Kgs/m^2
HEAD 1	*******	0.000	0.000	0.000	1.700	1.000	296.458
CHANNEL 01	*******	0.000	0.000	0.000	1.700	1.000	296.458
BODY FLANGE 01	*******	0.000	0.000	0.000	1.700	1.000	296.458
SHELL	*******	0.000	0.000	0.000	1.700	1.000	296.458
BODY FLANGE 002	*******	0.000	0.000	0.000	1.700	1.000	296.458
CHANNEL 002	*******	0.000	0.000	0.000	1.700	1.000	296.458
HEAD 002	*******	0.000	0.000	0.000	1.700	1.000	296.458

Wind Loads on Masses/Equipment/Piping

ID	Wind Area cm^2	Elevation mm.	Pressure Kgs/m^2	Force kN
WEIGHT BAFFLE	0.00	123950.00	296.46	0.00

Wind Load Calculation:

From	To	Wind Height mm.	Wind Diameter mm.	Wind Area cm^2	Wind Pressure Kgs/m^2	Element Wind Load kN
10	20	123950	1447.2	3640.95	296.458	0.31295
20	30	123950	1452	10875.5	296.458	0.93479
30	40	123950	1416	2067.36	296.458	0.1777
40	50	123950	1452	70334.9	296.458	6.04556
50	60	123950	1416	2067.36	296.458	0.1777
60	70	123950	1452	4341.48	296.458	0.37317
70	80	123950	1447.2	3640.95	296.458	0.31295

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 * ($5.0525^{0.75}$)
= 0.067 seconds

The Coefficient Cu from Table 12.8-1 is : 1.400

Fundamental Period (1/Frequency) [T]:

= (1/Natural Frequency) = (1/33.0)
= 0.030

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

= Minimum Value of (1.4 * 0.067, 0.03) per 12.8.2
= 0.030

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 * 186 * 1.5
= 64.999 kN

Final Base Shear, V = 45.50 kN

Earthquake Load Calculation:

From	To	Earthquake Height mm.	Earthquake Weight kN	Ope	Element Load kN
10	20	590	20.6996		5.05547

20	30	590	20.6996	5.05547
30	40	590	20.6996	5.05547
40	Sadl	590	20.6996	5.05547
Sadl	50	590	20.6996	5.05547
40	50	590	20.6996	5.05547
50	60	590	20.6996	5.05547
60	70	590	20.6996	5.05547
70	80	590	20.6996	5.05547

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                          3448.175 mm.
Center of Gravity of Liquid                           3124.842 mm.
Center of Gravity of Nozzles                          2066.386 mm.
Center of Gravity of Added Weights (Operating)        3448.175 mm.
Center of Gravity of Added Weights (Empty)            3448.175 mm.
Center of Gravity of Tubesheet(s)                     3450.000 mm.
Center of Gravity of Tubes                            3450.000 mm.

Center of Gravity of Bare Shell New and Cold          3237.513 mm.
Center of Gravity of Bare Shell Corroded              3241.852 mm.

Vessel CG in the Operating Condition                  3297.941 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition    3332.604 mm.
Vessel CG in the Test Condition                       3286.647 mm.
```

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

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

Horizontal Vessel Stress Calculations : Operating Case

Note:
Wear Pad Width (225.00) 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( 172.0 + 1.56*sqrt( 599.0 * 12.0 ), 2 * 346.0 )
  = 304.2600 mm.
```

Input and Calculated Values:

Vessel Mean Radius	Rm	599.00	mm.
Stiffened Vessel Length per 4.15.6	L	4844.00	mm.
Distance from Saddle to Vessel tangent	a	346.00	mm.
Saddle Width	b	172.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Shell Allowable Stress used in Calculation		137.90	N./mm^2
Head Allowable Stress used in Calculation		137.90	N./mm^2
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Operating Case		161.27	kN

Horizontal Vessel Analysis Results:	Actual N./mm^2	Allowable N./mm^2
Long. Stress at Top of Midspan	46.80	137.90
Long. Stress at Bottom of Midspan	68.31	137.90
Long. Stress at Top of Saddles	56.17	137.90
Long. Stress at Bottom of Saddles	58.32	137.90
Tangential Shear in Shell	22.52	110.32
Circ. Stress at Horn of Saddle	43.58	172.37
Circ. Compressive Stress in Shell	3.36	137.90

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:
```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0 * ( 8.3/2 + 0 ) * 950.0/1073.8716
  = 11.1 kN
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 2.41, 0.0, 0 ) * 950.0/3004.0
  = 0.8 kN
```

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:
```
  = max( Fl, Friction Force, Sum of X Forces ) * B / Ls
  = max( 45.5, 0.0, 0 ) * 950.0/3004.0
  = 14.4 kN
```

Saddle Reaction Force due to Earthquake Ft [Fst]:
```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0 * ( 45/2 + 0 ) * 950.0/1073.8716
  = 60.4 kN
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 101 + Max( 0.8, 11, 14, 60 )
  = 161.3 kN
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		162.84	kN
Transverse Shear Load Saddle	Ft	22.75	kN
Longitudinal Shear Load Saddle		45.50	kN

Formulas and Substitutions for Horizontal Vessel Analysis:

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

The Computed K values from Table 4.15.1:
```
 K1  = 0.1066     K2  = 1.1707     K3  = 0.8799     K4  = 0.4011
 K5  = 0.7603     K6  = 0.0529     K7  = 0.0194     K8  = 0.3405
 K9  = 0.2711     K10 = 0.0581     K1* = 0.1923
```

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)]
  = -161*346.0[1-(1-346.0/4844.0+(599.0²-0.0²)/
    (2*346.0*4844.0))/(1+(4*0.0)/(3*4844.0))]
  = 1987.9 N-m
```

Moment per Equation 4.15.4 [M2]:
```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 161*4844/4(1+2(599²-0²)/(4844²))/(1+(4*0)/
    (3*4844))-4*346/4844
  = 145529.6 N-m
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 23.058 * 599.0/(2*12.0) - 145529.6/(pi*599.0²*12.0)
  = 46.80 N./mm^2
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 23.058 * 599.0/(2 * 12.0) + 145529.6/(pi * 599.0² * 12.0 )
  = 68.31 N./mm^2
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 23.058*599.0/(2*12.0)-1987.9/(0.1066*pi*599.0²*12.0)
  = 56.17 N./mm^2
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 23.058*599.0/(2*12.0)+1987.9/(0.1923*pi*599.0²*12.0)
  = 58.32 N./mm^2
```

Maximum Shear Force in the Saddle (4.15.5) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 161( 4844.0 - 2 * 346.0)/(4844.0 + ( 4 * 0.0/3))
```


= 138.2 kN

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
= K2 * T / (Rm * t)
= 1.1707 * 138.23/(599.0 * 12.0)
= 22.52 N./mm^2

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

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
= -K5 * Q * k / (t * (b + X1 + X2))
= - 0.7603 * 161 * 0.1/(12.0 * (172.0 + 66.13 + 66.13))
= -3.36 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)
= -161/(4*12.0*(172.0+66.13+66.13)) -
3* 0.0194*161/(2*12.0²)
= -43.58 N./mm^2

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

Free Un-Restrained Thermal Expansion between the Saddles [Exp]:
= Alpha * Ls * (Design Temperature - Ambient Temperature)
= 0.000012 * 3004.0 * (125.0 - 21.1)
= 3.827 mm.

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1050.0000	mm.
Baseplate Thickness	Bpthk	16.0000	mm.
Baseplate Width	Bpwid	220.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	12.0000	mm.
Web Thickness	Webtk	12.0000	mm.
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	206.9	N./
Height of Web at Center	Hw,c	314.0	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	356.6	12.0	6.0	42.8	25674.9	0.710E+04
Wearplate	225.0	15.0	19.5	33.8	65812.5	0.449E+04
Web	12.0	314.0	184.0	37.7	693312.2	0.401E+04
BasePlate	220.0	16.0	349.0	35.2	1228480.1	0.162E+05
Totals	...	...	...	149.4	2013279.8	0.318E+05

Distance to Centroid [C1]:
= AY / A
= 792.63/149.422
= 134.738 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 * 161.269
  = 32.8218 kN

 Tension Stress, St = ( Fh/As )       =          3.0784  N./mm^2
 Allowed Stress, Sa = 0.6 * Yield Str =        124.1100  N./mm^2
```

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

 Bending Moment, M  = Fh * d          =      15090.7861  N-m

 Bending Stress, Sb = ( M * C1 / I  ) =          6.3995  N./mm^2
 Allowed Stress, Sa = 2/3 * Yield Str =        137.9000  N./mm^2
```

Minimum Thickness of Baseplate per Moss:
```
  = ( 3( Q + Saddle_Wt )BasePlateWidth / ( 4 * BasePlateLength * AllStress ))½
  = ( 3(161 + 2)220.0/( 4 * 1050.0 * 137.9 ))½
  = 13.623 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 )( 590.0 + 15.0 + 15.0 )
  = 1073.871 mm.
```

Distance between Ribs [e]:
```
  = Web Length / ( Nribs - 1 )
  = 1073.8715/( 4 - 1 )
  = 357.957 mm.
```

Baseplate Pressure Area [Ap]:
```
  = e * Bpwid / 2
  = 357.9572 * 220.0/2
  = 393.753 cm^2
```

Axial Load [P]:
```
  = Ap * Bp
  = 393.8 * 0.07
  = 27.489 kN
```

Area of the Rib and Web [Ar]:
```
  = Rib Area + Web Area
  = 19.2 + 21.477
  = 40.677 cm^2
```

Compressive Stress [Sc]:
```
  = P/Ar
  = 27.5/40.6774
  = 6.758 N./mm^2
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	12.0	172.0	...	20.6	...	509.

Rib dimension [D]:
```
  = Saddle Width - Web Thickness
  = 172.0 - 12.0
  = 160.000 mm.
```

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 0.0/40.677
  = 0.000 mm.
```

Distance to Centroid [C1]:
```
  = Saddle Width / 2
  = 172.0/2
  = 86.000 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 508.8/40.677 )
  = 35.368 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 * 342.73/35.368
  = 9.690
```

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 45.5/( 2 * 1050.0 ) * 357.957 * 342.73/2
  = 1329.578 N-m
```

Compressive Allowable, KL/r < Cc (9.6903 < 138.1347) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 9.69 )²/(2 * 138.13² ))207/
    ( 5/3+3*(9.69)/(8* 138.13)-( 9.69³)/(8*138.13³)
  = 121.9 N./mm^2
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 6.76/121.88 + ( 1329.58 * 86.0/5088449 )/137.9
  = 0.218
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	12.0	160.0	0.0	19.2	0.0	509.
Web	358.0	12.0	0.0	43.0	0.0	5.15
Totals	...	...	...	62.2	...	514.

Distance to Centroid from Datum [ytot]:
= AY / A
= 0.0/62.155
= 0.000 mm.

Distance to Centroid [C1]:
= Saddle Width / 2
= 172.0/2
= 86.000 mm.

Length of Inner Rib [L]:
= Saddle Height - sqrt((Ro + Wpdthk)^2 - (Pitch/2)^2) - Bpthk
= 950.0 - sqrt((620.0 + 15.0)^2 - (357.957/2)^2) - 16.0
= 340.395 mm.

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(513.8/62.155)
= 28.752 mm.

Slenderness ratio [KL/r]:
= KL/r
= 1 * 340.395/28.752
= 11.839

Unit Force [Force,u]:
= Fl / (2 * Baseplate Length)
= 45.499/(2 * 1050.0)
= 0.022 kN/mm.

Moment at base of inner Rib [Mbase,c]:
= Unit Force * e * L
= 0.022 * 357.957 * 340.395
= 2641.043 N-m

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
= Bending Moment / Section Modulus
= 2641.043/59747.277
= 44.189 N./mm^2

Compressive Allowable, KL/r < Cc (11.8389 < 138.1347) per AISC E2-1 [Sca]:
= $(1-(Klr)^2/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)$
= $(1-(11.84)^2/(2 * 138.13^2))207/$
$(5/3+3*(11.84)/(8* 138.13)-(11.84^3)/(8*138.13^3)$
= 121.3 N./mm^2

AISC Unity Check of Inside Ribs (must be <= 1)
= Sc/Sca + (Mbase,c * C1/I)/Sba
= 8.48/121.32 + (2641.04 * 86.0/513.826)/137.9
= 0.390

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

Total Number of Bolts per BasePlate Nbolts 4

Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	172.38	N./mm^2
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	85.0	mm.
Nominal Bolt Diameter	Bnd	24.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	3.1275	cm^2
Saddle Load QO (Weight)	QO	102.5	kN
Saddle Load QL (Wind/Seismic contribution)	QL	14.4	kN
Maximum Transverse Force	Ft	22.7	kN
Maximum Longitudinal Force	Fl	45.5	kN
Saddle Bolted to Steel Foundation		Yes	

Shear Stress in a Single Bolt [taub]:
```
  = Shear Force / ( 2 * Bolt Area * Number of Bolts )
  = 45/( 2 * 3.13 * 4 )
  = 18.2 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)
  = 45.5/(172.38 * 4.0)
  = 0.6599 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 950.0 * 22.75 + 0.0
  = 21620.91 N-m
```

Eccentricity (e):
```
  = Rmom / QO
  = 21620.91/102.47
  = 210.92 mm. > Bplen/6 --> Uplift in Transverse direction

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

 K1 = 3 (e - 0.5 * Bplen)
    = 3 (210.92 - 0.5*1050.0)
    = -942.24 mm.

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 1.0 * 6.25/220.0 * (440.0 + 210.92)
    = 11104.06 mm.²

 K3 = -K2 * (0.5 * Bplen + f)
    = -11104.06 * (0.5 * 1050.0 + 440.0)
    = -10715415.35 mm.³
```

Iterately Solving for the Effective Bearing Length:
```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + -942.24 * Y² + 11104.06 * Y + -0.1E+08 = 0
```

```
 Y  = 942.52 mm.

 Num = (Bplen / 2 - Y / 3 - e)
     = (1050.0/2 - 942.52/3 - 210.92)
     = -0.09

 Denom = (Bplen / 2 - Y / 3 + f)
       = (1050.0/2 - 942.52/3 + 440.0)
       = 650.83
```

Total Bolt Tension Force [Tforce]:
```
  = - QO * Num / Denom
  = - 102.47 * -0.09/650.83
  = 0.01 kN
```

Bolt Area Required due to Transverse Load [Bltareart]:
```
  = Tforce / (Stba * Nbt)
  = 0.01/( 172.38 * 2.0 )
  = 0.0004 cm^2
```

Required Area of a Single Bolt [Bltarear]:
```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0.0, 0.6599, 0.0004]
  = 0.6599 cm^2
```

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

Bearing Pressure (fc)
```
  = 2(QO + Tforce) / (Y * Bpwid)
  = 2(102.47 + 0.01)/(942.52 * 220.0)
  = 9.88 bars
```

Distance from Baseplate Edge to the Web [ADIST]:
```
  = (Bplen - Weblngth) / 2
  = (1050.0 - 999.2)/2
  = 25.4000 mm.
```

Overturning Moment due To Bolt Tension [Mt]:
```
  = Tforce * Adist
  = 0.01 * 25.4
  = 0.37 N-m
```

Equivalent Bearing Pressure (f1):
```
  = fc * (Y - Adist) / Y
  = 9.88 * (942.52 - 25.4)/942.52
  = 9.62 bars
```

Overturning Moment due to Bearing Pressure [Mc]:
```
  = (Adist² * Bpwid / 6) * (f1 + 2 * fc)
  = (25.4² * 220.0/6) * (9.62 + 2 * 9.88)
  = 69.55 N-m
```

Baseplate Required Thickness [Treq]:
```
  = (6 * max(Mt,Mc) / (Bpwid * Sba))½
  = (6 *max( 0.37,69.55/(220.0 * 162.38))½
  = 3.4172 mm.
```

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

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for CONDENSER E-PK6101-2 -----
Horizontal Vessel Analysis (Ope.): Step: 12 7:41am Dec 24,2021

Note:
Wear Pad Width (225.00) 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( 172.0 + 1.56*sqrt( 599.0 * 12.0 ), 2 * 346.0 )
  = 304.2600 mm.
```

Input and Calculated Values:

Vessel Mean Radius	Rm	599.00	mm.
Stiffened Vessel Length per 4.15.6	L	4844.00	mm.
Distance from Saddle to Vessel tangent	a	346.00	mm.
Saddle Width	b	172.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Shell Allowable Stress used in Calculation		137.90	N./mm^2
Head Allowable Stress used in Calculation		137.90	N./mm^2
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Operating Case		142.64	kN

Horizontal Vessel Analysis Results:	Actual N./mm^2	Allowable N./mm^2
Long. Stress at Top of Midspan	48.04	137.90
Long. Stress at Bottom of Midspan	67.06	137.90
Long. Stress at Top of Saddles	56.33	137.90
Long. Stress at Bottom of Saddles	58.23	137.90
Tangential Shear in Shell	19.91	110.32
Circ. Stress at Horn of Saddle	38.55	172.37
Circ. Compressive Stress in Shell	2.97	137.90

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:

```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0 * ( 8.3/2 + 0 ) * 950.0/1073.8716
  = 11.1 kN
```

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

```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 2.41, 0.0, 0 ) * 950.0/3004.0
  = 0.8 kN
```

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

```
  = max( Fl, Friction Force, Sum of X Forces ) * B / Ls
  = max( 45.5, 0.0, 0 ) * 950.0/3004.0
  = 14.4 kN
```

Saddle Reaction Force due to Earthquake Ft [Fst]:

```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0 * ( 45/2 + 0 ) * 950.0/1073.8716
  = 60.4 kN
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 82 + Max( 0.8, 11, 14, 60 )
  = 142.6 kN
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		144.21	kN
Transverse Shear Load Saddle	Ft	22.75	kN
Longitudinal Shear Load Saddle		45.50	kN

Formulas and Substitutions for Horizontal Vessel Analysis:

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

The Computed K values from Table 4.15.1:
```
 K1  = 0.1066     K2  = 1.1707     K3  = 0.8799     K4  = 0.4011
 K5  = 0.7603     K6  = 0.0529     K7  = 0.0194     K8  = 0.3405
 K9  = 0.2711     K10 = 0.0581     K1* = 0.1923
```

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)]
  = -143*346.0[1-(1-346.0/4844.0+(599.0²-0.0²)/
    (2*346.0*4844.0))/(1+(4*0.0)/(3*4844.0))]
  = 1758.2 N-m
```

Moment per Equation 4.15.4 [M2]:
```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 143*4844/4(1+2(599²-0²)/(4844²))/(1+(4*0)/
    (3*4844))-4*346/4844
  = 128714.4 N-m
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 23.058 * 599.0/(2*12.0) - 128714.4/(pi*599.0²*12.0)
  = 48.04 N./mm^2
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 23.058 * 599.0/(2 * 12.0) + 128714.4/(pi * 599.0² * 12.0 )
  = 67.06 N./mm^2
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 23.058*599.0/(2*12.0)-1758.2/(0.1066*pi*599.0²*12.0)
  = 56.33 N./mm^2
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 23.058*599.0/(2*12.0)+1758.2/(0.1923*pi*599.0²*12.0)
  = 58.23 N./mm^2
```

Maximum Shear Force in the Saddle (4.15.5) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 143( 4844.0 - 2 * 346.0)/(4844.0 + ( 4 * 0.0/3))
  = 122.3 kN
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 122.26/( 599.0 * 12.0 )
```

```
  = 19.91 N./mm^2
```

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

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 143 * 0.1/( 12.0 * ( 172.0 + 66.13 + 66.13 ) )
  = -2.97 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)
  = -143/(4*12.0*(172.0+66.13+66.13)) -
     3* 0.0194*143/(2*12.0²)
  = -38.55 N./mm^2
```

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

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1050.0000	mm.
Baseplate Thickness	Bpthk	16.0000	mm.
Baseplate Width	Bpwid	220.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	12.0000	mm.
Web Thickness	Webtk	12.0000	mm.
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	206.9	N./
Height of Web at Center	Hw,c	314.0	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	356.6	12.0	6.0	42.8	25674.9	0.710E+04
Wearplate	225.0	15.0	19.5	33.8	65812.5	0.449E+04
Web	12.0	314.0	184.0	37.7	693312.2	0.401E+04
BasePlate	220.0	16.0	349.0	35.2	1228480.1	0.162E+05
Totals	...	...	...	149.4	2013279.8	0.318E+05

Distance to Centroid [C1]:
```
  = AY / A
  = 792.63/149.422
  = 134.738 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 * 142.635
  = 29.0294 kN

 Tension Stress, St = ( Fh/As )       =         2.7227  N./mm^2
 Allowed Stress, Sa = 0.6 * Yield Str =       124.1100  N./mm^2
```

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

 Bending Moment, M  = Fh * d          =     13347.1191  N-m

 Bending Stress, Sb = ( M * C1 / I  ) =         5.6600  N./mm^2
 Allowed Stress, Sa = 2/3 * Yield Str =       137.9000  N./mm^2
```

Minimum Thickness of Baseplate per Moss:
```
  = ( 3( Q + Saddle_Wt )BasePlateWidth / ( 4 * BasePlateLength * AllStress ))½
  = ( 3(143 + 2)220.0/( 4 * 1050.0 * 137.9 ))½
  = 12.820 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 )( 590.0 + 15.0 + 15.0 )
  = 1073.871 mm.
```

Distance between Ribs [e]:
```
  = Web Length / ( Nribs - 1 )
  = 1073.8715/( 4 - 1 )
  = 357.957 mm.
```

Baseplate Pressure Area [Ap]:
```
  = e * Bpwid / 2
  = 357.9572 * 220.0/2
  = 393.753 cm^2
```

Axial Load [P]:
```
  = Ap * Bp
  = 393.8 * 0.06
  = 24.313 kN
```

Area of the Rib and Web [Ar]:
```
  = Rib Area + Web Area
  = 19.2 + 21.477
  = 40.677 cm^2
```

Compressive Stress [Sc]:
```
  = P/Ar
  = 24.3/40.6774
  = 5.978 N./mm^2
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	12.0	172.0	...	20.6	...	509.

Rib dimension [D]:
= Saddle Width - Web Thickness
= 172.0 - 12.0
= 160.000 mm.

Distance to Centroid from Datum [ytot]:
= AY / A
= 0.0/40.677
= 0.000 mm.

Distance to Centroid [C1]:
= Saddle Width / 2
= 172.0/2
= 86.000 mm.

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(508.8/40.677)
= 35.368 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 * 342.73/35.368
= 9.690

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * L / 2
= 45.5/(2 * 1050.0) * 357.957 * 342.73/2
= 1329.578 N-m

Compressive Allowable, KL/r < Cc (9.6903 < 138.1347) per AISC E2-1 [Sca]:
= (1-$(Klr)^2/(2*Cc^2)$)Fy/(5/3+3*(Klr)/(8*Cc)-$(Klr^3)/(8*Cc^3)$)
= (1-(9.69 $)^2/(2$ * 138.13^2))207/
(5/3+3*(9.69)/(8* 138.13)-(9.69^3)/(8*138.13^3)
= 121.9 N./mm^2

AISC Unity Check of Outside Ribs (must be <= 1)
= Sc/Sca + (Rm * C1 / I)/Sba
= 5.98/121.88 + (1329.58 * 86.0/5088449)/137.9
= 0.212

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	12.0	160.0	0.0	19.2	0.0	509.
Web	358.0	12.0	0.0	43.0	0.0	5.15
Totals	...	...	...	62.2	...	514.

Distance to Centroid from Datum [ytot]:
= AY / A

```
  = 0.0/62.155
  = 0.000 mm.
```

Distance to Centroid [C1]:
```
  = Saddle Width / 2
  = 172.0/2
  = 86.000 mm.
```

Length of Inner Rib [L]:
```
  = Saddle Height - sqrt( (Ro + Wpdthk)^2 - (Pitch/2)^2 ) - Bpthk
  = 950.0 - sqrt( (620.0 + 15.0)^2 - (357.957/2)^2 ) - 16.0
  = 340.395 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 513.8/62.155 )
  = 28.752 mm.
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 340.395/28.752
  = 11.839
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 45.499/( 2 * 1050.0 )
  = 0.022 kN/mm.
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 0.022 * 357.957 * 340.395
  = 2641.043 N-m
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 2641.043/59747.277
  = 44.189 N./mm^2
```

Compressive Allowable, KL/r < Cc (11.8389 < 138.1347) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 11.84 )²/(2 * 138.13² ))207/
    ( 5/3+3*(11.84)/(8* 138.13)-( 11.84³)/(8*138.13³)
  = 121.3 N./mm^2
```

AISC Unity Check of Inside Ribs (must be <= 1)
```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 7.5/121.32 + ( 2641.04 * 86.0/513.826 )/137.9
  = 0.382
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	172.38	N./mm^2
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	85.0	mm.
Nominal Bolt Diameter	Bnd	24.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	3.1275	cm^2

```
 Saddle Load QO (Weight)                             QO        83.8  kN
 Saddle Load QL (Wind/Seismic contribution)          QL        14.4  kN
 Maximum Transverse Force                            Ft        22.7  kN
 Maximum Longitudinal Force                          Fl        45.5  kN
 Saddle Bolted to Steel Foundation                         Yes
```

Shear Stress in a Single Bolt [taub]:

```
  = Shear Force / ( 2 * Bolt Area * Number of Bolts )
  = 45/( 2 * 3.13 * 4 )
  = 18.2 N./mm^2.  Must be less than 103.4 N./mm^2.
```

<u>Bolt Area Calculation per Dennis R. Moss</u>

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)
  = 45.5/(172.38 * 4.0)
  = 0.6599 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
  = B * Ft + Sum of X Moments
  = 950.0 * 22.75 + 0.0
  = 21620.91 N-m
```

Eccentricity (e):

```
  = Rmom / QO
  = 21620.91/83.83
  = 257.80 mm. > Bplen/6 --> Uplift in Transverse direction

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

 K1 = 3 (e - 0.5 * Bplen)
    = 3 (257.8 - 0.5*1050.0)
    = -801.59 mm.

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 1.0 * 6.25/220.0 * (440.0 + 257.8)
    = 11903.84 mm.²

 K3 = -K2 * (0.5 * Bplen + f)
    = -11903.84 * (0.5 * 1050.0 + 440.0)
    = -11487203.42 mm.³
```

Iteratively Solving for the Effective Bearing Length:

```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + -801.59 * Y² + 11903.84 * Y + -0.1E+08 = 0
 Y  = 804.54 mm.

 Num = (Bplen / 2 - Y / 3 - e)
     = (1050.0/2 - 804.54/3 - 257.8)
     = -0.98

 Denom = (Bplen / 2 - Y / 3 + f)
       = (1050.0/2 - 804.54/3 + 440.0)
       = 696.82
```

Total Bolt Tension Force [Tforce]:
```
  = - QO * Num / Denom
  = - 83.83 * -0.98/696.82
  = 0.12 kN
```

Bolt Area Required due to Transverse Load [Bltareart]:
```
  = Tforce / (Stba * Nbt)
  = 0.12/( 172.38 * 2.0 )
  = 0.0034 cm^2
```

Required Area of a Single Bolt [Bltarear]:
```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0.0, 0.6599, 0.0034]
  = 0.6599 cm^2
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)
```
  = 2(QO + Tforce) / (Y * Bpwid)
  = 2(83.83 + 0.12)/(804.54 * 220.0)
  = 9.49 bars
```

Distance from Baseplate Edge to the Web [ADIST]:
```
  = (Bplen - Weblngth) / 2
  = (1050.0 - 999.2)/2
  = 25.4000 mm.
```

Overturning Moment due To Bolt Tension [Mt]:
```
  = Tforce * Adist
  = 0.12 * 25.4
  = 3.01 N-m
```

Equivalent Bearing Pressure (f1):
```
  = fc * (Y - Adist) / Y
  = 9.49 * (804.54 - 25.4)/804.54
  = 9.19 bars
```

Overturning Moment due to Bearing Pressure [Mc]:
```
  = (Adist² * Bpwid / 6) * (f1 + 2 * fc)
  = (25.4² * 220.0/6) * (9.19 + 2 * 9.49)
  = 66.64 N-m
```

Baseplate Required Thickness [Treq]:
```
  = (6 * max(Mt,Mc) / (Bpwid * Sba))½
  = (6 *max(3.01,66.64/(220.0 * 162.38))½
  = 3.3450 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 (225.00) 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( 172.0 + 1.56*sqrt( 599.0 * 12.0 ), 2 * 346.0 )
  = 304.2600 mm.
```

Input and Calculated Values:

Vessel Mean Radius	Rm	599.00	mm.
Stiffened Vessel Length per 4.15.6	L	4844.00	mm.
Distance from Saddle to Vessel tangent	a	346.00	mm.
Saddle Width	b	172.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Shell Allowable Stress used in Calculation		235.81	N./mm^2
Head Allowable Stress used in Calculation		235.81	N./mm^2
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Test Case, no Ext. Forces		114.94	kN

Horizontal Vessel Analysis Results:	Actual N./mm^2	Allowable N./mm^2
Long. Stress at Top of Midspan	67.11	235.81
Long. Stress at Bottom of Midspan	82.44	235.81
Long. Stress at Top of Saddles	73.79	235.81
Long. Stress at Bottom of Saddles	75.32	235.81
Tangential Shear in Shell	16.05	188.65
Circ. Stress at Horn of Saddle	31.06	353.71
Circ. Compressive Stress in Shell	2.39	235.81

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:
```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0 * ( 2.8/2 + 0 ) * 950.0/1073.8716
  = 3.6 kN
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 0.79, 0.0, 0 ) * 950.0/3004.0
  = 0.3 kN
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 111 + Max( 0.3, 4, 0, 0 )
  = 114.9 kN
```

```
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for CONDENSER E-PK6101-2    -----
Horizontal Vessel Analysis (Test):    Step:   13   7:41am  Dec 24,2021
```

Summary of Loads at the base of this Saddle:

```
 Vertical Load (including saddle weight)            116.51  kN
 Transverse Shear Load Saddle          Ft             1.38  kN
 Longitudinal Shear Load Saddle                       0.79  kN
```

Hydrostatic Test Pressure at center of Vessel: 29.959 bars

Formulas and Substitutions for Horizontal Vessel Analysis:

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

The Computed K values from Table 4.15.1:

```
 K1  = 0.1066     K2  = 1.1707     K3  = 0.8799     K4  = 0.4011
 K5  = 0.7603     K6  = 0.0529     K7  = 0.0194     K8  = 0.3405
 K9  = 0.2711     K10 = 0.0581     K1* = 0.1923
```

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)]
  = -115*346.0[1-(1-346.0/4844.0+(599.0²-0.0²)/
    (2*346.0*4844.0))/(1+(4*0.0)/(3*4844.0))]
  = 1416.7 N-m
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 115*4844/4(1+2(599²-0²)/(4844²))/(1+(4*0)/
    (3*4844))-4*346/4844
  = 103718.5 N-m
```

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

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 29.959 * 599.0/(2*12.0) - 103718.5/(pi*599.0²*12.0)
  = 67.11 N./mm^2
```

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

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 29.959 * 599.0/(2 * 12.0) + 103718.5/(pi * 599.0² * 12.0 )
  = 82.44 N./mm^2
```

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

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 29.959*599.0/(2*12.0)-1416.7/(0.1066*pi*599.0²*12.0)
  = 73.79 N./mm^2
```

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

```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 29.959*599.0/(2*12.0)+1416.7/(0.1923*pi*599.0²*12.0)
  = 75.32 N./mm^2
```

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

```
  = Q(L-2a)/(L+(4*h2/3))
  = 115( 4844.0 - 2 * 346.0)/(4844.0 + ( 4 * 0.0/3))
  = 98.5 kN
```

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

```
  = K2 * T / ( Rm * t )
  = 1.1707 * 98.52/( 599.0 * 12.0 )
  = 16.05 N./mm^2
```

Decay Length (4.15.22) [x1,x2]:


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

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

```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 115 * 0.1/( 12.0 * ( 172.0 + 66.13 + 66.13 ) )
  = -2.39 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)
  = -115/(4*12.0*(172.0+66.13+66.13)) -
     3* 0.0194*115/(2*12.0²)
  = -31.06 N./mm^2
```

Effective reinforcing plate width (4.15.1) [B1]:

```
  = min( b + 1.56 * sqrt( Rm * t ), 2a   )
  = min( 172.0 + 1.56 * sqrt( 599.0 * 12.0 ), 2 * 346.0 )
  = 304.26 mm.
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1050.0000	mm.
Baseplate Thickness	Bpthk	16.0000	mm.
Baseplate Width	Bpwid	220.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	
Rib Thickness	Ribtk	12.0000	mm.
Web Thickness	Webtk	12.0000	mm.
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	206.9	N./
Height of Web at Center	Hw,c	314.0	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	356.6	12.0	6.0	42.8	25674.9	0.710E+04
Wearplate	225.0	15.0	19.5	33.8	65812.5	0.449E+04
Web	12.0	314.0	184.0	37.7	693312.2	0.401E+04
BasePlate	220.0	16.0	349.0	35.2	1228480.1	0.162E+05
Totals	...	...	...	149.4	2013279.8	0.318E+05

Distance to Centroid [C1]:

```
  = AY / A
  = 792.63/149.422
  = 134.738 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 * 114.936
  = 23.3920 kN

 Tension Stress, St = ( Fh/As )       =          2.1939  N./mm^2
 Allowed Stress, Sa = 0.6 * Yield Str =        124.1100  N./mm^2
```

Saddle Splitting Dimension [d]:

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

 Bending Moment, M  = Fh * d          =      10755.1533  N-m

 Bending Stress, Sb = ( M * C1 / I  ) =          4.5609  N./mm^2
 Allowed Stress, Sa = 2/3 * Yield Str =        137.9000  N./mm^2
```

Minimum Thickness of Baseplate per Moss:

```
  = ( 3( Q + Saddle_Wt )BasePlateWidth / ( 4 * BasePlateLength * AllStress ))½
  = ( 3(115 + 2)220.0/( 4 * 1050.0 * 137.9 ))½
  = 11.523 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 )( 590.0 + 15.0 + 15.0 )
  = 1073.871 mm.
```

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 1073.8715/( 4 - 1 )
  = 357.957 mm.
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 357.9572 * 220.0/2
  = 393.753 cm^2
```

Axial Load [P]:

```
  = Ap * Bp
  = 393.8 * 0.05
  = 19.592 kN
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 19.2 + 21.477
  = 40.677 cm^2
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 19.6/40.6774
  = 4.817 N./mm^2
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	12.0	172.0	...	20.6	...	509.

Rib dimension [D]:
```
  = Saddle Width - Web Thickness
  = 172.0 - 12.0
  = 160.000 mm.
```

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 0.0/40.677
  = 0.000 mm.
```

Distance to Centroid [C1]:
```
  = Saddle Width / 2
  = 172.0/2
  = 86.000 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 508.8/40.677 )
  = 35.368 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 * 342.73/35.368
  = 9.690
```

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 0.8/( 2 * 1050.0 ) * 357.957 * 342.73/2
  = 23.210 N-m
```

Compressive Allowable, KL/r < Cc (9.6903 < 138.1347) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 9.69 )²/(2 * 138.13² ))207/
    ( 5/3+3*(9.69)/(8* 138.13)-( 9.69³)/(8*138.13³)
  = 121.9 N./mm^2
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 4.82/121.88 + ( 23.21 * 86.0/5088449 )/137.9
  = 0.042
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	12.0	160.0	0.0	19.2	0.0	509.
Web	358.0	12.0	0.0	43.0	0.0	5.15
Totals	...	...	...	62.2	...	514.

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 0.0/62.155
  = 0.000 mm.
```

Distance to Centroid [C1]:

```
  = Saddle Width / 2
  = 172.0/2
  = 86.000 mm.
```

Length of Inner Rib [L]:
```
  = Saddle Height - sqrt( (Ro + Wpdthk)^2 - (Pitch/2)^2 ) - Bpthk
  = 950.0 - sqrt( (620.0 + 15.0)^2 - (357.957/2)^2 ) - 16.0
  = 340.395 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 513.8/62.155 )
  = 28.752 mm.
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 340.395/28.752
  = 11.839
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 0.794/( 2 * 1050.0 )
  = 0.000 kN/mm.
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 0. * 357.957 * 340.395
  = 46.104 N-m
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 46.104/59747.277
  = 0.771 N./mm^2
```

Compressive Allowable, KL/r < Cc (11.8389 < 138.1347) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 11.84 )²/(2 * 138.13² ))207/
    ( 5/3+3*(11.84)/(8* 138.13)-( 11.84³)/(8*138.13³)
  = 121.3 N./mm^2
```

AISC Unity Check of Inside Ribs (must be <= 1)
```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 6.04/121.32 + ( 46.1 * 86.0/513.826 )/137.9
  = 0.055
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	172.38	N./mm^2
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	85.0	mm.
Nominal Bolt Diameter	Bnd	24.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	3.1275	cm^2
Saddle Load QO (Weight)	QO	112.9	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.3	kN
Maximum Transverse Force	Ft	1.4	kN
Maximum Longitudinal Force	Fl	0.8	kN

```
 Saddle Bolted to Steel Foundation                          Yes
```

Shear Stress in a Single Bolt [taub]:
```
  = Shear Force / ( 2 * Bolt Area * Number of Bolts )
  = 1/( 2 * 3.13 * 4 )
  = 0.5 N./mm^2.  Must be less than 103.4 N./mm^2.
```

<u>Bolt Area Calculation per Dennis R. Moss</u>

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)
  = 0.79/(172.38 * 4.0)
  = 0.0115 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 950.0 * 1.38 + 0.0
  = 1307.01 N-m
```

Eccentricity (e):
```
  = Rmom / QO
  = 1307.01/112.86
  = 11.58 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, 0.0115, 0.0]
  = 0.0115 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 (225.00) 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( 172.0 + 1.56*sqrt( 599.0 * 12.0 ), 2 * 346.0 )
  = 304.2600 mm.
```

Input and Calculated Values:

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

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

 Shell Allowable Stress used in Calculation              235.81  N./mm^2
 Head Allowable Stress used in Calculation               235.81  N./mm^2
```

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

 Saddle Force Q, Test Case, no Ext. Forces              93.02  kN

 Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                         N./mm^2 |      N./mm^2 |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan         68.57 |       235.81 |
 Long. Stress at Bottom of Midspan         80.98 |       235.81 |
 Long. Stress at Top    of Saddles         73.98 |       235.81 |
 Long. Stress at Bottom of Saddles         75.22 |       235.81 |
 ----------------------------------------------------------------
 Tangential Shear in Shell                 12.99 |       188.65 |
 Circ. Stress at Horn of Saddle            25.14 |       353.71 |
 Circ. Compressive Stress in Shell          1.94 |       235.81 |
 ----------------------------------------------------------------
```

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:
```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0 * ( 2.8/2 + 0 ) * 950.0/1073.8716
  = 3.6 kN
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 0.79, 0.0, 0 ) * 950.0/3004.0
  = 0.3 kN
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 89 + Max( 0.3, 4, 0, 0 )
  = 93.0 kN
```

Summary of Loads at the base of this Saddle:
```
 Vertical Load (including saddle weight)              94.59  kN
 Transverse Shear Load Saddle            Ft            1.38  kN
 Longitudinal Shear Load Saddle                        0.79  kN
```

Hydrostatic Test Pressure at center of Vessel: 29.959 bars

Formulas and Substitutions for Horizontal Vessel Analysis:

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

The Computed K values from Table 4.15.1:
```
 K1  = 0.1066      K2  = 1.1707      K3  = 0.8799      K4  = 0.4011
 K5  = 0.7603      K6  = 0.0529      K7  = 0.0194      K8  = 0.3405
 K9  = 0.2711      K10 = 0.0581      K1* = 0.1923
```

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)]
  = -93*346.0[1-(1-346.0/4844.0+(599.0²-0.0²)/
    (2*346.0*4844.0))/(1+(4*0.0)/(3*4844.0))]
  = 1146.6 N-m
```

Moment per Equation 4.15.4 [M2]:
```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
```

```
  = 93*4844/4(1+2(599^2-0^2)/(4844^2))/(1+(4*0)/
    (3*4844))-4*346/4844
  = 83940.6 N-m
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
```
  = P * Rm/(2t) - M2/(pi*Rm^2t)
  = 29.959 * 599.0/(2*12.0) - 83940.6/(pi*599.0^2*12.0)
  = 68.57 N./mm^2
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
```
  = P * Rm/(2t) + M2/(pi * Rm^2 * t)
  = 29.959 * 599.0/(2 * 12.0) + 83940.6/(pi * 599.0^2 * 12.0 )
  = 80.98 N./mm^2
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
```
  = P * Rm/(2t) - M1/(K1*pi*Rm^2t)
  = 29.959*599.0/(2*12.0)-1146.6/(0.1066*pi*599.0^2*12.0)
  = 73.98 N./mm^2
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
```
  = P * Rm/(2t) + M1/(K1* * pi * Rm^2 * t)
  = 29.959*599.0/(2*12.0)+1146.6/(0.1923*pi*599.0^2*12.0)
  = 75.22 N./mm^2
```

Maximum Shear Force in the Saddle (4.15.5) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 93( 4844.0 - 2 * 346.0)/(4844.0 + ( 4 * 0.0/3))
  = 79.7 kN
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 79.73/( 599.0 * 12.0 )
  = 12.99 N./mm^2
```

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

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 93 * 0.1/( 12.0 * ( 172.0 + 66.13 + 66.13 ) )
  = -1.94 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*t^2)
  = -93/(4*12.0*(172.0+66.13+66.13)) -
     3* 0.0194*93/(2*12.0^2)
  = -25.14 N./mm^2
```

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

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1050.0000	mm.
Baseplate Thickness	Bpthk	16.0000	mm.
Baseplate Width	Bpwid	220.0000	mm.
Number of Ribs (inc. outside ribs)	Nribs	4	

Rib Thickness	Ribtk	12.0000	mm.
Web Thickness	Webtk	12.0000	mm.
Web Location	Webloc	Center	
Saddle Yield Stress	Sy	206.9	N./
Height of Web at Center	Hw,c	314.0	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	356.6	12.0	6.0	42.8	25674.9	0.710E+04
Wearplate	225.0	15.0	19.5	33.8	65812.5	0.449E+04
Web	12.0	314.0	184.0	37.7	693312.2	0.401E+04
BasePlate	220.0	16.0	349.0	35.2	1228480.1	0.162E+05
Totals	...	...	...	149.4	2013279.8	0.318E+05

Distance to Centroid [C1]:
= AY / A
= 792.63/149.422
= 134.738 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 * 93.019
= 18.9314 kN

Tension Stress, St = (Fh/As)	=	1.7756	N./mm^2
Allowed Stress, Sa = 0.6 * Yield Str	=	124.1100	N./mm^2

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

Bending Moment, M = Fh * d	=	8704.2676	N-m
Bending Stress, Sb = (M * C1 / I)	=	3.6912	N./mm^2
Allowed Stress, Sa = 2/3 * Yield Str	=	137.9000	N./mm^2

Minimum Thickness of Baseplate per Moss:
= (3(Q + Saddle_Wt)BasePlateWidth / (4 * BasePlateLength * AllStress))½
= (3(93 + 2)220.0/(4 * 1050.0 * 137.9))½
= 10.383 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 )( 590.0 + 15.0 + 15.0 )
  = 1073.871 mm.
```

Distance between Ribs [e]:
```
  = Web Length / ( Nribs - 1 )
  = 1073.8715/( 4 - 1 )
  = 357.957 mm.
```

Baseplate Pressure Area [Ap]:
```
  = e * Bpwid / 2
  = 357.9572 * 220.0/2
  = 393.753 cm^2
```

Axial Load [P]:
```
  = Ap * Bp
  = 393.8 * 0.04
  = 15.856 kN
```

Area of the Rib and Web [Ar]:
```
  = Rib Area + Web Area
  = 19.2 + 21.477
  = 40.677 cm^2
```

Compressive Stress [Sc]:
```
  = P/Ar
  = 15.9/40.6774
  = 3.898 N./mm^2
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib+Web	12.0	172.0	...	20.6	...	509.

Rib dimension [D]:
```
  = Saddle Width - Web Thickness
  = 172.0 - 12.0
  = 160.000 mm.
```

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 0.0/40.677
  = 0.000 mm.
```

Distance to Centroid [C1]:
```
  = Saddle Width / 2
  = 172.0/2
  = 86.000 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 508.8/40.677 )
  = 35.368 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 * 342.73/35.368
  = 9.690
```

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 0.8/( 2 * 1050.0 ) * 357.957 * 342.73/2
  = 23.210 N-m
```

Compressive Allowable, KL/r < Cc (9.6903 < 138.1347) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 9.69 )²/(2 * 138.13² ))207/
    ( 5/3+3*(9.69)/(8* 138.13)-( 9.69³)/(8*138.13³)
  = 121.9 N./mm^2
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 3.9/121.88 + ( 23.21 * 86.0/5088449 )/137.9
  = 0.035
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	12.0	160.0	0.0	19.2	0.0	509.
Web	358.0	12.0	0.0	43.0	0.0	5.15
Totals	...	...	...	62.2	...	514.

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 0.0/62.155
  = 0.000 mm.
```

Distance to Centroid [C1]:
```
  = Saddle Width / 2
  = 172.0/2
  = 86.000 mm.
```

Length of Inner Rib [L]:
```
  = Saddle Height - sqrt( (Ro + Wpdthk)^2 - (Pitch/2)^2 ) - Bpthk
  = 950.0 - sqrt( (620.0 + 15.0)^2 - (357.957/2)^2 ) - 16.0
  = 340.395 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 513.8/62.155 )
  = 28.752 mm.
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 340.395/28.752
  = 11.839
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 0.794/( 2 * 1050.0 )
  = 0.000 kN/mm.
```

Moment at base of inner Rib [Mbase,c]:

```
  = Unit Force * e * L
  = 0. * 357.957 * 340.395
  = 46.104 N-m
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 46.104/59747.277
  = 0.771 N./mm^2
```

Compressive Allowable, KL/r < Cc (11.8389 < 138.1347) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 11.84 )²/(2 * 138.13² ))207/
    ( 5/3+3*(11.84)/(8* 138.13)-( 11.84³)/(8*138.13³)
  = 121.3 N./mm^2
```

AISC Unity Check of Inside Ribs (must be <= 1)
```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 4.89/121.32 + ( 46.1 * 86.0/513.826 )/137.9
  = 0.046
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	4	
Total Number of Bolts in Tension/Baseplate	Nbt	2	
Bolt Material Specification		SA-193 B7	
Bolt Allowable Stress	Stba	172.38	N./mm^2
Bolt Corrosion Allowance	Bca	0.0	mm.
Distance from Bolts to Edge	Edgedis	85.0	mm.
Nominal Bolt Diameter	Bnd	24.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	3.1275	cm^2
Saddle Load QO (Weight)	QO	90.9	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.3	kN
Maximum Transverse Force	Ft	1.4	kN
Maximum Longitudinal Force	Fl	0.8	kN
Saddle Bolted to Steel Foundation		Yes	

Shear Stress in a Single Bolt [taub]:
```
  = Shear Force / ( 2 * Bolt Area * Number of Bolts )
  = 1/( 2 * 3.13 * 4 )
  = 0.5 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)
  = 0.79/(172.38 * 4.0)
  = 0.0115 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 950.0 * 1.38 + 0.0
  = 1307.01 N-m
```

Eccentricity (e):

```
  = Rmom / QO
  = 1307.01/90.94
  = 14.37 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, 0.0115, 0.0]
  = 0.0115 cm^2
```

Nozzle Calculation Summary:

Description	MAWP bars	Ext	MAPNC bars	UG-45	[tr] mm.	Weld Path	Areas or Stresses
T1	...	OK	...	OK	11.33	OK	Passed
T2	...	OK	...	OK	11.33	OK	Passed
S2	...	OK	...	OK	10.16	OK	Passed
S1	...	OK	...	OK	11.33	OK	Passed
S3	...	OK	...	OK	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	T1	425.000	270.000	598.626
20	T2	425.000	90.000	598.626
40	S2	1291.175	270.000	405.700
40	S1	5506.175	90.000	598.626
40	S3	1291.175	90.000	102.068
60	T4	6247.351	90.000	71.550
60	T3	6247.351	270.000	78.000

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

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

Input, Nozzle Desc: T1 From: 20

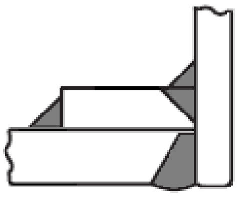
Pressure for Reinforcement Calculations	P	23.081	bars
Temperature for Internal Pressure	Temp	120	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	120	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1180.00	mm.
Design Length of Section	L	897.3333	mm.
Shell Finished (Minimum) Thickness	t	15.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		425.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type		Smls. & wld. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
Diameter Basis (for tr calc only)		OD	
Layout Angle		270.00	deg
Diameter		12.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	14.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	15.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
Diameter of Pad along vessel surface	Dp	483.8500	mm.
Thickness of Pad	te	15.0000	mm.
Weld leg size between Pad and Shell	Wp	10.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		80.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: T1

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

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.08*593.0)/(138*1.0-0.6*23.08)
  = 10.0266 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = (23.08*161.925)/(118*1.0+0.4*23.08)
  = 3.1454 mm.
```

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

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl   598.6257  mm.
 Parallel to Vessel Wall, opening length              d   299.3128  mm.
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp    30.0000  mm.
```

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

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

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

Weld Strength Reduction Factor [fr3]:

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	30.368	5.299	NA
Area in Shell	A1	5.836	25.141	NA
Area in Nozzle Wall	A2	4.680	5.848	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	2.676	2.676	NA
Area in Element	A5	18.000	18.000	NA
TOTAL AREA AVAILABLE	Atot	31.192	51.665	NA

The Internal Pressure Case Governs the Analysis.

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

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

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	476.5182	15.0000	mm.
Based on given Pad Diameter:	483.8500	14.3126	mm.
Based on Shell or Nozzle Thickness:	476.5182	15.0000	mm.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (299.3128*10.0266*1.0+2*12.2686*10.0266*1.0*(1-0.86))
  = 30.368 cm^2
```

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 299.313( 1.0 * 12.0 - 1.0 * 10.027 ) - 2 * 12.269
    ( 1.0 * 12.0 - 1.0 * 10.0266 ) * ( 1 - 0.855 )
  = 5.836 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 30.0 ) * ( 12.27 - 3.15 ) * 0.855
  = 4.680 cm^2
```

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

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

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 6.1454 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 13.0266 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 13.0266 mm.
```

```
 Wall Thickness, shell/head, external pressure     trb2 = 3.4733 mm.
 Wall Thickness                    tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                     tb3 = 11.3312 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 11.331, max( 13.0266, 4.5 ) ]
  = 11.3312 mm.
```

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

```
  = max( ta, tb )
  = max( 6.1454, 11.3312 )
  = 11.3312 mm.
```

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

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

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

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

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

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

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

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

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

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

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

Govrn. thk, tg = 15.0, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.836, Temp. Reduction = 9 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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

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

Govrn. thk, tg = 15.0, tr = 10.027, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.836, Temp. Reduction = 9 °C

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

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

Govrn. thk, tg = 15.0, tr = 10.027, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.836, Temp. Reduction = 9 °C

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

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ANSI B16.5/47 flange per Matl. Specification    -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)        -85 °C
Flange MDMT with Temp reduction per UCS-66(i)(3)       -104 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
Design Pressure/Ambient Rating = 23.08/51.10 = 0.452

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

Weld Size Calculations, Description: T1

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

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          8.5880 = 0.7 * tmin.  9.8980 = 0.7 * Wo mm.
Pad Weld             6.0000 = 0.5*TminPad  7.0700 = 0.7 * Wp mm.
```

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

Weld Load [W]:
```
 = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
 = max( 0, (30.3676 - 5.8365 + 2 * 12.2686 * 0.855 *
   (1.0 * 12.0 - 10.0266 ) )138)
 = 343.96 kN
```

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

Weld Load [W1]:
```
 = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
 = ( 4.6802 + 18.0 + 2.6758 - 0.0 * 0.86 ) * 138
 = 349.63 kN
```

Weld Load [W2]:
```
 = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
 = ( 4.6802 + 0.0 + 1.6758 + ( 2.5175 ) ) * 138
 = 122.36 kN
```

Weld Load [W3]:
```
 = (A2+A3+A4+A5+(2*tn*t*fr1))*S
 = ( 4.6802 + 0.0 + 2.6758 + 18.0 + ( 2.5175 ) ) * 138
 = 384.34 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 323.85 * 14.0 * 0.49 * 118
  = 411. kN
```

Shear, Pad Element Weld [Spew]:
```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 483.85 * 10.0 * 0.49 * 138
  = 514. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 155.7907) * ( 15.2686 - 3.0 ) * 0.7 * 118
  = 496. kN
```

Tension, Pad Groove Weld [Tpgw]:
```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 323.85 * 10.0 * 0.74 * 138
  = 519. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 323.85 * ( 15.0 - 3.0 ) * 0.74 * 138
  = 623. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 514 + 496 ) = 1009 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 411 + 519 + 623 + 0 ) = 1553 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 514 + 623 + 0 ) = 1136 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 1009 kN , must exceed W = 343 kN  or W1 = 349 kN
 Path 2-2 = 1553 kN , must exceed W = 343 kN  or W2 = 122 kN
 Path 3-3 = 1136 kN , must exceed W = 343 kN  or W3 = 384 kN

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

The Drop for this Nozzle is : 22.6551 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 237.6551 mm.

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

```
 Diameter Basis for Vessel                  Vbasis      ID
 Cylindrical or Spherical Vessel            Cylsph      Cylindrical
 Internal Corrosion Allowance                  Cas      3.0000  mm.
 Vessel Diameter                                Dv    1180.000  mm.
 Vessel Thickness                               Tv      15.000  mm.

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

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

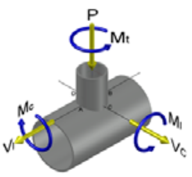
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	323.850	mm.
Nozzle Thickness	Tn	15.269	mm.
Nozzle Material		SA-333 6	
Nozzle UNS Number		K03006	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm^2
Thickness of Reinforcing Pad	Tpad	15.000	mm.
Diameter of Reinforcing Pad	Dpad	483.850	mm.
Design Internal Pressure	Dp	23.081	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

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

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

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



Stress Attenuation Diameter (for Insert Plates) per WRC 297:
= NozzleOD + 2 * 1.65 * sqrt(Rmean(t - ca))
= 323.85 + 2 * 1.65 * sqrt(599.0 (15.0 - 3.0))
= 603.631 mm.

WRC 107 Stress Calculation for SUStained loads:

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

Dimensionless Parameters used : Gamma = 22.46

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

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

Dimensionless Parameters used : Gamma = 49.92

Dimensionless Loads for Cylindrical Shells at Pad edge:

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for CONDENSER E-PK6101-2 -----
Nozzle Calcs.: T1 Nozl: 8 7:41am Dec 24,2021

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.353	4C	4.461	(A,B)
N(PHI) / (P/Rm)	0.353	3C	1.855	(C,D)
M(PHI) / (P)	0.353	2C1	0.009	(A,B)
M(PHI) / (P)	0.353	1C !	0.065	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.353	3A	1.401	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.353	1A	0.059	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.353	3B	2.663	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.353	1B	0.007	(A,B,C,D)
N(x) / (P/Rm)	0.353	3C	1.855	(A,B)
N(x) / (P/Rm)	0.353	4C	4.461	(C,D)
M(x) / (P)	0.353	1C1	0.024	(A,B)
M(x) / (P)	0.353	2C !	0.033	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.353	4A	4.827	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.353	2A	0.023	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.353	4B	1.536	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.353	2B	0.011	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-7.4	-7.4	-7.4	-7.4	-3.1	-3.1	-3.1	-3.1
Circ. Bend. P	-4.7	4.7	-4.7	4.7	-32.6	32.6	-32.6	32.6
Circ. Memb. MC	0.0	0.0	0.0	0.0	-14.1	-14.1	14.1	14.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	-177.6	177.6	177.6	-177.6
Circ. Memb. ML	-26.8	-26.8	26.8	26.8	0.0	0.0	0.0	0.0
Circ. Bend. ML	-21.5	21.5	21.5	-21.5	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-60.5	-8.0	36.1	2.5	-227.3	193.0	156.0	-134.0
Long. Memb. P	-3.1	-3.1	-3.1	-3.1	-7.4	-7.4	-7.4	-7.4
Long. Bend. P	-12.1	12.1	-12.1	12.1	-16.7	16.7	-16.7	16.7
Long. Memb. MC	0.0	0.0	0.0	0.0	-48.5	-48.5	48.5	48.5
Long. Bend. MC	0.0	0.0	0.0	0.0	-70.1	70.1	70.1	-70.1
Long. Memb. ML	-15.4	-15.4	15.4	15.4	0.0	0.0	0.0	0.0
Long. Bend. ML	-33.2	33.2	33.2	-33.2	0.0	0.0	0.0	0.0
Tot. Long. Str.	-63.8	26.8	33.5	-8.8	-142.7	30.8	94.4	-12.3
Shear VC	1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.3	-1.3	1.3	1.3
Shear MT	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Tot. Shear	5.6	5.6	3.0	3.0	3.0	3.0	5.6	5.6
Str. Int.	68.0	36.5	38.1	12.8	227.4	193.0	156.5	134.3

WRC 107/537 Stress Summations:

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

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm	(SUS)	49.6	51.9	49.6	51.9	49.6	51.9	49.6	51.9
Circ. Pl	(SUS)	-18.3	-18.3	13.5	13.5	-7.8	-7.8	4.6	4.6
Circ. Q	(SUS)	-29.7	29.7	21.7	-21.7	-80.6	80.6	66.8	-66.8
Long. Pm	(SUS)	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8
Long. Pl	(SUS)	-7.6	-7.6	4.3	4.3	-13.0	-13.0	8.2	8.2
Long. Q	(SUS)	-49.8	49.8	35.4	-35.4	-40.7	40.7	32.6	-32.6
Shear Pm	(SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl	(SUS)	0.9	0.9	-0.9	-0.9	-0.9	-0.9	0.9	0.9
Shear Q	(SUS)	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Pm (SUS)		49.6	51.9	49.6	51.9	49.6	51.9	49.6	51.9
Pm+Pl (SUS)		31.3	33.6	63.1	65.4	41.8	44.1	54.2	56.5
Pm+Pl+Q (Total)		35.6	70.6	85.3	50.5	39.9	124.8	121.4	14.8

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	51.88	137.90	Passed
Pm+Pl (SUS)	65.39	206.85	Passed
Pm+Pl+Q (TOTAL)	124.84	413.70	Passed

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

WRC 107/537 Stress Summations:

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

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm	(SUS)	112.9	115.2	112.9	115.2	112.9	115.2	112.9	115.2
Circ. Pl	(SUS)	-34.2	-34.2	19.3	19.3	-17.2	-17.2	11.0	11.0
Circ. Q	(SUS)	-26.3	26.3	16.8	-16.8	-210.1	210.1	145.0	-145.0
Long. Pm	(SUS)	56.5	56.5	56.5	56.5	56.5	56.5	56.5	56.5
Long. Pl	(SUS)	-18.5	-18.5	12.3	12.3	-56.0	-56.0	41.1	41.1
Long. Q	(SUS)	-45.3	45.3	21.1	-21.1	-86.8	86.8	53.4	-53.4
Shear Pm	(SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl	(SUS)	1.3	1.3	-1.3	-1.3	-1.3	-1.3	1.3	1.3
Shear Q	(SUS)	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Pm (SUS)		112.9	115.2	112.9	115.2	112.9	115.2	112.9	115.2
Pm+Pl (SUS)		78.7	81.1	132.3	134.6	95.8	98.1	124.0	126.3

Pm+Pl+Q (Total)	60.8	108.5	149.2	117.9	114.7	308.2	269.2	63.9

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	115.23	137.90	Passed
Pm+Pl (SUS)	134.58	206.85	Passed
Pm+Pl+Q (TOTAL)	308.22	413.70	Passed

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

Input, Nozzle Desc: T2 From: 20

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

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

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

Distance from Bottom/Left Tangent                     425.00  mm.

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

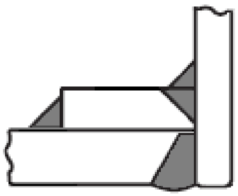
Type of Element Connected to the Shell : Nozzle

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

Diameter Basis (for tr calc only)                        OD
Layout Angle                                           90.00  deg
Diameter                                             12.0000  in.

Size and Thickness Basis                               Minimum
Nominal Thickness                            tn       80

Flange Material                                    SA-350 LF2
Flange Type                                  Weld Neck Flange

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

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

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

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

```
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for CONDENSER E-PK6101-2    -----
Nozzle Calcs.: T2                        Nozl:    9   7:41am  Dec 24,2021
```

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: T2

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

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

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.0*593.0)/(138*1.0-0.6*23.0)
  = 9.9911 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = (23.0*161.925)/(118*1.0+0.4*23.0)
  = 3.1344 mm.
```

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

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl    598.6257  mm.
 Parallel to Vessel Wall, opening length              d    299.3128  mm.
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp     30.0000  mm.
```

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

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

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

Weld Strength Reduction Factor [fr3]:


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

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

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

The Internal Pressure Case Governs the Analysis.

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

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

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

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

Reinforcement Areas per Figure UG-37.1

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

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

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

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

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

```
 Wall Thickness, shell/head, external pressure     trb2 = 3.4733 mm.
 Wall Thickness                   tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 11.3312 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 11.331, max( 12.9911, 4.5 ) ]
  = 11.3312 mm.
```

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

```
  = max( ta, tb )
  = max( 6.1344, 11.3312 )
  = 11.3312 mm.
```

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

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

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

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ANSI B16.5/47 flange per Matl. Specification      -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)          -86 °C
Flange MDMT with Temp reduction per UCS-66(i)(3)         -104 °C
```

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

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

Weld Size Calculations, Description: T2

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

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          8.5880 = 0.7 * tmin.  9.8980 = 0.7 * Wo mm.
Pad Weld             6.0000 = 0.5*TminPad  7.0700 = 0.7 * Wp mm.
```

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

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

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

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

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

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

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 323.85 * 14.0 * 0.49 * 118
  = 411. kN
```

Shear, Pad Element Weld [Spew]:
```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 483.85 * 10.0 * 0.49 * 138
  = 514. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 155.7907) * ( 15.2686 - 3.0 ) * 0.7 * 118
  = 496. kN
```

Tension, Pad Groove Weld [Tpgw]:
```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 323.85 * 10.0 * 0.74 * 138
  = 519. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 323.85 * ( 15.0 - 3.0 ) * 0.74 * 138
  = 623. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 514 + 496 ) = 1009 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 411 + 519 + 623 + 0 ) = 1553 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 514 + 623 + 0 ) = 1136 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 1009 kN , must exceed W = 341 kN  or W1 = 349 kN
 Path 2-2 = 1553 kN , must exceed W = 341 kN  or W2 = 122 kN
 Path 3-3 = 1136 kN , must exceed W = 341 kN  or W3 = 384 kN

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

The Drop for this Nozzle is : 22.6551 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 237.6551 mm.

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

```
 Diameter Basis for Vessel                 Vbasis      ID
 Cylindrical or Spherical Vessel           Cylsph      Cylindrical
 Internal Corrosion Allowance                 Cas      3.0000  mm.
 Vessel Diameter                               Dv    1180.000  mm.
 Vessel Thickness                              Tv      15.000  mm.

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

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

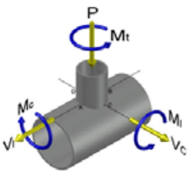
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	323.850	mm.
Nozzle Thickness	Tn	15.269	mm.
Nozzle Material		SA-333 6	
Nozzle UNS Number		K03006	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm^2
Thickness of Reinforcing Pad	Tpad	15.000	mm.
Diameter of Reinforcing Pad	Dpad	483.850	mm.
Design Internal Pressure	Dp	23.000	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

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

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

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



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

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

WRC 107 Stress Calculation for SUStained loads:

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

Dimensionless Parameters used : Gamma = 22.46

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

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

Dimensionless Parameters used : Gamma = 49.92

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure		Value	Location
N(PHI) / (P/Rm)	0.353	4C		4.461	(A,B)
N(PHI) / (P/Rm)	0.353	3C		1.855	(C,D)
M(PHI) / (P)	0.353	2C1		0.009	(A,B)
M(PHI) / (P)	0.353	1C	!	0.065	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.353	3A		1.401	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.353	1A		0.059	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.353	3B		2.663	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.353	1B		0.007	(A,B,C,D)
N(x) / (P/Rm)	0.353	3C		1.855	(A,B)
N(x) / (P/Rm)	0.353	4C		4.461	(C,D)
M(x) / (P)	0.353	1C1		0.024	(A,B)
M(x) / (P)	0.353	2C	!	0.033	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.353	4A		4.827	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.353	2A		0.023	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.353	4B		1.536	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.353	2B		0.011	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
Circ. Memb. P	-7.4	-7.4	-7.4	-7.4	-3.1	-3.1	-3.1	-3.1
Circ. Bend. P	-4.7	4.7	-4.7	4.7	-32.6	32.6	-32.6	32.6
Circ. Memb. MC	0.0	0.0	0.0	0.0	-14.1	-14.1	14.1	14.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	-177.6	177.6	177.6	-177.6
Circ. Memb. ML	-26.8	-26.8	26.8	26.8	0.0	0.0	0.0	0.0
Circ. Bend. ML	-21.5	21.5	21.5	-21.5	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-60.5	-8.0	36.1	2.5	-227.3	193.0	156.0	-134.0
Long. Memb. P	-3.1	-3.1	-3.1	-3.1	-7.4	-7.4	-7.4	-7.4
Long. Bend. P	-12.1	12.1	-12.1	12.1	-16.7	16.7	-16.7	16.7
Long. Memb. MC	0.0	0.0	0.0	0.0	-48.5	-48.5	48.5	48.5
Long. Bend. MC	0.0	0.0	0.0	0.0	-70.1	70.1	70.1	-70.1
Long. Memb. ML	-15.4	-15.4	15.4	15.4	0.0	0.0	0.0	0.0
Long. Bend. ML	-33.2	33.2	33.2	-33.2	0.0	0.0	0.0	0.0
Tot. Long. Str.	-63.8	26.8	33.5	-8.8	-142.7	30.8	94.4	-12.3
Shear VC	1.3	1.3	-1.3	-1.3	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.3	-1.3	1.3	1.3
Shear MT	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Tot. Shear	5.6	5.6	3.0	3.0	3.0	3.0	5.6	5.6
Str. Int.	68.0	36.5	38.1	12.8	227.4	193.0	156.5	134.3

WRC 107/537 Stress Summations:

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

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

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

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

*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)	112.5	114.8	112.5	114.8	112.5	114.8	112.5	114.8
Circ. Pl	(SUS)	-34.2	-34.2	19.3	19.3	-17.2	-17.2	11.0	11.0
Circ. Q	(SUS)	-26.3	26.3	16.8	-16.8	-210.1	210.1	145.0	-145.0
Long. Pm	(SUS)	56.3	56.3	56.3	56.3	56.3	56.3	56.3	56.3
Long. Pl	(SUS)	-18.5	-18.5	12.3	12.3	-56.0	-56.0	41.1	41.1
Long. Q	(SUS)	-45.3	45.3	21.1	-21.1	-86.8	86.8	53.4	-53.4
Shear Pm	(SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl	(SUS)	1.3	1.3	-1.3	-1.3	-1.3	-1.3	1.3	1.3
Shear Q	(SUS)	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Pm	(SUS)	112.5	114.8	112.5	114.8	112.5	114.8	112.5	114.8
Pm+Pl	(SUS)	78.3	80.6	131.9	134.2	95.4	97.7	123.6	125.9

Pm+Pl+Q (Total)	60.6	108.1	148.8	117.5	115.1	307.8	268.8	64.1

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

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

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

Input, Nozzle Desc: S2 From: 40

Pressure for Reinforcement Calculations	P	23.116	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1180.00	mm.
Design Length of Section	L	4844.0005	mm.
Shell Finished (Minimum) Thickness	t	15.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1291.18	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

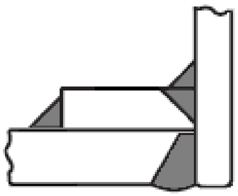
Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type		Smls. & wld. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
Diameter Basis (for tr calc only)		OD	
Layout Angle		270.00	deg
Diameter		8.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	80	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	15.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
Diameter of Pad along vessel surface	Dp	379.0750	mm.
Thickness of Pad	te	15.0000	mm.
Weld leg size between Pad and Shell	Wp	10.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	10.0000	mm.
Reinforcing Pad Width		80.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

```
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for CONDENSER E-PK6101-2    -----
Nozzle Calcs.: S2                      Nozl:   10   7:41am  Dec 24,2021
```

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: S2

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

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

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.12*593.0)/(138*1.0-0.6*23.12)
  = 10.0418 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = (23.12*109.5375)/(118*1.0+0.4*23.12)
  = 2.1309 mm.
```

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

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl   405.7000  mm.
 Parallel to Vessel Wall, opening length              d   202.8500  mm.
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp    30.0000  mm.
```

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

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

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

Weld Strength Reduction Factor [fr3]:


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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	20.606	7.264	NA
Area in Shell	A1	3.926	9.866	NA
Area in Nozzle Wall	A2	3.069	3.806	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.855	1.855	NA
Area in Element	A5	18.000	18.000	NA
TOTAL AREA AVAILABLE	Atot	26.850	33.527	NA

The Internal Pressure Case Governs the Analysis.

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

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

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	323.5766	15.0000	mm.
Based on given Pad Diameter:	379.0750	9.7970	mm.
Based on Shell or Nozzle Thickness:	360.1346	11.1125	mm.

Area Required [A]:

```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (202.85*10.0418*1.0+2*8.1125*10.0418*1.0*(1-0.86))
  = 20.606 cm^2
```

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 202.85( 1.0 * 12.0 - 1.0 * 10.042 ) - 2 * 8.113
    ( 1.0 * 12.0 - 1.0 * 10.0418 ) * ( 1 - 0.855 )
  = 3.926 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 30.0 ) * ( 8.11 - 2.13 ) * 0.855
  = 3.069 cm^2
```

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

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

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

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

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

```
 Wall Thickness for Internal/External pressures      ta = 5.1309 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 13.0418 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 13.0418 mm.
```

```
 Wall Thickness, shell/head, external pressure     trb2 = 3.4733 mm.
 Wall Thickness                   tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 10.1600 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 10.16, max( 13.0418, 4.5 ) ]
  = 10.1600 mm.
```

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

```
  = max( ta, tb )
  = max( 5.1309, 10.16 )
  = 10.1600 mm.
```

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

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

```
 Sustained    :     50.5,  Allowable :    117.9 N./mm^2  Passed
 Expansion    :      0.0,  Allowable :    244.2 N./mm^2  Passed
 Occasional   :     13.9,  Allowable :    156.8 N./mm^2  Passed
 Shear        :     20.4,  Allowable :     82.5 N./mm^2  Passed
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

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

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

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

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

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

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

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

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

Govrn. thk, tg = 11.113, tr = 2.131, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.263, Temp. Reduction = 78 °C

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

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

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

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

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

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

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

 Calculated Minimum Design Metal Temperature                -104 °C

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
 MDMT of ANSI B16.5/47 flange per Matl. Specification        -46 °C
 Flange MDMT with Temp reduction per UCS-66(i)(2)            -85 °C
 Flange MDMT with Temp reduction per UCS-66(i)(3)           -104 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
 Design Pressure/Ambient Rating = 23.12/51.10 = 0.452

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

Weld Size Calculations, Description: S2

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

Results Per UW-16.1:

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

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (20.6061 - 3.9261 + 2 * 8.1125 * 0.855 *
    (1.0 * 12.0 - 10.0418 ) )138)
  = 233.74 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.0685 + 18.0 + 1.855 - 0.0 * 0.86 ) * 138
  = 316.09 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.0685 + 0.0 + 0.855 + ( 1.6647 ) ) * 138
  = 77.06 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.0685 + 0.0 + 1.855 + 18.0 + ( 1.6647 ) ) * 138
  = 339.04 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 219.075 * 10.0 * 0.49 * 118
  = 199. kN
```

Shear, Pad Element Weld [Spew]:
```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 379.075 * 10.0 * 0.49 * 138
  = 402. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 105.4813) * ( 11.1125 - 3.0 ) * 0.7 * 118
  = 222. kN
```

Tension, Pad Groove Weld [Tpgw]:
```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 219.075 * 10.0 * 0.74 * 138
  = 351. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 219.075 * ( 15.0 - 3.0 ) * 0.74 * 138
  = 421. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 402 + 222 ) = 624 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 199 + 351 + 421 + 0 ) = 971 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 402 + 421 + 0 ) = 824 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 624 kN , must exceed W = 233 kN  or W1 = 316 kN
 Path 2-2 = 971 kN , must exceed W = 233 kN  or W2 = 77 kN
 Path 3-3 = 823 kN , must exceed W = 233 kN  or W3 = 339 kN

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

The Drop for this Nozzle is : 10.2574 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 225.2574 mm.

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

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1180.000	mm.
Vessel Thickness	Tv	15.000	mm.
Design Temperature	T1	125.0	°C
Vessel Material		SA-516 70	
Vessel UNS Number		K02700	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	137.90	N./mm^2

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

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for CONDENSER E-PK6101-2 -----
Nozzle Calcs.: S2 Nozl: 10 7:41am Dec 24,2021

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

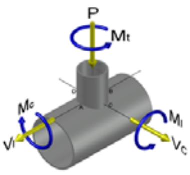
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	219.075	mm.
Nozzle Thickness	Tn	11.113	mm.
Nozzle Material		SA-333 6	
Nozzle UNS Number		K03006	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm^2
Thickness of Reinforcing Pad	Tpad	15.000	mm.
Diameter of Reinforcing Pad	Dpad	379.075	mm.
Design Internal Pressure	Dp	23.116	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

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

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

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



Stress Attenuation Diameter (for Insert Plates) per WRC 297:
= NozzleOD + 2 * 1.65 * sqrt(Rmean(t - ca))
= 219.075 + 2 * 1.65 * sqrt(599.0 (15.0 - 3.0))
= 498.856 mm.

WRC 107 Stress Calculation for SUStained loads:

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

Torsional Moment MT 8400.0 N-m

Dimensionless Parameters used : Gamma = 22.46

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.158	4C	3.689	(A,B)
N(PHI) / (P/Rm)	0.158	3C	3.023	(C,D)
M(PHI) / (P)	0.158	2C1	0.072	(A,B)
M(PHI) / (P)	0.158	1C	0.104	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.158	3A	0.773	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.158	1A	0.093	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.158	3B	2.443	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.158	1B	0.041	(A,B,C,D)
N(x) / (P/Rm)	0.158	3C	3.023	(A,B)
N(x) / (P/Rm)	0.158	4C	3.689	(C,D)
M(x) / (P)	0.158	1C1	0.109	(A,B)
M(x) / (P)	0.158	2C	0.072	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.158	4A	1.177	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.158	2A	0.050	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.158	4B	0.745	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.158	2B	0.067	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
Circ. Memb. P	-1.8	-1.8	-1.8	-1.8	-1.5	-1.5	-1.5	-1.5
Circ. Bend. P	-4.7	4.7	-4.7	4.7	-6.9	6.9	-6.9	6.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	-3.3	-3.3	3.3	3.3
Circ. Memb. MC	0.0	0.0	0.0	0.0	-54.3	54.3	54.3	-54.3
Circ. Memb. ML	-10.6	-10.6	10.6	10.6	0.0	0.0	0.0	0.0
Circ. Bend. ML	-24.1	24.1	24.1	-24.1	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-41.3	16.5	28.2	-10.6	-66.0	56.4	49.4	-45.6
Long. Memb. P	-1.5	-1.5	-1.5	-1.5	-1.8	-1.8	-1.8	-1.8
Long. Bend. P	-7.2	7.2	-7.2	7.2	-4.7	4.7	-4.7	4.7
Long. Memb. MC	0.0	0.0	0.0	0.0	-5.1	-5.1	5.1	5.1
Long. Bend. MC	0.0	0.0	0.0	0.0	-29.0	29.0	29.0	-29.0
Long. Memb. ML	-3.2	-3.2	3.2	3.2	0.0	0.0	0.0	0.0
Long. Bend. ML	-39.1	39.1	39.1	-39.1	0.0	0.0	0.0	0.0
Tot. Long. Str.	-51.0	41.6	33.7	-30.2	-40.6	26.8	27.5	-21.0
Shear VC	0.9	0.9	-0.9	-0.9	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Shear MT	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
Tot. Shear	5.0	5.0	3.3	3.3	3.3	3.3	5.0	5.0
Str. Int.	53.1	42.5	35.2	30.7	66.4	56.7	50.4	46.6

Dimensionless Parameters used : Gamma = 49.92

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.277	4C	5.562	(A,B)
N(PHI) / (P/Rm)	0.277	3C	2.690	(C,D)
M(PHI) / (P)	0.277	2C1	0.016	(A,B)
M(PHI) / (P)	0.277	1C !	0.065	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.277	3A	1.715	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.277	1A	0.061	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.277	3B	3.655	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.277	1B	0.012	(A,B,C,D)
N(x) / (P/Rm)	0.277	3C	2.690	(A,B)
N(x) / (P/Rm)	0.277	4C	5.562	(C,D)
M(x) / (P)	0.277	1C1	0.038	(A,B)
M(x) / (P)	0.277	2C !	0.033	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.277	4A	4.650	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.277	2A	0.025	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.277	4B	1.839	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.277	2B	0.018	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
		Stress Intensity Values at							
Circ. Memb.	P	-6.2	-6.2	-6.2	-6.2	-3.0	-3.0	-3.0	-3.0
Circ. Bend.	P	-5.2	5.2	-5.2	5.2	-21.7	21.7	-21.7	21.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-9.8	-9.8	9.8	9.8
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-104.5	104.5	104.5	-104.5
Circ. Memb.	ML	-20.8	-20.8	20.8	20.8	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-19.8	19.8	19.8	-19.8	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-52.0	-2.0	29.3	0.0	-139.0	113.4	89.6	-76.0
Long. Memb.	P	-3.0	-3.0	-3.0	-3.0	-6.2	-6.2	-6.2	-6.2
Long. Bend.	P	-12.6	12.6	-12.6	12.6	-11.1	11.1	-11.1	11.1
Long. Memb.	MC	0.0	0.0	0.0	0.0	-26.5	-26.5	26.5	26.5
Long. Bend.	MC	0.0	0.0	0.0	0.0	-43.1	43.1	43.1	-43.1
Long. Memb.	ML	-10.5	-10.5	10.5	10.5	0.0	0.0	0.0	0.0
Long. Bend.	ML	-29.9	29.9	29.9	-29.9	0.0	0.0	0.0	0.0
Tot. Long. Str.		-56.0	29.1	24.8	-9.8	-87.0	21.5	52.3	-11.7
Shear	VC	1.1	1.1	-1.1	-1.1	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-1.1	-1.1	1.1	1.1
Shear	MT	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Tot. Shear		4.2	4.2	2.0	2.0	2.0	2.0	4.2	4.2
Str. Int.		58.7	32.2	30.1	10.6	139.1	113.5	90.0	76.3

WRC 107/537 Stress Summations:

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

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
		Stress Intensity Values at							
Circ. Pm	(SUS)	49.6	52.0	49.6	52.0	49.6	52.0	49.6	52.0
Circ. Pl	(SUS)	-12.4	-12.4	8.8	8.8	-4.8	-4.8	1.9	1.9
Circ. Q	(SUS)	-28.9	28.9	19.4	-19.4	-61.2	61.2	47.5	-47.5
Long. Pm	(SUS)	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8
Long. Pl	(SUS)	-4.7	-4.7	1.7	1.7	-6.9	-6.9	3.3	3.3
Long. Q	(SUS)	-46.3	46.3	32.0	-32.0	-33.7	33.7	24.2	-24.2
Shear Pm	(SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl	(SUS)	0.9	0.9	-0.9	-0.9	-0.9	-0.9	0.9	0.9
Shear Q	(SUS)	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
Pm (SUS)		49.6	52.0	49.6	52.0	49.6	52.0	49.6	52.0
Pm+Pl (SUS)		37.3	39.6	58.4	60.8	44.8	47.2	51.5	53.9
Pm+Pl+Q (Total)		36.0	72.5	78.4	47.2	19.4	108.5	99.5	10.3

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	51.95	137.90	Passed
Pm+Pl (SUS)	60.75	206.85	Passed
Pm+Pl+Q (TOTAL)	108.51	413.70	Passed

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

WRC 107/537 Stress Summations:

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

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
		Stress Intensity Values at							
Circ. Pm	(SUS)	113.1	115.4	113.1	115.4	113.1	115.4	113.1	115.4
Circ. Pl	(SUS)	-27.0	-27.0	14.7	14.7	-12.8	-12.8	6.8	6.8
Circ. Q	(SUS)	-25.0	25.0	14.7	-14.7	-126.2	126.2	82.8	-82.8
Long. Pm	(SUS)	56.5	56.5	56.5	56.5	56.5	56.5	56.5	56.5
Long. Pl	(SUS)	-13.5	-13.5	7.5	7.5	-32.7	-32.7	20.3	20.3
Long. Q	(SUS)	-42.6	42.6	17.3	-17.3	-54.2	54.2	32.0	-32.0
Shear Pm	(SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl	(SUS)	1.1	1.1	-1.1	-1.1	-1.1	-1.1	1.1	1.1
Shear Q	(SUS)	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Pm (SUS)		113.1	115.4	113.1	115.4	113.1	115.4	113.1	115.4

Pm+Pl (SUS)	86.1	88.4	127.8	130.1	100.3	102.6	119.9	122.2
Pm+Pl+Q (Total)	61.4	114.0	142.5	115.5	31.2	228.9	202.9	47.2

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	115.40	137.90	Passed
Pm+Pl (SUS)	130.07	206.85	Passed
Pm+Pl+Q (TOTAL)	228.88	413.70	Passed

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

Input, Nozzle Desc: S1 From: 40

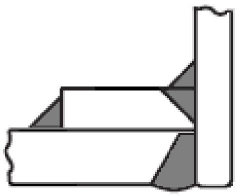
Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1180.00	mm.
Design Length of Section	L	4844.0005	mm.
Shell Finished (Minimum) Thickness	t	15.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		5506.18	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

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

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: S1

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

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

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.0*593.0)/(138*1.0-0.6*23.0)
  = 9.9911 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = (23.0*161.925)/(118*1.0+0.4*23.0)
  = 3.1344 mm.
```

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

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl    598.6257   mm.
 Parallel to Vessel Wall, opening length              d    299.3128   mm.
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp     30.0000   mm.
```

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

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

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

Weld Strength Reduction Factor [fr3]:

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	30.260	10.721	NA
Area in Shell	A1	5.942	14.553	NA
Area in Nozzle Wall	A2	4.686	5.848	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.855	1.855	NA
Area in Element	A5	18.000	18.000	NA
TOTAL AREA AVAILABLE	Atot	30.482	40.256	NA

The Internal Pressure Case Governs the Analysis.

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

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

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	521.3797	12.0000	mm.
Based on given Pad Diameter:	523.8500	11.8518	mm.
Based on Shell or Nozzle Thickness:	481.8738	15.0000	mm.

Area Required [A]:

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

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:

```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 299.313( 1.0 * 12.0 - 1.0 * 9.991 ) - 2 * 12.269
    ( 1.0 * 12.0 - 1.0 * 9.9911 ) * ( 1 - 0.855 )
  = 5.942 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 30.0 ) * ( 12.27 - 3.13 ) * 0.855
  = 4.686 cm^2
```

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

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

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

```
  = (min(Dp,DL)-(Nozzle OD))(min(tp,Tlwp,te)) * fr4 * 0.75
  = ( 523.85 - 323.85 )12.0 * 1.0 * 0.75
  = 18.000 cm^2
```

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

```
 Wall Thickness for Internal/External pressures      ta = 6.1344 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 12.9911 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 12.9911 mm.
```

```
 Wall Thickness, shell/head, external pressure     trb2 = 3.4733 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 11.3312 mm.
```

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

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

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

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

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

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

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

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

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

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

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

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

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

Govrn. thk, tg = 12.0, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.833, Temp. Reduction = 9 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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

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

Govrn. thk, tg = 12.0, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.833, Temp. Reduction = 9 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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

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

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

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

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ANSI B16.5/47 flange per Matl. Specification        -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)            -86 °C
Flange MDMT with Temp reduction per UCS-66(i)(3)           -104 °C
```

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

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

Weld Size Calculations, Description: S1

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

Results Per UW-16.1:

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

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

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

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 4.6858 + 18.0 + 1.855 - 0.0 * 0.86 ) * 138
  = 338.39 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 4.6858 + 0.0 + 0.855 + ( 2.5175 ) ) * 138
  = 111.11 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 4.6858 + 0.0 + 1.855 + 18.0 + ( 2.5175 ) ) * 138
  = 373.10 kN
```

Strength of Connection Elements for Failure Path Analysis

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

```
  = ( 3.1416/2.0 ) * 323.85 * 10.0 * 0.49 * 118
  = 294. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 523.85 * 10.0 * 0.49 * 138
  = 556. kN
```

Shear, Nozzle Wall [Snw]:

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

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 323.85 * 12.0 * 0.74 * 138
  = 623. kN
```

Tension, Shell Groove Weld [Tngw]:

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

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 556 + 496 ) = 1052 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 294 + 623 + 623 + 0 ) = 1540 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 556 + 623 + 0 ) = 1179 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 1051 kN , must exceed W = 341 kN  or W1 = 338 kN
 Path 2-2 = 1539 kN , must exceed W = 341 kN  or W2 = 111 kN
 Path 3-3 = 1178 kN , must exceed W = 341 kN  or W3 = 373 kN

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

The Drop for this Nozzle is : 22.6551 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 237.6551 mm.

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

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1180.000	mm.
Vessel Thickness	Tv	15.000	mm.
Design Temperature	T1	125.0	°C
Vessel Material		SA-516 70	
Vessel UNS Number		K02700	
Vessel Cold S.I. Allowable	Smc	137.90	N./mm^2
Vessel Hot S.I. Allowable	Smh	137.90	N./mm^2

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

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for CONDENSER E-PK6101-2 -----
Nozzle Calcs.: S1 Nozl: 11 7:41am Dec 24,2021

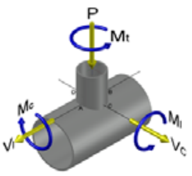
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	323.850	mm.
Nozzle Thickness	Tn	15.269	mm.
Nozzle Material		SA-333 6	
Nozzle UNS Number		K03006	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm^2
Thickness of Reinforcing Pad	Tpad	12.000	mm.
Diameter of Reinforcing Pad	Dpad	523.850	mm.
Design Internal Pressure	Dp	23.000	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

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

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

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



Stress Attenuation Diameter (for Insert Plates) per WRC 297:
= NozzleOD + 2 * 1.65 * sqrt(Rmean(t - ca))
= 323.85 + 2 * 1.65 * sqrt(599.0 (15.0 - 3.0))
= 603.631 mm.

WRC 107 Stress Calculation for SUStained loads:

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

Dimensionless Parameters used : Gamma = 25.21

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.234	4C	3.562	(A,B)
N(PHI) / (P/Rm)	0.234	3C	2.326	(C,D)
M(PHI) / (P)	0.234	2C1	0.036	(A,B)
M(PHI) / (P)	0.234	1C !	0.066	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.234	3A	1.068	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.234	1A	0.081	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.234	3B	2.666	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.234	1B	0.026	(A,B,C,D)
N(x) / (P/Rm)	0.234	3C	2.326	(A,B)
N(x) / (P/Rm)	0.234	4C	3.562	(C,D)
M(x) / (P)	0.234	1C1	0.068	(A,B)
M(x) / (P)	0.234	2C !	0.036	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.234	4A	1.842	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.234	2A	0.039	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.234	4B	1.023	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.234	2B	0.045	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
Circ. Memb. P	-2.9	-2.9	-2.9	-2.9	-1.9	-1.9	-1.9	-1.9
Circ. Bend. P	-4.6	4.6	-4.6	4.6	-8.2	8.2	-8.2	8.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	-7.9	-7.9	7.9	7.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	-91.1	91.1	91.1	-91.1
Circ. Memb. ML	-19.8	-19.8	19.8	19.8	0.0	0.0	0.0	0.0
Circ. Bend. ML	-29.7	29.7	29.7	-29.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-57.1	11.5	42.1	-8.3	-109.2	89.5	88.9	-76.9
Long. Memb. P	-1.9	-1.9	-1.9	-1.9	-2.9	-2.9	-2.9	-2.9
Long. Bend. P	-8.5	8.5	-8.5	8.5	-4.6	4.6	-4.6	4.6
Long. Memb. MC	0.0	0.0	0.0	0.0	-13.7	-13.7	13.7	13.7
Long. Bend. MC	0.0	0.0	0.0	0.0	-43.7	43.7	43.7	-43.7
Long. Memb. ML	-7.6	-7.6	7.6	7.6	0.0	0.0	0.0	0.0
Long. Bend. ML	-50.2	50.2	50.2	-50.2	0.0	0.0	0.0	0.0
Tot. Long. Str.	-68.2	49.2	47.4	-36.0	-64.9	31.6	49.9	-28.4
Shear VC	1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear MT	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Tot. Shear	5.8	5.8	3.8	3.8	3.8	3.8	5.8	5.8
Str. Int.	70.7	50.0	49.4	36.5	109.6	89.8	89.7	77.6

Dimensionless Parameters used : Gamma = 49.92

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.383	4C	4.119	(A,B)
N(PHI) / (P/Rm)	0.383	3C	1.626	(C,D)
M(PHI) / (P)	0.383	2C1	0.008	(A,B)
M(PHI) / (P)	0.383	1C !	0.065	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.383	3A	1.305	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.383	1A	0.058	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.383	3B	2.364	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.383	1B	0.006	(A,B,C,D)
N(x) / (P/Rm)	0.383	3C	1.626	(A,B)
N(x) / (P/Rm)	0.383	4C	4.119	(C,D)
M(x) / (P)	0.383	1C1	0.020	(A,B)
M(x) / (P)	0.383	2C !	0.033	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.383	4A	4.788	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.383	2A	0.023	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.383	4B	1.407	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.383	2B	0.010	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at							
	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-6.9	-6.9	-6.9	-6.9	-2.7	-2.7	-2.7	-2.7
Circ. Bend. P	-4.0	4.0	-4.0	4.0	-32.6	32.6	-32.6	32.6
Circ. Memb. MC	0.0	0.0	0.0	0.0	-12.1	-12.1	12.1	12.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	-162.1	162.1	162.1	-162.1
Circ. Memb. ML	-21.9	-21.9	21.9	21.9	0.0	0.0	0.0	0.0
Circ. Bend. ML	-17.0	17.0	17.0	-17.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-49.9	-7.8	28.1	2.0	-209.5	179.8	138.9	-120.1
Long. Memb. P	-2.7	-2.7	-2.7	-2.7	-6.9	-6.9	-6.9	-6.9
Long. Bend. P	-10.2	10.2	-10.2	10.2	-16.7	16.7	-16.7	16.7
Long. Memb. MC	0.0	0.0	0.0	0.0	-44.5	-44.5	44.5	44.5
Long. Bend. MC	0.0	0.0	0.0	0.0	-64.2	64.2	64.2	-64.2
Long. Memb. ML	-13.1	-13.1	13.1	13.1	0.0	0.0	0.0	0.0
Long. Bend. ML	-26.4	26.4	26.4	-26.4	0.0	0.0	0.0	0.0
Tot. Long. Str.	-52.4	20.8	26.6	-5.9	-132.3	29.6	85.1	-10.0
Shear VC	1.2	1.2	-1.2	-1.2	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.2	-1.2	1.2	1.2
Shear MT	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
Tot. Shear	4.9	4.9	2.4	2.4	2.4	2.4	4.9	4.9
Str. Int.	56.2	30.2	29.9	9.3	209.5	179.9	139.3	120.3

WRC 107/537 Stress Summations:

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

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
		Stress Intensity Values at							
Circ. Pm	(SUS)	55.7	58.0	55.7	58.0	55.7	58.0	55.7	58.0
Circ. Pl	(SUS)	-22.8	-22.8	16.9	16.9	-9.9	-9.9	6.0	6.0
Circ. Q	(SUS)	-34.3	34.3	25.2	-25.2	-99.4	99.4	82.9	-82.9
Long. Pm	(SUS)	27.9	27.9	27.9	27.9	27.9	27.9	27.9	27.9
Long. Pl	(SUS)	-9.5	-9.5	5.7	5.7	-16.6	-16.6	10.8	10.8
Long. Q	(SUS)	-58.7	58.7	41.7	-41.7	-48.2	48.2	39.1	-39.1
Shear Pm	(SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl	(SUS)	1.0	1.0	-1.0	-1.0	-1.0	-1.0	1.0	1.0
Shear Q	(SUS)	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Pm (SUS)		55.7	58.0	55.7	58.0	55.7	58.0	55.7	58.0
Pm+Pl (SUS)		33.0	35.3	72.6	74.9	45.9	48.2	61.8	64.1
Pm+Pl+Q (Total)		41.2	80.1	98.4	58.4	54.4	147.7	145.1	21.7

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	58.01	137.90	Passed
Pm+Pl (SUS)	74.91	206.85	Passed
Pm+Pl+Q (TOTAL)	147.69	413.70	Passed

*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)	112.5	114.8	112.5	114.8	112.5	114.8	112.5	114.8
Circ. Pl	(SUS)	-28.8	-28.8	15.1	15.1	-14.8	-14.8	9.4	9.4
Circ. Q	(SUS)	-21.0	21.0	13.1	-13.1	-194.6	194.6	129.5	-129.5
Long. Pm	(SUS)	56.3	56.3	56.3	56.3	56.3	56.3	56.3	56.3
Long. Pl	(SUS)	-15.8	-15.8	10.3	10.3	-51.3	-51.3	37.6	37.6
Long. Q	(SUS)	-36.6	36.6	16.2	-16.2	-80.9	80.9	47.5	-47.5
Shear Pm	(SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl	(SUS)	1.2	1.2	-1.2	-1.2	-1.2	-1.2	1.2	1.2
Shear Q	(SUS)	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
Pm (SUS)		112.5	114.8	112.5	114.8	112.5	114.8	112.5	114.8

Pm+Pl (SUS)	83.7	86.0	127.6	129.9	97.7	100.0	122.0	124.3
Pm+Pl+Q (Total)	63.1	107.8	140.8	116.9	97.2	294.7	251.6	52.5

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	114.83	137.90	Passed
Pm+Pl (SUS)	129.92	206.85	Passed
Pm+Pl+Q (TOTAL)	294.67	413.70	Passed

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

Input, Nozzle Desc: S3 From: 40

Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1180.00	mm.
Design Length of Section	L	4844.0005	mm.
Shell Finished (Minimum) Thickness	t	15.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		1291.18	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

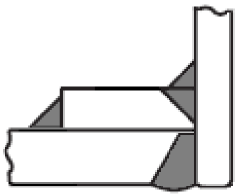
Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-333 6	
Material UNS Number		K03006	
Material Specification/Type		Smls. & wld. pipe	
Allowable Stress at Temperature	Sn	117.90	N./mm^2
Allowable Stress At Ambient	Sna	117.90	N./mm^2
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Minimum	
Nominal Thickness	tn	160	
Flange Material		SA-350 LF2	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	15.0000	mm.
Inside Projection	h	0.0000	mm.
Weld leg size, Inside Element to Shell	Wi	0.0000	mm.
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	137.90	N./mm^2
Pad Allowable Stress At Ambient	Spa	137.90	N./mm^2
Diameter of Pad along vessel surface	Dp	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	

```
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for CONDENSER E-PK6101-2    -----
Nozzle Calcs.: S3                      Nozl:    12   7:41am  Dec 24,2021
```

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: S3

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

```
 Actual Outside Diameter Used in Calculation            2.375  in.
 Actual Thickness Used in Calculation                   0.301  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.0*593.0)/(138*1.0-0.6*23.0)
  = 9.9911 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = (23.0*30.1625)/(118*1.0+0.4*23.0)
  = 0.5839 mm.
```

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

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)             Dl   102.0684  mm.
 Parallel to Vessel Wall, opening length               d    51.0342  mm.
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp    21.6135  mm.
```

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

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

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

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

Weld Strength Reduction Factor [fr3]:

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	5.233	1.854	NA
Area in Shell	A1	0.998	2.445	NA
Area in Nozzle Wall	A2	1.501	1.596	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.547	0.547	NA
Area in Element	A5	4.174	4.174	NA
TOTAL AREA AVAILABLE	Atot	7.221	8.763	NA

The Internal Pressure Case Governs the Analysis.

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

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

SELECTION OF POSSIBLE REINFORCING PADS:	Diameter	Thickness	
Based on given Pad Thickness:	82.1947	10.0000	mm.
Based on given Pad Diameter:	160.3250	5.2391	mm.
Based on Shell or Nozzle Thickness:	88.9300	7.6454	mm.

Area Required [A]:

```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (51.0342*9.9911*1.0+2*4.6454*9.9911*1.0*(1-0.86))
  = 5.233 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 * 12.0 - 1.0 * 9.991 ) - 2 * 4.645
    ( 1.0 * 12.0 - 1.0 * 9.9911 ) * ( 1 - 0.855 )
  = 0.998 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 21.61 ) * ( 4.65 - 0.58 ) * 0.855
  = 1.501 cm^2
```

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

```
  = Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
  = 8.0² * 0.86 + (0.0)² * 0.86 + 0.0² * 1.0
  = 0.547 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 = 3.5839 mm.
 Wall Thickness per UG16(b),                        tr16b = 4.5000 mm.
```

```
Wall Thickness, shell/head, internal pressure     trb1 = 12.9911 mm.
Wall Thickness                   tb1 = max(trb1, tr16b) = 12.9911 mm.
Wall Thickness, shell/head, external pressure     trb2 = 3.4733 mm.
Wall Thickness                   tb2 = max(trb2, tr16b) = 4.5000 mm.
Wall Thickness per table UG-45                     tb3 = 6.4200 mm.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 6.42, max( 12.9911, 4.5 ) ]
  = 6.4200 mm.
```

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

```
  = max( ta, tb )
  = max( 3.5839, 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   :    62.0,  Allowable :    117.9 N./mm^2  Passed
Expansion   :     0.0,  Allowable :    232.7 N./mm^2  Passed
Occasional  :     5.8,  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 (Impact tested) :

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

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

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

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

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

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

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

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

Govrn. thk, tg = 7.645, tr = 0.584, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.126, Temp. Reduction = 78 °C

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

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

Govrn. thk, tg = 10.0, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.833, Temp. Reduction = 9 °C
Pad governing, Conservatively assuming Pad stress = Shell stress(Div. 1 L-9.3).

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

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

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

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

 Calculated Minimum Design Metal Temperature               -104 °C

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
 MDMT of ANSI B16.5/47 flange per Matl. Specification        -46 °C
 Flange MDMT with Temp reduction per UCS-66(i)(2)            -86 °C
 Flange MDMT with Temp reduction per UCS-66(i)(3)           -104 °C
```

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

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

Weld Size Calculations, Description: S3

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

Results Per UW-16.1:

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

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (5.2335 - 0.9982 + 2 * 4.6454 * 0.855 *
    (1.0 * 12.0 - 9.9911 ) )138)
  = 60.60 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.5011 + 4.1743 + 0.5472 - 0.0 * 0.86 ) * 138
  = 85.80 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.5011 + 0.0 + 0.5472 + ( 0.9532 ) ) * 138
  = 41.39 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.5011 + 0.0 + 0.5472 + 4.1743 + ( 0.9532 ) ) * 138
```

```
  = 98.95 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 * 138
  = 136. 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 * ( 15.0 - 3.0 ) * 0.74 * 138
  = 116. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 136 + 34 ) = 170 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 44 + 97 + 116 + 0 ) = 257 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 136 + 116 + 0 ) = 252 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 169 kN , must exceed W = 60 kN  or W1 = 85 kN
 Path 2-2 = 256 kN , must exceed W = 60 kN  or W2 = 41 kN
 Path 3-3 = 252 kN , must exceed W = 60 kN  or W3 = 98 kN

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

The Drop for this Nozzle is : 0.7715 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 215.7715 mm.

Input Echo, WRC107/537 Item 1, Description: S3 :

```
 Diameter Basis for Vessel                   Vbasis      ID
 Cylindrical or Spherical Vessel             Cylsph      Cylindrical
 Internal Corrosion Allowance                   Cas      3.0000  mm.
 Vessel Diameter                                 Dv    1180.000  mm.
 Vessel Thickness                                Tv      15.000  mm.

 Design Temperature                              T1       125.0  °C
 Vessel Material                                      SA-516 70
 Vessel UNS Number                                       K02700
 Vessel Cold S.I. Allowable                     Smc      137.90  N./mm^2
 Vessel Hot  S.I. Allowable                     Smh      137.90  N./mm^2
```

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for CONDENSER E-PK6101-2 -----
Nozzle Calcs.: S3 Nozl: 12 7:41am Dec 24,2021

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

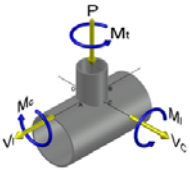
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	60.325	mm.
Nozzle Thickness	Tn	7.645	mm.
Nozzle Material		SA-333 6	
Nozzle UNS Number		K03006	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm^2
Thickness of Reinforcing Pad	Tpad	10.000	mm.
Diameter of Reinforcing Pad	Dpad	160.325	mm.
Design Internal Pressure	Dp	23.000	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	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( 599.0 ( 15.0 - 3.0 ) )
  = 340.106 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 =   27.45
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

```
-------------------------------------------------------------------
Curves read for 1979             Beta  Figure    Value   Location
-------------------------------------------------------------------
N(PHI) / ( P/Rm )               0.044   4C        5.291   (A,B)
N(PHI) / ( P/Rm )               0.044   3C        5.309   (C,D)
M(PHI) / ( P )                  0.044   2C1       0.178   (A,B)
M(PHI) / ( P )                  0.044   1C        0.216   (C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )  0.044   3A        0.246   (A,B,C,D)
M(PHI) / ( MC/(Rm    * Beta) )  0.044   1A        0.104   (A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )  0.044   3B        0.958   (A,B,C,D)
M(PHI) / ( ML/(Rm    * Beta) )  0.044   1B        0.061   (A,B,C,D)

N(x)   / ( P/Rm )               0.044   3C        5.309   (A,B)
N(x)   / ( P/Rm )               0.044   4C        5.291   (C,D)
M(x)   / ( P )                  0.044   1C1       0.222   (A,B)
M(x)   / ( P )                  0.044   2C        0.177   (C,D)
N(x)   / ( MC/(Rm**2 * Beta) )  0.044   4A        0.301   (A,B,C,D)
M(x)   / ( MC/(Rm    * Beta) )  0.044   2A        0.063   (A,B,C,D)
N(x)   / ( ML/(Rm**2 * Beta) )  0.044   4B        0.235   (A,B,C,D)
M(x)   / ( ML/(Rm    * Beta) )  0.044   2B        0.102   (A,B,C,D)
```

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

```
               |                    Stress Intensity Values at                            |
Type of        |                                                                          |
Stress    Load |      Au        Al        Bu        Bl        Cu        Cl        Du        Dl|
-----------------------------------------------------------------------------------------------
Circ. Memb. P  |    -0.8|     -0.8|     -0.8|     -0.8|     -0.8|     -0.8|     -0.8|     -0.8|
Circ. Bend. P  |    -4.4|      4.4|     -4.4|      4.4|     -5.4|      5.4|     -5.4|      5.4|
Circ. Memb. MC |     0.0|      0.0|      0.0|      0.0|     -0.3|     -0.3|      0.3|      0.3|
Circ. Memb. MC |     0.0|      0.0|      0.0|      0.0|    -19.6|     19.6|     19.6|    -19.6|
Circ. Memb. ML |    -1.1|     -1.1|      1.1|      1.1|      0.0|      0.0|      0.0|      0.0|
Circ. Bend. ML |   -11.5|     11.5|     11.5|    -11.5|      0.0|      0.0|      0.0|      0.0|
               |                                                                          |
Tot. Circ. Str.|   -17.8|     14.0|      7.4|     -6.8|    -26.0|     23.9|     13.7|    -14.7|
-----------------------------------------------------------------------------------------------
Long. Memb. P  |    -0.8|     -0.8|     -0.8|     -0.8|     -0.8|     -0.8|     -0.8|     -0.8|
Long. Bend. P  |    -5.5|      5.5|     -5.5|      5.5|     -4.4|      4.4|     -4.4|      4.4|
Long. Memb. MC |     0.0|      0.0|      0.0|      0.0|     -0.3|     -0.3|      0.3|      0.3|
Long. Bend. MC |     0.0|      0.0|      0.0|      0.0|    -11.8|     11.8|     11.8|    -11.8|
Long. Memb. ML |    -0.3|     -0.3|      0.3|      0.3|      0.0|      0.0|      0.0|      0.0|
Long. Bend. ML |   -19.3|     19.3|     19.3|    -19.3|      0.0|      0.0|      0.0|      0.0|
               |                                                                          |
Tot. Long. Str.|   -25.8|     23.7|     13.2|    -14.3|    -17.3|     15.0|      6.9|     -7.8|
-----------------------------------------------------------------------------------------------
      Shear VC |     1.0|      1.0|     -1.0|     -1.0|      0.0|      0.0|      0.0|      0.0|
      Shear VL |     0.0|      0.0|      0.0|      0.0|     -1.0|     -1.0|      1.0|      1.0|
      Shear MT |     4.0|      4.0|      4.0|      4.0|      4.0|      4.0|      4.0|      4.0|
               |                                                                          |
     Tot. Shear|     4.9|      4.9|      3.0|      3.0|      3.0|      3.0|      4.9|      4.9|
-----------------------------------------------------------------------------------------------
```

Str. Int.	28.2	25.8	14.5	15.3	27.0	24.8	16.3	17.3

Dimensionless Parameters used : Gamma = 49.92

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.117	4C	8.263	(A,B)
N(PHI) / (P/Rm)	0.117	3C	6.777	(C,D)
M(PHI) / (P)	0.117	2C1	0.065	(A,B)
M(PHI) / (P)	0.117	1C	0.098	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.117	3A	1.837	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.117	1A	0.089	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.117	3B	5.754	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.117	1B	0.039	(A,B,C,D)
N(x) / (P/Rm)	0.117	3C	6.777	(A,B)
N(x) / (P/Rm)	0.117	4C	8.263	(C,D)
M(x) / (P)	0.117	1C1	0.103	(A,B)
M(x) / (P)	0.117	2C	0.065	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.117	4A	2.759	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.117	2A	0.047	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.117	4B	1.745	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.117	2B	0.060	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at							
	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-2.3	-2.3	-2.3	-2.3	-1.9	-1.9	-1.9	-1.9
Circ. Bend. P	-5.4	5.4	-5.4	5.4	-8.2	8.2	-8.2	8.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	-1.5	-1.5	1.5	1.5
Circ. Memb. MC	0.0	0.0	0.0	0.0	-21.0	21.0	21.0	-21.0
Circ. Memb. ML	-4.6	-4.6	4.6	4.6	0.0	0.0	0.0	0.0
Circ. Bend. ML	-9.2	9.2	9.2	-9.2	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-21.4	7.7	6.0	-1.5	-32.6	25.9	12.4	-13.3
Long. Memb. P	-1.9	-1.9	-1.9	-1.9	-2.3	-2.3	-2.3	-2.3
Long. Bend. P	-8.6	8.6	-8.6	8.6	-5.4	5.4	-5.4	5.4
Long. Memb. MC	0.0	0.0	0.0	0.0	-2.2	-2.2	2.2	2.2
Long. Bend. MC	0.0	0.0	0.0	0.0	-11.1	11.1	11.1	-11.1
Long. Memb. ML	-1.4	-1.4	1.4	1.4	0.0	0.0	0.0	0.0
Long. Bend. ML	-14.2	14.2	14.2	-14.2	0.0	0.0	0.0	0.0
Tot. Long. Str.	-26.1	19.6	5.1	-6.1	-21.0	12.0	5.6	-5.8
Shear VC	0.7	0.7	-0.7	-0.7	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Shear MT	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Tot. Shear	1.7	1.7	0.4	0.4	0.4	0.4	1.7	1.7
Str. Int.	26.6	19.8	6.2	6.1	32.6	25.9	12.8	13.6

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)	60.9	63.2	60.9	63.2	60.9	63.2	60.9	63.2
Circ. Pl	(SUS)	-1.9	-1.9	0.3	0.3	-1.1	-1.1	-0.5	-0.5
Circ. Q	(SUS)	-15.9	15.9	7.1	-7.1	-25.0	25.0	14.2	-14.2
Long. Pm	(SUS)	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4
Long. Pl	(SUS)	-1.1	-1.1	-0.5	-0.5	-1.1	-1.1	-0.5	-0.5
Long. Q	(SUS)	-24.8	24.8	13.7	-13.7	-16.2	16.2	7.4	-7.4
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)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Pm (SUS)		60.9	63.2	60.9	63.2	60.9	63.2	60.9	63.2
Pm+Pl (SUS)		59.0	61.3	61.2	63.5	59.8	62.1	60.4	62.7
Pm+Pl+Q (Total)		43.7	78.2	68.6	56.6	35.3	87.3	75.2	49.3

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	63.17	137.90	Passed
Pm+Pl (SUS)	63.49	206.85	Passed
Pm+Pl+Q (TOTAL)	87.26	413.70	Passed

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

WRC 107/537 Stress Summations:

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

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
		Stress Intensity Values at							
Circ. Pm	(SUS)	112.5	114.8	112.5	114.8	112.5	114.8	112.5	114.8
Circ. Pl	(SUS)	-6.9	-6.9	2.3	2.3	-3.3	-3.3	-0.4	-0.4
Circ. Q	(SUS)	-14.6	14.6	3.8	-3.8	-29.2	29.2	12.8	-12.8
Long. Pm	(SUS)	56.3	56.3	56.3	56.3	56.3	56.3	56.3	56.3
Long. Pl	(SUS)	-3.3	-3.3	-0.5	-0.5	-4.5	-4.5	-0.1	-0.1
Long. Q	(SUS)	-22.8	22.8	5.6	-5.6	-16.5	16.5	5.7	-5.7
Shear Pm	(SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl	(SUS)	0.7	0.7	-0.7	-0.7	-0.7	-0.7	0.7	0.7
Shear Q	(SUS)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Pm (SUS)		112.5	114.8	112.5	114.8	112.5	114.8	112.5	114.8

Pm+Pl (SUS)	105.7	108.0	114.8	117.1	109.2	111.5	112.1	114.4
Pm+Pl+Q (Total)	91.1	122.6	118.6	113.3	80.0	140.7	125.0	101.6

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	114.83	137.90	Passed
Pm+Pl (SUS)	117.10	206.85	Passed
Pm+Pl+Q (TOTAL)	140.71	413.70	Passed

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

Input, Nozzle Desc: T4 From: 60

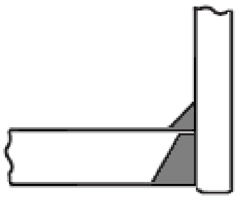
```
Pressure for Reinforcement Calculations        P         23.000  bars
Temperature for Internal Pressure           Temp            190  °C
Design External Pressure                    Pext           1.10  bars
Temperature for External Pressure         Tempex            190  °C

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

Inside Diameter of Cylindrical Shell           D        1180.00  mm.
Design Length of Section                       L       447.3333  mm.
Shell Finished (Minimum) Thickness             t        15.0000  mm.
Shell Internal Corrosion Allowance             c         3.0000  mm.
Shell External Corrosion Allowance            co         0.0000  mm.

Distance from Bottom/Left Tangent                       6247.35  mm.

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

Type of Element Connected to the Shell : Nozzle

```
Material        [Impact Tested]                      SA-350 LF2
Material UNS Number                                      K03011
Material Specification/Type                            Forgings
Allowable Stress at Temperature               Sn         137.90  N./mm^2
Allowable Stress At Ambient                  Sna         137.90  N./mm^2

Diameter Basis (for tr calc only)                            ID
Layout Angle                                              90.00  deg
Diameter                                                 0.7500  in.

Size and Thickness Basis                                 Actual
Actual Thickness                              tn        14.2500  mm.

Flange Material                                      SA-350 LF2
Flange Type                                             Slip on

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

Outside Projection                            ho       200.0000  mm.
Weld leg size between Nozzle and Pad/Shell    Wo        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                    0.561  in.
```

Nozzle input data check completed without errors.

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

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

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]

```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 12.525(exp([23.0/(137.9*1.0]-1)
  = 0.2107 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2876 mm.

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl     71.5500  mm.
Parallel to Vessel Wall                        Rn+tn+t     35.7750  mm.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     28.1250  mm.
```

Weld Strength Reduction Factor [fr1]:

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

Weld Strength Reduction Factor [fr2]:

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

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 1.0, 1.0 )
  = 1.000
```

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	2.503	0.332	NA
Area in Shell	A1	0.934	4.347	NA

Area in Nozzle Wall	A2	6.210	6.166	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	8.144	11.514	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (25.05*9.9911*1.0+2*11.25*9.9911*1.0*(1-1.0))
  = 2.503 cm^2
```

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
```
  = d( E1*t - F*tr ) - 2 * tn( E1*t - F*tr ) * ( 1 - fr1 )
  = 46.5( 1.0 * 12.0 - 1.0 * 9.991 ) - 2 * 11.25
    ( 1.0 * 12.0 - 1.0 * 9.9911 ) * ( 1 - 1.0 )
  = 0.934 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 28.13 )( 11.25 - 0.21 )1.0
  = 6.210 cm^2
```

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

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures        ta = 3.2876 mm.
 Wall Thickness per UG16(b),                         tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure        trb1 = 12.9911 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 12.9911 mm.
 Wall Thickness, shell/head, external pressure        trb2 = 3.4733 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                        tb3 = 6.2200 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 6.22, max( 12.9911, 4.5 ) ]
  = 6.2200 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.2876, 6.22 )
  = 6.2200 mm.
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld (Impact tested) :

Note:

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

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

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

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

Govrn. thk, tg = 14.25, tr = 0.211, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.019, Temp. Reduction = 78 °C

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

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
 MDMT of ANSI B16.5/47 flange per Matl. Specification       -46 °C
 Flange MDMT with Temp reduction per UCS-66(i)(2)           -86 °C
 Flange MDMT with Temp reduction per UCS-66(i)(3)          -104 °C
```

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

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

Weld Size Calculations, Description: T4

```
 Intermediate Calc. for nozzle/shell Welds   Tmin     11.2500  mm.
```

Results Per UW-16.1:

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

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (2.5028 - 0.9342 + 2 * 11.25 * 1.0 *
    (1.0 * 12.0 - 9.9911 ) )138)
  = 27.86 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 6.2096 + 0.0 + 1. - 0.0 * 1.0 ) * 138
  = 99.41 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 6.2096 + 0.0 + 1. + ( 2.7 ) ) * 138
  = 136.64 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 6.2096 + 0.0 + 1. + 0.0 + ( 2.7 ) ) * 138
  = 136.64 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 47.55 * 10.0 * 0.49 * 138
  = 50. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 18.15) * ( 14.25 - 3.0 ) * 0.7 * 138
  = 62. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 47.55 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 53. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 50 + 62 ) = 112 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 50 + 0 + 53 + 0 ) = 104 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 50 + 53 + 0 ) = 104 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 112 kN , must exceed W = 27 kN  or W1 = 99 kN
 Path 2-2 = 103 kN , must exceed W = 27 kN  or W2 = 136 kN
 Path 3-3 = 103 kN , must exceed W = 27 kN  or W3 = 136 kN

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

The Drop for this Nozzle is : 0.4792 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 215.4792 mm.

Input, Nozzle Desc: T3 From: 60

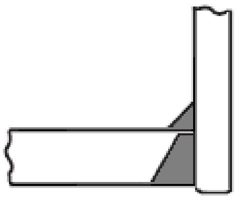
Pressure for Reinforcement Calculations	P	23.081	bars
Temperature for Internal Pressure	Temp	190	°C
Design External Pressure	Pext	1.10	bars
Temperature for External Pressure	Tempex	190	°C
Shell Material [Normalized]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1180.00	mm.
Design Length of Section	L	447.3333	mm.
Shell Finished (Minimum) Thickness	t	15.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		6247.35	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm^2
Allowable Stress At Ambient	Sna	137.90	N./mm^2
Diameter Basis (for tr calc only)		ID	
Layout Angle		270.00	deg
Diameter		1.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	14.3000	mm.
Flange Material		SA-350 LF2	
Flange Type		Slip on	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	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)
  = (23.08*593.0)/(138*1.0-0.6*23.08)
  = 10.0266 mm.
```

Reqd thk per App. 1 of Nozzle Wall, Trn [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 15.7(exp([23.08/(137.9*1.0]-1)
  = 0.2650 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3088 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl     78.0000  mm.
 Parallel to Vessel Wall                        Rn+tn+t     39.0000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     28.2500  mm.
```

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

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

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	3.148	0.416	NA
Area in Shell	A1	0.920	4.357	NA

Area in Nozzle Wall	A2	6.235	6.210	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	8.154	11.567	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (31.4*10.0266*1.0+2*11.3*10.0266*1.0*(1-1.0))
= 3.148 cm^2

Reinforcement Areas per Figure UG-37.1

Area Available in Shell [A1]:
= d(E1*t - F*tr) - 2 * tn(E1*t - F*tr) * (1 - fr1)
= 46.6(1.0 * 12.0 - 1.0 * 10.027) - 2 * 11.3
(1.0 * 12.0 - 1.0 * 10.0266) * (1 - 1.0)
= 0.920 cm^2

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2
= (2 * 28.25)(11.3 - 0.27)1.0
= 6.235 cm^2

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo^2 * fr2 + (Wi-can/0.707 $)^2$ * fr2
= 10.0^2 * 1.0 + (0.0 $)^2$ * 1.0
= 1.000 cm^2

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

Wall Thickness for Internal/External pressures	ta =	3.3088 mm.
Wall Thickness per UG16(b),	tr16b =	4.5000 mm.
Wall Thickness, shell/head, internal pressure	trb1 =	13.0266 mm.
Wall Thickness	tb1 = max(trb1, tr16b) =	13.0266 mm.
Wall Thickness, shell/head, external pressure	trb2 =	3.4733 mm.
Wall Thickness	tb2 = max(trb2, tr16b) =	4.5000 mm.
Wall Thickness per table UG-45	tb3 =	6.4200 mm.

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[6.42, max(13.0266, 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: D

Govrn. thk, tg = 14.3, tr = 0.265, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.023, Temp. Reduction = 78 °C

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

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ANSI B16.5/47 flange per Matl. Specification        -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)            -85 °C
Flange MDMT with Temp reduction per UCS-66(i)(3)           -104 °C
```

Where the Stress Reduction Ratio per UCS-66(i)(2) is :
Design Pressure/Ambient Rating = 23.08/51.10 = 0.452

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

Weld Size Calculations, Description: T3

```
Intermediate Calc. for nozzle/shell Welds   Tmin     11.3000  mm.
```

Results Per UW-16.1:

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

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (3.1484 - 0.9196 + 2 * 11.3 * 1.0 *
    (1.0 * 12.0 - 10.0266 ) )138)
  = 36.88 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 6.2348 + 0.0 + 1. - 0.0 * 1.0 ) * 138
  = 99.76 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 6.2348 + 0.0 + 1. + ( 2.712 ) ) * 138
  = 137.15 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 6.2348 + 0.0 + 1. + 0.0 + ( 2.712 ) ) * 138
  = 137.15 kN
```


Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 54.0 * 10.0 * 0.49 * 138
  = 57. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 21.35) * ( 14.3 - 3.0 ) * 0.7 * 138
  = 73. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 54.0 * ( 10.0 - 3.0 ) * 0.74 * 138
  = 61. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 57 + 73 ) = 130 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 57 + 0 + 61 + 0 ) = 118 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 57 + 61 + 0 ) = 118 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 130 kN , must exceed W = 36 kN  or W1 = 99 kN
 Path 2-2 = 117 kN , must exceed W = 36 kN  or W2 = 137 kN
 Path 3-3 = 117 kN , must exceed W = 36 kN  or W3 = 137 kN

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

The Drop for this Nozzle is : 0.6181 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 215.6181 mm.

Nozzle Schedule:

Description	Nominal or Actual Size	Schd or FVC Type	Flg Type	Nozzle O/Dia in	Wall Thk mm.	Reinforcing Pad Diameter mm.	Reinforcing Pad Thk mm.	Cut Length mm.	Flg Class
T4	0.750 in	Actual	SlipOn	1.872	14.250	...	...	215.48	300
T3	1.000 in	Actual	SlipOn	2.126	14.300	...	...	215.62	300
S3	2.000 in	160	WNF	2.375	8.738	160.32	10.00	215.77	300
S2	8.000 in	80	WNF	8.625	12.700	379.08	15.00	225.26	300
T1	12.000 in	80	WNF	12.750	17.450	483.85	15.00	237.66	300
T2	12.000 in	80	WNF	12.750	17.450	483.85	15.00	237.66	300
S1	12.000 in	80	WNF	12.750	17.450	523.85	12.00	237.66	300

General Notes for the above table:

The Cut Length is the Outside Projection + Inside Projection + Drop + In Plane Shell Thickness. This value does not include weld gaps, nor does it account for shrinkage.

In the case of Oblique Nozzles, the Outside Diameter must be increased. The Re-Pad WIDTH around the nozzle is calculated as follows: Width of Pad = (Pad Outside Dia. (per above) - Nozzle Outside Dia.)/2

For hub nozzles, the thickness and diameter shown are those of the smaller and thinner section.

Nozzle Material and Weld Fillet Leg Size Details (mm.):

Description	Material	Shl Grve Weld	Noz Shl/Pad Weld	Pad OD Weld	Pad Grve Weld	Inside Weld
T4	SA-350 LF2	10.000	10.000	...	...	...
T3	SA-350 LF2	10.000	10.000	...	...	...
S3	SA-333 6	15.000	8.000	8.000	10.000	...
S2	SA-333 6	15.000	10.000	10.000	10.000	...
T1	SA-333 6	15.000	14.000	10.000	10.000	...
T2	SA-333 6	15.000	14.000	10.000	10.000	...
S1	SA-333 6	15.000	10.000	10.000	12.000	...

Note: The Outside projections below do not include the flange thickness.

Nozzle Miscellaneous Data:

Description	Elev/Distance From Datum mm.	Layout Angle deg	Proj Outside mm.	Proj Inside mm.	Installed in Component
T4	6197.351	90.0	200.00	0.00	CHANNEL 002

T3	6197.351	270.0	200.00	0.00	CHANNEL 002
S3	1241.175	90.0	200.00	0.00	SHELL
S2	1241.175	270.0	200.00	0.00	SHELL
T1	375.000	270.0	200.00	0.00	CHANNEL 01
T2	375.000	90.0	200.00	0.00	CHANNEL 01
S1	5456.175	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	1.872	11.250	10.033	7.023	10.033
T3	1.000 in	Actua	SlipOn	2.126	11.300	9.652	6.756	9.652

Input Echo, Tubesheet Number 1, Description: TUBE SHEET

Shell Data:

Main Shell Description: SHELL

Shell Maximum Design Pressure	Psd,max	23.00	bars
Shell Maximum Operating Pressure	Psox,max	23.00	bars
Shell Minimum Operating Pressure	Psox,min	0.00	bars
Shell Thickness	ts	15.0000	mm.
Shell Internal Corrosion Allowance	cas	3.0000	mm.
Shell External Corrosion Allowance	caext	0.0000	mm.
Inside Diameter of Shell	Ds	1180.000	mm.
Shell Circumferential Joint Efficiency	Esw	1.000	
Shell Temperature for Internal Pressure	Ts	190.00	°C
Shell Material		SA-516 70	

Note:
Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

Shell Material UNS Number		K02700	
Shell Allowable Stress at Temperature	Ss	137.90	N./mm^2
Shell Allowable Stress at Ambient		137.90	N./mm^2

Channel Description: CHANNEL 01

Channel Type:		Cylinder	
Channel Maximum Design Pressure	Ptd,max	23.00	bars
Channel Maximum Operating Pressure	Ptox,max	23.00	bars
Channel Minimum Operating Pressure	Ptox,min	0.00	bars
Channel Thickness	tc	15.0000	mm.
Channel Corrosion Allowance	cac	3.0000	mm.
Inside Diameter of Channel	Dc	1180.000	mm.
Channel Design Temperature	TEMPC	190.00	°C
Channel Material		SA-516 70	

Note:
Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

Channel Material UNS Number		K02700	
Channel Allowable Stress at Temperature	Sc	137.90	N./mm^2
Channel Allowable Stress at Ambient		137.90	N./mm^2

Tube Data:

Number of Tube Holes	Nt	1802	
Tube Wall Thickness	et	2.1080	mm.
Tube Outside Diameter	D	19.0500	mm.
Total Straight Tube Length	Lt	5000.00	mm.
Straight Tube Length (bet. inner tubsht faces)	L	4850.00	mm.
Design Temperature of the Tubes		190.00	°C
Tube Material		SA-334 6	
Tube Material UNS Number		K03006	
Is this a Welded Tube		No	
Tube Material Specification used		Smls. & wld. tube	
Tube Allowable Stress at Temperature		117.90	N./mm^2
Tube Allowable Stress At Ambient		117.90	N./mm^2
Tube Yield Stress At design Temperature	Syt	208.13	N./mm^2
Tube Pitch (Center to Center Spacing)	P	24.0000	mm.
Tube Layout Pattern		Triangular	

```
 Fillet Weld Leg                               af       1.5000  mm.
 Groove Weld Leg                               ag       1.5000  mm.
 Tube-Tubesheet Joint Weld Type                     Full Strength
 Method for Tube-Tubesheet Jt. Allow.                  UW-20
 Tube-Tubesheet Joint Classification                      b-1

 Radius to Outermost Tube Hole Center          ro      571.120  mm.
 Largest Center-to-Center Tube Distance        Ul      38.1000  mm.
 Length of Expanded Portion of Tube           ltx      20.0000  mm.
 Tube-side pass partition groove depth         hg       5.0000  mm.
```

Tubesheet Data:

Tubesheet TYPE: Fixed Tubesheet Exchanger, Conf B

```
 Tubesheet Design Metal Temperature             T       190.00  °C
 Tubesheet Material                                 SA-350 LF2
```

Note:
Using 2 * Yield for Discontinuity Stress Allowable (UG-23(e)), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-350 LF2

```
 Tubesheet Material UNS Number                          K03011
 Tubesheet Allowable Stress at Temperature      S       137.90  N./mm^2
 Tubesheet Allowable Stress at Ambient         Tt       137.90  N./mm^2
 Thickness of Tubesheet                         h      75.0000  mm.
 Tubesheet Corr. Allowance (Shell side)      Cats       3.0000  mm.
 Tubesheet Corr. Allowance (Channel side)    Catc       3.0000  mm.
 Tubesheet Outside Diameter                     A     1350.000  mm.
```

Additional Data for Stepped Tubesheets:

```
 Is the Tubesheet Stepped?                                  NO

 Area of the Untubed Lanes                     AL        479.0  cm^2
```

Additional Data for Fixed/Floating Tubesheet Exchangers:

```
 Unsupported Tube Span under consideration      l     1354.000  mm.
 Tube End condition corresponding to Span (l)   k         0.80

 Ignore Radial Thermal Exp. effects (UHX-13.8/14.6)        YES
```

Note: The Metal temperatures at the Rim are set to ambient (21 °C)

```
 Tubesheet Metal Temp. at Rim                  T'        21.11  °C
 Shell Metal Temp. at Tubesheet               T'S        21.11  °C
 Channel Metal Temp. at Tubesheet             T'C        21.11  °C
 Perform Differential Pressure Design                        N
 Run Multiple Load Cases                                   YES
 Shell Side Min. Design Pressure          Psd,min       1.0342  bars
 Channel Side Min. Design Pressure        Ptd,min       1.0314  bars

 Mean Shell Metal Temp. along Shell len.      Tsm        53.80  °C
 Mean Tube Metal Temp. along Tube length      Ttm        42.50  °C
 Junction Stress Reduction option       Perform Plastic Calculation
```

Additional Data for Gasketed Tubesheets:

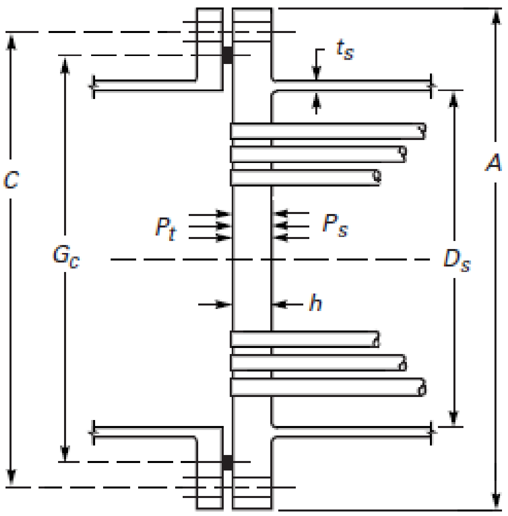
```
 Tubesheet Gasket on which Side                        Channel
 Flange Outside Diameter                        A     1350.000  mm.
 Flange Inside Diameter                         B     1180.000  mm.
 Flange Face Outside Diameter                 Fod     1266.000  mm.
```

Flange Face Inside Diameter	Fid	1180.000	mm.
Gasket Outside Diameter	Go	1263.000	mm.
Gasket Inside Diameter	Gi	1223.000	mm.
Small end Hub thk.	g0	15.0000	mm.
Large end Hub thk.	g1	27.0000	mm.
Gasket Factor,	m	3.78	
Gasket Design Seating Stress	y	62.05	N./mm^2
Flange Facing Sketch	Code Sketch 1a		
Column for Gasket Seating	Code Column II		
Gasket Thickness	tg	3.0000	mm.
Full face Gasket Flange Option	Program Selects		
Length of Partition Gasket	lp	1078.000	mm.
Width of Partition Gasket	wp	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	1298.000	mm.
Nominal Bolt Diameter	dB	22.2250	mm.
Type of Thread Series	UNC Thread Series		
Number of Bolts	n	76	

Tubesheet Integral With Shell and Gasketed
With Channel, Extended as a Flange



Configuration b:

Bolt Material SA-320 L7

Bolt Allowable Stress At Temperature	Sb	172.38	N./mm^2
Bolt Allowable Stress At Ambient	Sa	172.38	N./mm^2
Weld between Flange and Shell/Channel		0.0000	mm.

Tubesheet Integral with		Shell	
Tubesheet Extended as Flange		Yes	
Thickness of Extended Portion of Tubesheet	Tf	52.0000	mm.
Is Bolt Load Transferred to the Tubesheet		Yes	

Is Exchanger in Creep range (skip EP, Use 3S for Sps) NO

```
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for CONDENSER E-PK6101-2    -----
ASME TS Calc:                          Case:    1   7:41a Dec 24,2021
```

ASME TubeSheet Results per Part UHX, 2017

Elasticity/Expansion Material Properties:

Shell - TE-1 Carbon & Low Alloy Steels, Group 1
Shell - TM-1 Carbon Steels with C<= 0.3%

```
 ---------------------------------------------------------------
 Th. Exp. Coeff. Metal Temp. along Len    53.8 °C    0.0000118028 /°C
 Elastic Mod. at Design Temperature      190.0 °C      0.19308E+09 KPa.
 Th. Exp. Coeff. Metal Temp. at Tubsht    21.1 °C    0.0000115190 /°C
 Elastic Mod. at Metal Temp. along Len    53.8 °C      0.20083E+09 KPa.
 Elastic Mod. at Ambient Temperature      21.1 °C      0.20270E+09 KPa.
```

Channel - TE-1 Carbon & Low Alloy Steels, Group 1
Channel - TM-1 Carbon Steels with C<= 0.3%

```
 ---------------------------------------------------------------
 Th. Exp. Coeff. Metal Temp. at Tubsht    21.1 °C    0.0000115190 /°C
 Elastic Mod. at Design Temperature      190.0 °C      0.19308E+09 KPa.
 Elastic Mod. at Ambient Temperature      21.1 °C      0.20270E+09 KPa.
```

Tubes - TE-1 Carbon & Low Alloy Steels, Group 1
Tubes - TM-1 Carbon Steels with C<= 0.3%

```
 ---------------------------------------------------------------
 Th. Exp. Coeff. Metal Temp. along Len    42.5 °C    0.0000117296 /°C
 Elastic Mod. at Design Temperature      190.0 °C      0.19308E+09 KPa.
 Elastic Mod. at Metal Temp. along Len    42.5 °C      0.20148E+09 KPa.
 Elastic Mod. at Tubsht. Design Temp.    190.0 °C      0.19308E+09 KPa.
 Elastic Mod. at Ambient Temperature      21.1 °C      0.20270E+09 KPa.
```

TubeSheet - TE-1 Carbon & Low Alloy Steels, Group 1
TubeSheet - TM-1 Carbon Steels with C<= 0.3%

```
 ---------------------------------------------------------------
 Th. Exp. Coeff. Metal Temp. at Rim       21.1 °C    0.0000115190 /°C
 Elastic Mod. at Design Temperature      190.0 °C      0.19308E+09 KPa.
 Elastic Mod. at Metal Temp. at Rim       21.1 °C      0.20270E+09 KPa.
 Elastic Mod. at Ambient Temperature      21.1 °C      0.20270E+09 KPa.
```

Note:
The Elasticity and Alpha values are taken from Tables in ASME II D.
Please insure these properties are consistent with the
type of Material for the tubes, shell, channel etc.

Tube Required Thickness under Internal Pressure (Tubeside pressure):
Thickness Due to Internal Pressure:

```
  = (P*(D/2-CAE)) / (S*E+0.4*P) per Appendix 1-1 (a)(1)
  = (24.03*(19.05/2-0.0)/(117.9*1.0+0.4*24.03)
  = 0.1926 + 0.0000 = 0.1926 mm.
```

Tube Required Thickness under External Pressure (Shellside pressure) :

```
 External Pressure Chart     CS-2              at       190.00   °C
 Elastic Modulus for Material                      194843456.00   KPa.
```

Results for Max. Allowable External Pressure (Emawp):

```
     TCA       ODCA      SLEN        D/T        L/D   Factor A        B
   2.1080     19.05   4850.00       9.04    50.0000  0.0134693       118.20
 EMAWP = (2.167/(D/T)-0.0833)*B = 184.9632 bars
```

Results for Reqd Thickness for Ext. Pressure (Tca):

TCA	ODCA	SLEN	D/T	L/D	Factor A	B
0.4881	19.05	4850.00	39.03	50.0000	0.0007221	70.35

EMAWP = (4*B)/(3*(D/T)) = (4 *70.3514)/(3 *39.0302) = 24.0318 bars

Summary of Tube Required Thickness Results:

Total Required Thickness including Corrosion all.	0.4881	mm.
Allowable Internal Pressure at Corroded thickness	286.26	bars
Required Internal Design Pressure	24.03	bars
Allowable External Pressure at Corroded thickness	184.96	bars
Required External Design Pressure	24.03	bars
Required Thickness due to Shell Side pressure	0.4881	mm.

Detailed Results for load Case D3 un-corr. (Psd,max + Ptd,max)

Intermediate Calculations For Tubesheets Extended As Flanges:

ASME Code, Section VIII Division 1, 2017

Gasket Contact Width,	N = (Goc-Gic) / 2	20.000	mm.
Basic Gasket Width,	b0 = N / 2.0	10.000	mm.
Effective Gasket Width,	b = SQRT(b0) * 2.5	7.966	mm.
Gasket Reaction Diameter,	G = Go-2.0*b	1247.068	mm.

Bolting Information for UNC Thread Series (Non Mandatory):

Distance Across Corners for Nuts		40.361	mm.
Circular Wrench End Diameter	a	60.325	mm.

	Minimum	Actual	Maximum
Bolt Area, cm^2	197.705	205.445	
Radial Distance between Hub and Bolts:	23.812	44.000	
Radial Distance between Bolts and Edge:	23.812	26.000	
Circ. Spacing between the Bolts:	52.400	53.640	96.450

Flange Design Bolt Load, Seating Condition	W :	3474.35	kN
Flange Design Bolt Load, Operating Condition	Wm1:	3407.64	kN

Results for ASME Fixed Tubesheet Calculations for Configuration b,

Results for Tubesheet Calculations Original Thickness :

UHX-13.5.1 Step 1:

Compute the Tube Expansion Depth Ratio [rho]:
= ltx / h (modified for corrosion if present)
= 20.0/75.0 = 0.2667 (must be 0 <= rho <= 1)

Compute the Effective Tube Hole Diameter [d*]:
= Max(dt - 2tt*(Et/E)(StT/S)(rho), dt - 2tt)
= Max(19.05 -2*2.108 *(.19308E+09/.19308E+09)*
(117/137)*(0.267), 19.05 -2*2.108)
= 18.0888 mm.

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
= 2 * ro + dt = 2 * 571.12 + 19.05 = 1161.29 mm.

Determine the Basic Ligament Efficiency for Shear [mu]:
```
  = (p - dt)/p = (24.0 - 19.05 )/24.0 = 0.2063
```

Compute the Equivalent Outer Tube Limit Radius [ao]:
```
  = Do/2 = 1161.2899/2 = 580.645 mm.
```

Compute the Effective Tube Pitch [p*]:
```
  = p / sqrt( 1 - 4 * min( AL * CNV_factor, 4*Do*p)/(Pi * Do²) )
  = 24.0/sqrt( 1 - 4 * min( 479.0 *100.0, 4*1161.29 *24.0 )/( 3.141 * 1161.29²) )
  = 24.5618 mm.
```

Compute the Effective Ligament Efficiency for Bending [mu*]:
```
  = (p* - d*)/p* = (24.5618 - 18.0888 )/24.5618 = 0.2635
```

Compute the Ratio [Rhos]:
```
  = as/ao = 590.0/580.645 = 1.016111
```

Compute the Ratio [Rhoc]:
```
  = ac/ao = 623.5342/580.645 = 1.073865
```

Compute Parameter [xt]:
```
  = 1 - Nt * (( dt - 2 * tt )/( 2 * ao ))²
  = 1 - 1802 * ((19.05 - 2 * 2.108 )/(2 * 580.645 ))² = 0.706
```

Determine Parameter [xs]:
```
  = 1 - Nt*( dt/(2*ao) )²
  = 1 - 1802 *( 19.05/(2*580.645 ) )² = 0.5151
```

Determine the Value [h'g]:
```
  = Max(( hg - CATC ), 0 )  (For pressure only cases)
  = Max(( 5.0 - 0.0 ), 0 ) = 5.0 mm.
```

UHX-13.5.2 Step 2:

Determine the Axial Shell Stiffness [Ks]:
```
  = pi * ts( Ds + ts )Es/L
  = 3.1416 * 15.0 ( 1180.0 + 15.0 ).19308E+09/4850.0
  = 2241807360.0000 KPa. * mm.
```

Determine the Axial Tube Stiffness [Kt]:
```
  = pi * tt( Dt - tt )Et/L
  = 3.1416 * 2.108 ( 19.05 - 2.108 ).19308E+09/4850.0
  = 4466573.0000 KPa. * mm.
```

Compute the Stiffness Factor [Ks,t]:
```
  = Ks/( Nt * Kt ) = 0.22418E+1/( 1802 * 4466573 ) = 0.27853
```

Rigidty Ratio [J]:
```
  = 1 / ( 1 + Ks/Kj )
  = 1/(1 + 0.22418E+1/0.0 ) = 1. (= 1 if No Exp. Jt.)
```

Compute Shell Coefficient [betas]:
```
  = (( 12 * (1-nus²))^0.25 )/((Ds + ts) * ts )^0.5
  = (( 12 * (1 - 0.3²) )^0.25 )/(( 1180.0 + 15.0 ) * 15.0 )^0.5
  = 0.0136 1/mm.
```

Determine Shell Coefficient [ks]:
```
  = betas * Es * ts³ / ( 6 * (1 - nus²) )
  = 0.014 * 0.19308E+09 * 15.0³/( 6 * (1 - 0.3²) )
  = 16204597.0000 bars*mm.²
```

Determine Shell Coefficient [Lambdas]:
```
  = (6*Ds*ks)/(h³) * (1 + h*betas + 0.5*(h*betas)²)
  = 6*1180.0 *16204597/(75.0³) * ( 1 + 75.0 * 0.014 + 0.518 )
  = 689886.6875 bars
```

Determine Shell Coefficient [deltaS]:
```
  = Ds²/(4 * Es * Ts) * ( 1 - nus/2 )
  = 1180.0²/( 4 * 0.19308E+09 * 15.0 ) * ( 1 - 0.3/2 )
  = 0.1021587178 mm./N./mm^2
```

Intermediate parameters for Tubesheet Gasketed on the Channel Side:
betac, kc, deltaC, Lambdac = 0

UHX-13.5.3 Step 3:

E*/E and nu* for Triangular pattern from Fig. UHX-11.3.
```
   h/p =    3.125000 ;  mu* =    0.263542
  E*/E =    0.233851 ;  nu* =    0.383167 ;  E* = 45151320. KPa.
```

Note: As h/p (3.125) is > 2, data values for h/p = 2 were used.

Compute the Tube Bundle Stiffness Factor [Xa]:
```
  = ((24 *(1 - nu*²)*Nt * Et* tt* (dt - tt)* ao²) /
    ( E* * L * H³ ) )^0.25
  = ((24 *(1 - 0.383²)*1802 *.19308E+09*2.108 *
    (19.05 - 2.108 )*580.645²)/( 45151320 *
    4850.0 * 75.0³ ))^0.25
  = 5.5201
```

Values from Table UHX-13.1
```
  Zd =       0.008945 ;  Zv =       0.032898 ;  Zm =       0.260747
  Za =    0.447508E+02 ;  Zw =       0.032898
```

UHX-13.5.4 Step 4:

Compute the Diameter Ratio [K]:
```
  = A/Do = 1350.0/1161.2899 = 1.1625
```

Compute Coefficient [F]:
```
  = (1 - nu*) / (E*) * ( Lambdas + Lambdac + E * ln(K) )
  = (1 - 0.38 )/(45151320 ) * ( 689886 + 0.0 +
    0.19308E+09 * ln(1.16 ) )
  = 1.3397
```

Compute Parameter [Phi]:
```
  = (1 + nu*) * F = (1 + 0.3832 ) * 1.3397 = 1.853
```

Compute Parameter [Q1]:
```
  = (Rhos - 1 - Phi * Zv)/(1 + Phi * Zm)
  = (1.0161 - 1 - 1.853 * 0.0329 )/(1 + 1.853 * 0.2607 )
  = -0.030238271
```

Compute Parameter [Qz1]:
```
  = (Zd + Q1*Zw)/2 *Xa⁴
  = ( 0.00895 + -0.03024 * 0.0329 )/2 *5.52014⁴ = 3.6912
```

Compute Parameter [Qz2]:
```
  = (Zv + Q1*Zm)/2 *Xa⁴
  = ( 0.0329 + -0.03024 * 0.26075 )/2 *5.52014⁴ = 11.6131
```

Compute Parameter [U]:
```
  = (Zw + (Rhos - 1)*Zm)*Xa⁴ / (1 + Phi*Zm)
  = ( 0.0329 + (1.0161 - 1)* 0.2607 )*5.52014⁴/(1 + 1.853 * 0.2607 )
  = 23.2262
```

UHX-13.5.5 Step 5:

Determine factor [gamab]:
```
  = ( Gc - C ) / Do (config b)
  = (1247.0685 - 1298.0 )/1161.2899 = -0.04386
```

Compute Parameter [gamma]:
```
  = 0.000 mm. (For Pressure only cases)
```

Calculate Parameter [OmegaS]:
```
  = rhos * ks * Betas * deltaS( 1 + h * Betas )
  = 1.0161 * 16204597 * 0.0136 * 0.102159 ( 1 + 75.0 * 0.0136 )
  = 4609.9678 mm.²
```

Calculate Parameter [Omega*S]:
```
  = Ao² * ( Rhos² - 1 ) * ( Rhos - 1 ) / 4 - OmegaS
  = 580.645² * ( 1.016² - 1 ) * ( 1.016 - 1 )/4 - 4609.968
  = -4565.8574 mm.²
```

Calculate Parameter [OmegaC]:
```
  = rhoc * kc * Betac * deltaC( 1 + h * Betac )
  = 1.0739 * 0.0 * 0.0 * 0. ( 1 + 75.0 * 0.0 )
  = 0.0000 mm.²
```

Calculate Parameter [Omega*C]:
```
  = ao²[( Rhoc²+1 )*( Rhoc-1 )/4 -(Rhos-1)/2]- OmegaC
  = 580.64496²[( 1.07386²+1 )*( 1.07386 -1 )/4 -(1.01611 -1)/2]- 0.
  = 10689.4580 mm.²
```

Compute the Pressure [P*S]:
= 0 For Pressure only cases or Configurations d,e,f,A,B,C,D

Compute the Pressure [P*C]:
= 0 For Pressure only cases or Configurations b,c,d,B,C,D

UHX-13.5.6 Step 6:

Compute the Pressure [P's]:
```
  = Ps * {xs + 2( 1 - xs )nut + [2/Kst(Ds/Do)²]nus -
    [(rhos²-1)/(J*Kst)]-[(1-J)/(2J*Kst)][(Dj²-(Ds)²)/Do²]}
  = 23.0 * { 0.515 + 2( 1 - 0.515 ) 0.3 +
    [2/0.279 (1180.0/1161.29 )²] 0.3 -
    [(1.016²-1)/( 1.0 * 0.279 )] -
    [(1 - 1.0 )/(2 * 1.0 * 0.279 )][(0.0²-(1180.0 )²)/1161.29²]}
  = 67.0121 bars
```

Compute the Pressure [P't]:
```
  = [ xt + 2(1 - xt)nut + 1/(J * Kst) ]*Pt
  = [ 0.706 + 2(1 - 0.706 ) 0.3 +
    1/(1. * 0.279 ) ]* 23.0
  = 102.8719 bars
```

Compute the Pressure [Pgama]:
```
  = Nt * Kt * gama / ( pi * ao² )
  = 1802 * 4466573 * 0.0/(3.142 * 580.645²) = 0.0 bars
```

Compute the Pressure [Pw]:
```
  = -gamab * U * W* / (2 * pi * ao²)
  = --0.044 * 23.226 * 3407.64/(2 * 3.142 * 580.645²)
  = 16.3866 bars
```

Calculate the Pressure [Prim]:
```
  = -( U/ao²)(Omega*S * Ps - Omega*C * Pt )
  = -( 23.226/580.645²)(-7.077 * 23.0 - 16.569 * 23.0 )
  = 24.1716 bars
```

Calculate the Pressure [POmega]:
```
  = U/ao²(OmegaS * P*s - OmegaC * P*c )
  = 23.226/580.645²( 7.1455 * 0.0 - 0.0 * 0.0 )
  = 0.0000 bars
```

Determine the Effective Pressure [Pe]:
```
  = J * Kst / (1 + J * Kst *(Qz1 + (Rhos - 1) * Qz2)) *
    (P's - P't + Pgama + Pw + Prim )
  = 0.1000E+01 * 0.279/(1 + 1.0 * 0.279 *(3.691 + (1.016 -
    1) * 11.613 )) * (67.012 - 102.872 + 0.0 + 16.387 + 24.172 )
  = 0.6291 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)
  = [( ( -4565.857 * 23.0 - 10689.458 * 23.0 ) -
    ( 4609.968 * 0.0 - 0.0 * 0.0 )) * 0. +
    3407.6 * -0.044/(2*3.141)]/(1 + 1.85297 * 0.26075 )
  = -39.693904877 kN
```

Calculate Factor [Q3]:
```
  = Q1 + 2 * Q2 / ( Pe * ao² )
  = -0.03 + 2 * -39.694/( 0.629 * 580.645² )
  = -3.773304
```

Fm Value from Table UHX-13.1 = 1.886652

The Tubesheet Bending Stress - Original Thickness [Sigma]:
```
  = (1.5 * Fm / mu* ) * (2 * ao/(H - h'g)² * Pe
  = (1.5 * 1.8867/0.2635 ) * (2 * 580.645/(75.0 - 5.0 ))² * 0.63
  = 185.9349 N./mm^2
```

The Allowable Tubesheet Bending Stress [Sigma allowed]:
```
  = 1.5 * S = 1.5 * 137.9 = 206.85 N./mm^2
```

The Tubesheet Bending Stress - Final Thickness [Sigmaf]:
```
  = (1.5 * Fm/mu*) * (2 * ao/( h - h'g)² * Pe
  = (1.5 * 1.1687/0.2635 ) * (2 * 580.645/(70.842 - 5.0 ))² * 1.
  = 206.8428 N./mm^2
```

Reqd Tubesheet Thickness, for Bending Stress (Including CA) [HReqB]:
```
  = h + Cats + Catc = 70.8424 + 0.0 + 0.0 = 70.8424 mm.
```

UHX-13.5.8 Step 8:

Shear Stress check [Tau_limit]:
```
  = 1.6 * S * MU * h / ao
  = 1.6 * 137.9 * 0.206 * 75.0/580.64
  = 5.8780 N./mm^2
```

The Shear Stress is not required to be computed; [Pe] <= Tau_limit

Note: Tubesheet Shear Stress is probably low, use the following req. thk:

```
  Tubesheet thickness (Incl. Corr.)= 5.5154 mm.
  Tubesheet Shear Stress           = 77.5871 N./mm^2
```

Reqd Tubesheet Thickness for Given Loadings (Including CA) [Hreqd] :

```
  = Max( HreqB, HreqS ) = Max( 70.8424, 5.5154 ) = 70.8424 mm.
```

UHX-13.5.9 Step 9:

The Ftmin and Ftmax Coefficients from Table UHX-13.2:

```
  Ftmin = -53.4791, Ftmax = 18.0756
```

First Extreme Tube Axial Stress from among all the tubes [Sigmat1]:

```
  = ( (Ps * xs - Pt * xt) - Pe * Ftmin ) / ( Xt - Xs )
  = ( (23.0 * 0.5151 - 23.0 * 0.706 ) - ( 0.629 ) * -53.479 )/
    ( 0.706 - 0.5151 ) )
  = 15.3260 N./mm^2
```

Second Extreme value of Tube Axial Stress from among all the tubes [Sigmat2]:

```
  = ( (Ps * xs - Pt * xt) - Pe * Ftmax ) / ( Xt - Xs )
  = ( (23.0 * 0.5151 - 23.0 * 0.706 ) - ( 0.629 ) * 18.076 )/
    ( 0.706 - 0.5151 ) )
  = -8.2577 N./mm^2
```

Maximum Tube Axial Stress [Sigmat,max]:

```
  = MAX( abs(Sigmat1), abs(Sigmat2) ) = 15.326 N./mm^2
```

The Allowable Tube Stress, [SigmatA]:

```
  = Sot = 117.9045 N./mm^2
```

Check for Buckling as some of the Tubes are in Compression

Determine the Factor of Safety [Fs]:

```
  = Max( (3.25 - 0.25*(Zd + Q3*Zw)*Xa^4 ), 1.25 )
  = Max((3.25 - 0.25*( 0.009 + -3.773 * 0.033 )*5.52^4), 1.25 )
  = 2.0000 (Should be <= 2 )
```

Determine the Factor [rt]:

```
  = ( ( dt² + (dt - 2*tt)² ).5 )/4
  = ( (19.05² + (19.05 - 2*2.108 )² ).5 )/4 = 6.0361 mm.
```

Determine the Factor [Ct]:

```
  = ( 2 * PI² * Et/Syt )0.5
  = ( 2 * 3.14² * 0.19308E+09/208 )0.5 = 135.3227
```

Determine the Factor [Ft]:

```
  = k * L/r = 0.8 * 1354.0/6.036 = 179.4539
```

The Buckling Allowable Stress [Stb]:

```
  = 1/Fs * PI²*Et/(Ft²) (Ct <= Ft)
  = 1/2.0 * 3.14²*.19308E+09/(179.4539²)
  = 29.588 N./mm^2    (Never greater than Sot)
```

Note: The Axial Compressive stress in Tubes is within limits.

The Largest tube-to-tubesheet Joint Load [Wt]:

```
  = Sigmat,max * Tube Area = 15.33 * 1.122 = 1.72 kN
```

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:
```
  = 3.1415 * t * ( do - t ) * Sa
  = 3.1415 * 2.108 * ( 19.05 - 2.108 ) * 117.9 = 13.228 kN
```

Fillet Weld Strength [Ff]:
```
  = 0.55 * 3.1415 * af * (do + 0.67*af) * Sw (but not > Ft)
  = 0.55 * 3.1415 * 1.5 * (19.05 + 0.67*1.5 ) * 117.9
  = 6.1280  kN
```

Groove Weld Strength [Fg]:
```
  = 0.85 * 3.1415 * ag * (do + 0.67*ag) * Sw (but not > Ft)
  = 0.85 * 3.1415 * 1.5 * (19.05 + 0.67*1.5 ) * 117.9
  = 9.4706  kN

 Max. Allow. Tube-Tubesheet Joint load, Lmax
  = Ft = 13.2275 kN
```

Design Strength Ratio [fd]:
```
  = 1.0000
```

Weld Strength Factor [fw]:
```
  = Sot / ( Min(Sot, S) ) = 1.0000
```

Min Weld Length [ar]:
```
  = 2 *( ( (0.75 * do)² + 1.07*t*(do - t)* fw * fd ) )½ - 0.75 * do)
  = 2.5600  mm.

 Minimum Required Fillet Weld Leg             afr      1.2800  mm.
 Minimum Required Groove Weld Leg             agr      1.2800  mm.

 Tube-Tubesheet Jt allowable, 13.23 is >= tube strength 13.23 kN
```
Note: This tube-tubesheet joint is a Full Strength joint

UHX-13.5.10 Step 10:

Shell Axial Membrane Allowable Stress:
```
  = Ss * Esw = 137.9 * 1.0 = 137.9 N./mm^2
```

Axial Membrane Stress in Shell [Sigmas,m]:
```
  = ao²/((Ds+ts)*ts)* [Pe + (Rhos²-1)(Ps-Pt)]+ as²*Pt/((Ds+ts)*ts)
  = 580.645²/((1180.0 +15.0 )*15.0 )* [ 0.63 + (1.016²-1)
    (23.0 -23.0 )] + 590.0²*23.0/((1180.0 +15.0 )
    * 15.0 )
  = 45.8515 N./mm^2
```

UHX-13.5.11 Step 11:

Note:
For a given Shell thickness of 15.0 mm., the minimum Shell
length adjacent to the tubesheet should be 239.474 mm.

The Shell Membrane Stress due to Joint Interaction [Sigmas,m]:
```
  = ao²/((Ds+ts)*ts)[Pe + (Rhos²-1)(Ps-Pt)]+ as²*Pt/((Ds+ts)*ts)
  = 580.645²/((1180.0 +15.0 )*15.0 )[ 0.63 + (1.016²-1)
    (23.0 -23.0 )] + 590.0²*23.0/((1180.0 +15.0 )
    * 15.0 )
  = 45.8515 N./mm^2
```


The Shell Bending Stress due to Joint Interaction [Sigmasb]:

```
  = 6*ks/ts² {betas[deltaS*Ps + as²*PstarS/(Es*ts)] +
    6(1 - nu*²)/(E*)(ao/h)³(1 + h*betas/2)[Pe(Zv + Zm*Q1) +
    2/ao² * Zm * Q2 ]}
  = 6 * 16204597/15.0² { 0.014 [ 0.102 * 23.0 + 590.0²
    * 0.0/(.28962E+1 ) ] +
    6(1 - 0.38²)/(45151320 )(580.64/75.0 )³(1 + 75.0 *
    0.01/2)[ 0.6 ( 0.033 + 0.261 * -0.03 ) +
    2/580.64² * 0.261 * -39.694 ] }
  = -67.3956 N./mm^2
```

Shell Stress Summation vs. Allowable

```
  abs(Sigmasm) + abs(Sigmasb) <= 1.5 * Ss
  abs(45.9 ) + abs(-67.4 ) <= 206.85 N./mm^2
  113.25 must be < or = 206.85 N./mm^2
```

Computations Completed for ASME Tubesheet Configuration b

Stress/Force Summary for Loadcase D3 un-corr. (Psd,max + Ptd,max):

Stress Description	Actual		Allowable	Pass/Fail
Tubesheet Bend. Stress	185.9	<=	206.9 N./mm^2	Ok
Tubesheet Shear Stress	1.2	<=	110.3 N./mm^2	Ok
Maximum Tube Stress	15.3	<=	117.9 N./mm^2	Ok
Minimum Tube Stress (Buckling)	-8.3	<=	-29.6 N./mm^2	Ok
Maximum Force on any one Tube	1.7	<=	13.2 kN	Ok
Axial Membrane Stress in Shell	45.9	<=	137.9 N./mm^2	Ok
Shell Stress (jt. inter.)	113.2	<=	206.9 N./mm^2	Ok

Thickness Results for Loadcase D3 un-corr. (Psd,max + Ptd,max):

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	70.842	75.000	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	66.399	31.267	172	207	18	110	Ps+Pt-Th	D1	Ok
D2uc	33.873	...	54	207	20	110	Ps+Pt-Th	D2	Ok
D3uc	70.842	...	186	207	1	110	Ps+Pt-Th	D3	Ok
D4uc	8.172	...	5	207	...	110	Ps+Pt-Th	D4	Ok
O1uc	31.962	...	172	428	30	110	Ps+Pt+Th	O1	Ok
O2uc	29.188	...	106	428	10	110	Ps+Pt+Th	O2	Ok
O3uc	38.036	...	166	428	11	110	Ps+Pt+Th	O3	Ok
O4uc	10.150	...	73	428	8	110	Ps+Pt+Th	O4	Ok
D1c	73.561	31.267	200	207	20	110	Ps+Pt-Th-c	D1	Ok
D2c	31.683	...	47	207	21	110	Ps+Pt-Th-c	D2	Ok
D3c	74.319	...	203	207	1	110	Ps+Pt-Th-c	D3	Ok
D4c	10.292	...	5	207	...	110	Ps+Pt-Th-c	D4	Ok
O1c	45.590	...	210	428	30	110	Ps+Pt+Th-c	O1	Ok

O2c	37.817	...	123	428	13	110	Ps+Pt+Th-c O2	Ok
O3c	48.203	...	200	428	10	110	Ps+Pt+Th-c O3	Ok
O4c	29.757	...	90	428	7	110	Ps+Pt+Th-c O4	Ok
Max:	74.3186	31.267 mm.		0.982		0.274	(Str. Ratio)	

Load Case Definitions:

[Ps & Pt]:
Shell-side and Tube-side Design or Operating Pressures
derived from Psd,min Ptd,max, Psox,min, Ptox,max etc. per the
Load Case Tables

[(+-)Th]:
With or Without Thermal Expansion, Tt,mx & Ts,mx

[c]:
With or Without Corrosion Allowance

[D1, D2, D3]:
Design Load Cases using the Maximum and Minimum Design Pressures

[D4]:
Design Load Case using the Minimum (Vacuum) Pressures (if specified)

[O1, O2, O3, O4]:
Operating Load Cases using the Maximum and Minimum Operating Pressures and
Operating Temperatures

Shell Axial Membrane Stress Summary:

	---- Shell Stresses ----				: ---- Shell Band Stress ----				: Pass
Case#	Ten	Allwd	Cmp	Allwd	Ten	Allwd	Cmp	Allwd	Fail
D1uc	25	137	...	...	...	...	...	...	Ok
D2uc	19	137	...	...	...	...	...	...	Ok
D3uc	46	137	...	...	...	...	...	...	Ok
D4uc	2	137	-2	-102	...	...	...	...	Ok
O1uc	13	452	...	...	...	...	...	...	Ok
O2uc	12	452	...	...	...	...	...	...	Ok
O3uc	33	452	...	...	...	...	...	...	Ok
O4uc	8	452	-8	-102	...	...	...	...	Ok
D1c	31	137	...	...	...	...	...	...	Ok
D2c	24	137	...	...	...	...	...	...	Ok
D3c	57	137	...	...	...	...	...	...	Ok
D4c	2	137	-2	-98	...	...	...	...	Ok
O1c	19	452	...	...	...	...	...	...	Ok
O2c	18	452	...	...	...	...	...	...	Ok
O3c	44	452	...	...	...	...	...	...	Ok
O4c	7	452	-7	-98	...	...	...	...	Ok
Max RATIO		0.415		0.081		...		...	

Tube, Shell and Channel Stress Summary:

	---- Tube Stresses				Tube Loads		Shell Stress		Channel Stress		Pass
Case#	Ten	Allwd	Cmp	Allwd	Ld	Allwd	Stress	Allwd	Stress	Allwd	Fail
D1uc	25	117	-15	-47	3	13	286	452	...	...	Ok
D2uc	11	117	-11	-35	1	13	213	452	...	...	Ok
D3uc	15	117	-8	-29	2	13	113	206	...	...	Ok

D4uc	1	117	-1	-47	...	13	2	206	...	...	Ok
O1uc	38	235	-16	-47	4	26	325	452	...	...	Ok
O2uc	7	235	...	...	1	26	73	452	...	...	Ok
O3uc	28	235	-9	-47	3	26	159	452	...	...	Ok
O4uc	16	235	-3	-47	2	26	133	452	...	...	Ok
D1c	30	117	-15	-47	3	13	328	452	...	...	Ok
D2c	12	117	-12	-40	1	13	267	452	...	...	Ok
D3c	18	117	-9	-29	2	13	110	206	...	...	Ok
D4c	1	117	-1	-47	...	13	3	206	...	...	Ok
O1c	42	235	-16	-47	5	26	362	452	...	...	Ok
O2c	7	235	...	...	1	26	118	452	...	...	Ok
O3c	30	235	-9	-47	3	26	154	452	...	...	Ok
O4c	16	235	-3	-47	2	26	141	452	...	...	Ok
Max RATIO		0.255		0.343		0.255		0.801		...	

Summary of Thickness Comparisons for 16 Load Cases:

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	74.319	75.000	Ok
Tubesheet Thickness Flanged Extension :	31.267	52.000	Ok
Tube Thickness :	0.488	2.108	Ok
Tube-Tubesheet Fillet Weld Leg :	1.280	1.500	Ok
Tube-Tubesheet Groove Weld Leg :	1.280	1.500	Ok

Min Shell length of thk, (15.000) adj. to tubesheet: 239.474 mm.

Note: This is a full strength Tube to Tubesheet Joint.

Summary of Axial Differential Expansion between Shell and Tubes :

Due to Thermal Expansion Shell Compresses by : -0.655 mm.
Due to Pressure Shell Compresses by : -0.069 mm.
Due to Pressure + Thermal Shell Compresses by : -0.724 mm.

Tubesheet MAWP used to Compute Hydrotest Pressure:

Stress / Force Condition	Tubeside MAWP	0 shellside Stress Rat.	Shellside MAWP	0 tubeside Stress Rat.
Tubesheet Bending Stress	23.823	1.000	84.284	1.000
Tubesheet Shear Stress	109.603	1.000	128.692	1.000
Tube Tensile Stress	91.683	1.000	240.476	1.000
Tube Compressive Stress	55.931	0.769	79.224	1.000
Tube-Tubesheet Joint load	91.683	1.000	240.476	1.000
Shell Stress (Axial, Junction)	23.823	1.000	40.217	1.000
Tube Pressure Stress	286.263	1.000	184.962	1.000
Tubesheet Extension Stress	23.899	...	No Calc	No Calc
Minimum MAWP	23.823		40.217	

Tubesheet MAPnc used to Compute Hydrotest Pressure:

Stress / Force Condition	Tubeside MAPnc	0 shellside Stress Rat.	Shellside MAPnc	0 tubeside Stress Rat.
Tubesheet Bending Stress	27.662	0.998	84.284	1.000
Tubesheet Shear Stress	145.172	1.000	135.985	1.000
Tube Tensile Stress	108.545	1.000	280.812	1.000
Tube Compressive Stress	79.526	1.000	85.674	1.000

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for CONDENSER E-PK6101-2 -----
ASME TS Calc: Case: 1 7:41a Dec 24,2021

Tube-Tubesheet Joint load	108.545	1.000	280.812	1.000
Shell Stress (Axial, Junction)	27.662	0.998	58.585	1.000
Tube Pressure Stress	286.263	1.000	192.052	1.000
Tubesheet Extension Stress	23.899	...	No Calc	No Calc
Minimum MAPnc	23.899		58.585	

(*) 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( 75.0/4, min( 75.0, 15.0 ) )
  = 18.750 mm.
```

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

Impact Test Temperature provided per Specification -46 °C

Channel Side MDMT calculation:

Governing thickness for the channel side:
```
  = tubesheet thickness/4
  = 75.0/4
  = 18.750 mm.
```

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

Impact Test Temperature provided per Specification -46 °C

where the MDMT reduction ratio per UCS 66 (b)(1)(b) is:
```
  = max( pt/Tubeside MAPnc, ps/Shellside MAPnc ), must be <= 1
  = max( 23.0/23.9, 23.0/58.58 )
  = 0.962
```

Minimum Design Metal Temperature Results Summary :

Description	Notes	Curve	Basic MDMT °C	Reduced MDMT °C	UG-20(f) MDMT °C	Thickness ratio	Gov Thk mm.	E*	PWHT reqd
SHELL	[8]	!	-45	-54		0.837	15.000	1.00	No
S2	[1]	D	-47	-48	-29	0.837	15.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
S1	[1]	D	-46	-46		0.833	12.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
S3	[1]	D	-48	-48	-29	0.833	10.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
Tubesheet: SS	[13]	!	-46	-46		0.962	18.750	1.00	No
Warmest MDMT:			-45	-46					
BODY FLANGE 0	[11]	!	-46	-46		0.837	15.000	1.00	No
BODY FLANGE 0	[11]	!	-46	-46		0.836	15.000	1.00	No
HEAD 1	[10]	D	-48	-48	-29	0.988	13.000	1.00	No
HEAD 1	[7]	D	-47	-48	-29	0.836	15.000	1.00	No
CHANNEL 01	[8]	D	-47	-48	-29	0.837	15.000	0.85	No
CHANNEL 002	[8]	D	-47	-48	-29	0.836	15.000	1.00	No
HEAD 002	[10]	D	-48	-48	-29	0.988	13.000	1.00	No
HEAD 002	[7]	D	-47	-48	-29	0.836	15.000	1.00	No
T1	[1]	D	-46	-46		0.836	15.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
T2	[1]	D	-46	-46		0.833	15.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
T4	[1]	D	-46	-104		0.019	14.250	1.00	No
Nozzle Flg	[4]	!	-46	-104					
T3	[1]	D	-46	-104		0.023	14.300	1.00	No
Nozzle Flg	[4]	!	-46	-104					
Tubesheet: CS	[14]	!	-46	-46		0.962	18.750	1.00	No
Warmest MDMT:			-46	-46					

Exchanger Side	Computed MDMT °C	Required MDMT °C	Pass/Fail
Shell	-46.0	-45.0	Pass
Channel/Tube	-46.0	-45.0	Pass

Notes:
[!] - This was an impact tested material.
[1] - Governing Nozzle Weld.
[4] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-c).
[5] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-b).
[6] - MDMT Calculations at the Shell/Head Joint.
[7] - MDMT Calculations for the Straight Flange.
[8] - Cylinder/Cone/Flange Junction MDMT.
[9] - Calculations in the Spherical Portion of the Head.
[10] - Calculations in the Knuckle Portion of the Head.
[11] - Calculated (Body Flange) Flange MDMT.
[12] - Calculated Flat Head MDMT per UCS-66.3
[13] - Tubesheet MDMT, shell side, if applicable
[14] - Tubesheet MDMT, tube side, if applicable
[15] - Nozzle Material
[16] - Shell or Head Material

MDMT Summary: Step: 23 7:41am Dec 24,2021

[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.

Vessel Design Summary: Step: 24 7:41am Dec 24,2021

ASME Code, Section VIII Division 1, 2017

Diameter Spec : 1180.000 mm. ID		
Vessel Design Length, Tangent to Tangent	6446.35	mm.
Specified Datum Line Distance	50.00	mm.
Shell Side Design Temperature	125	°C
Channel Side Design Temperature	190	°C
Shell Side Design Pressure	23.000	bars
Channel Side Design Pressure	23.000	bars
Wind Design Code	ASCE-2010	
Earthquake Design Code	ASCE 7-2010	

Materials of Construction:

Component Type	Material	Class	Thickness	UNS #	Normalized	Impact Tested
Shell	SA-516 70	...	...	K02700	Yes	No
Head	SA-516 70	...	...	K02700	Yes	No
Flange	SA-350 LF2	1	...	K03011	No	Yes
Nozzle	SA-333 6	...	...	K03006	No	Yes
Nozzle	SA-350 LF2	1	...	K03011	No	Yes
Re-Pad	SA-516 70	...	...	K02700	Yes	No
Nozzle Flg	SA-350 LF2	1	...	K03011	No	Yes
Tubes	SA-334 6	...	...	K03006	No	Yes
Tubesheet	SA-350 LF2	1	...	K03011	No	Yes
Flg Bolting	SA-320 L7	...	<= 2 1/2	G41400	No	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	23.081	1.10	No Calc	3.0000	No	No
CHANNEL 01	23.081	1.10	No Calc	3.0000	N/A	No
BODY FLANGE 01	23.081	1.10	No Calc	3.0000	N/A	No
SHELL	23.116	1.10	No Calc	3.0000	N/A	No
BODY FLANGE 002	23.037	1.10	No Calc	3.0000	N/A	No
CHANNEL 002	23.081	1.10	No Calc	3.0000	N/A	No
HEAD 002	23.081	1.10	No Calc	3.0000	No	No

Liquid Level: 1180.00 mm. Dens.: 0.001 kg./cm^3 Sp. Gr.: 0.700

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	15.0	13.0	12.9	6.3	1.00	0.85
Cylinder	749.0	749.0	15.0	15.0	14.8	6.5	0.85	0.85

Body Flg	895.0	146.0	79.0	110.0	108.3	68.4	1.00	1.00
Cylinder	5820.2	4844.0	15.0	15.0	13.0	10.1	1.00	1.00
Body Flg	5972.4	146.0	79.0	110.0	108.9	68.8	1.00	0.85
Cylinder	6346.4	299.0	15.0	15.0	13.0	5.7	1.00	1.00
Ellipse	6396.4	50.0	15.0	13.0	12.9	6.3	1.00	0.85

Saddle Parameters:

Saddle Width	172.000	mm.
Saddle Bearing Angle	120.000	deg.
Centerline Dimension	950.000	mm.
Wear Pad Width	225.000	mm.
Wear Pad Thickness	15.000	mm.
Wear Pad Bearing Angle	132.000	deg.
Distance from Saddle to Tangent	346.000	mm.
Baseplate Length	1050.000	mm.
Baseplate Thickness	16.000	mm.
Baseplate Width	220.000	mm.
Number of Ribs (including outside ribs)	4	
Rib Thickness	12.000	mm.
Web Thickness	12.000	mm.
Height of Center Web	314.000	mm.
Number of Bolts in Baseplate	4	

Baseplate Sketch

```
|------------------- 1050.000 mm. -------------------|
----------------------------------------------------- ---
|                                                   |
|                                                   | 220.000 mm.
|                                                   |
----------------------------------------------------- ---
```

Baseplate Plan View

```
----------------------------------------------------- ---
|                                                   | 16.000 mm.
----------------------------------------------------- ---
```

Baseplate Side View

Maximum Tensile Bolt Load	0.	kN

Summary of Maximum Saddle Loads, Operating Case :

Maximum Vertical Saddle Load	162.84	kN
Maximum Transverse Saddle Shear Load	22.75	kN
Maximum Longitudinal Saddle Shear Load	45.50	kN

Summary of Maximum Saddle Loads, Operating Case, Un-Factored :

Maximum Vertical Saddle Load	188.72	kN
Maximum Transverse Saddle Shear Load	60.38	kN
Maximum Longitudinal Saddle Shear Load	65.00	kN

Summary of Maximum Saddle Loads, Hydrotest Case :

Maximum Vertical Saddle Load	116.51	kN
Maximum Transverse Saddle Shear Load	1.38	kN
Maximum Longitudinal Saddle Shear Load	0.79	kN

Local Stress Analysis Results:

	Analysis	Max Stress	Pass

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:CONDENSER E-PK6101-2
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for CONDENSER E-PK6101-2 -----
Vessel Design Summary: Step: 24 7:41am Dec 24,2021

Description	Type	Ratio	Fail
T1	WRC-107/537	0.836	Passed
T2	WRC-107/537	0.833	Passed
S2	WRC-107/537	0.837	Passed
S1	WRC-107/537	0.833	Passed
S3	WRC-107/537	0.833	Passed

Weights:

Fabricated	- Bare W/O Removable Internals	14412.0	kg.
Shop Test	- Fabricated + Water (Full)	20783.2	kg.
Shipping	- Fab. + Rem. Intls.+ Shipping App.	14412.0	kg.
Erected	- Fab. + Rem. Intls.+ Insul. (etc)	14412.0	kg.
Empty	- Fab. + Intls. + Details + Wghts.	14412.0	kg.
Operating	- Empty + Operating Liquid (No CA)	19652.0	kg.
Field Test	- Empty Weight + Water (Full)	20203.7	kg.