	DEHDASHT PETROCHEMICAL INDUSTRY COMPANY DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT	
	DOCUMENT TITLE: Mechanical Calculation for Evaporator E-6101	POI: IFA
Contract No.: DPIC/98-12	DOCUMENT NUMBER: DPIC9812-000-VD-1002-ME-CLN-0092	Rev. No.: D0

DOCUMENT TITLE:

Mechanical Calculation for Evaporator (E-6101)

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-0092-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	
NARGAN	DOCUMENT TITLE: Mechanical Calculation for Evaporator E-6101	POI: IFA
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DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601

DESIGN CALCULATION

In Accordance with ASME Section VIII Division 1

```
ASME Code Version     : 2017

Analysis Performed by : SPLM Licensed User

Job File              :

Date of Analysis      : Dec 23,2021   11:47am

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.

```
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:Evaporator E-PK1601

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	125.0	°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	1.000
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 001
Distance "FROM" to "TO"                              50  mm.
Inside Diameter                                    1200  mm.
Element Thickness                                    15  mm.
Internal Corrosion Allowance                          3  mm.
Nominal Thickness                                    18  mm.
External Corrosion Allowance                          0  mm.
Design Internal Pressure                             23  bars
Design Temperature Internal Pressure                125  °C
Design External Pressure                         1.0342  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
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                        1200  mm.
    Liquid Density                            0.0009996  kg./cm^3

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

Element From Node                                    20
Element To Node                                      30
Element Type                                   Cylinder
Description                                   SHELL 001
Distance "FROM" to "TO"                             800  mm.
Inside Diameter                                    1200  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                         1.0342  bars
Design Temperature External Pressure                125  °C
Effective Diameter Multiplier                       1.2
Material Name                                 SA-516 70 [Impact Tested]
Efficiency, Longitudinal Seam                       1.0
Efficiency, Circumferential Seam                    1.0
Weld is pre-Heated                                   No

    Element From Node                                20
    Detail Type                                  Liquid
```

```
     Detail ID                                                2
     Dist. from "FROM" Node / Offset dist                     0  mm.
     Height/Length of Liquid                               1200  mm.
     Liquid Density                                   0.0009996  kg./cm^3

     Element From Node                                       20
     Detail Type                                         Nozzle
     Detail ID                                               T2
     Dist. from "FROM" Node / Offset dist                   400  mm.
     Nozzle Diameter                                         20  in.
     Nozzle Schedule                                       None
     Nozzle Class                                           300
     Layout Angle                                          90.0
     Blind Flange (Y/N)                                       N
     Weight of Nozzle ( Used if > 0 )                    2.9969  kN
     Grade of Attached Flange                            GR 1.1
     Nozzle Matl                                    SA-516 70 [Normalized]

     Element From Node                                       20
     Detail Type                                         Nozzle
     Detail ID                                               T1
     Dist. from "FROM" Node / Offset dist                   400  mm.
     Nozzle Diameter                                         20  in.
     Nozzle Schedule                                       None
     Nozzle Class                                           300
     Layout Angle                                         270.0
     Blind Flange (Y/N)                                       N
     Weight of Nozzle ( Used if > 0 )                    2.9969  kN
     Grade of Attached Flange                            GR 1.1
     Nozzle Matl                                    SA-516 70 [Normalized]

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

 Element From Node                                           30
 Element To Node                                             40
 Element Type                                          Flange
 Description                                   BODY FLANGE 001
 Distance "FROM" to "TO"                                    155  mm.
 Flange Inside Diameter                                    1200  mm.
 Element Thickness                                          110  mm.
 Internal Corrosion Allowance                                 3  mm.
 Nominal Thickness                                           60  mm.
 External Corrosion Allowance                                 0  mm.
 Design Internal Pressure                                    23  bars
 Design Temperature Internal Pressure                       125  °C
 Design External Pressure                                1.0342  bars
 Design Temperature External Pressure                       125  °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                             222.82  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                             1200  mm.
     Liquid Density                                 0.0009996  kg./cm^3

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

 Element From Node                                         40
 Element To Node                                           50
 Element Type                                          Flange
 Description                                    body flange 02
 Distance "FROM" to "TO"                                  155  mm.
 Flange Inside Diameter                                  1200  mm.
 Element Thickness                                        110  mm.
 Internal Corrosion Allowance                               3  mm.
 Nominal Thickness                                         60  mm.
 External Corrosion Allowance                               0  mm.
 Design Internal Pressure                                  23  bars
 Design Temperature Internal Pressure                     125  °C
 Design External Pressure                              1.0342  bars
 Design Temperature External Pressure                     125  °C
 Effective Diameter Multiplier                            1.2
 Material Name                                    SA-350 LF2 [Impact Tested]
 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                                     40
     Detail Type                                       Liquid
     Detail ID                                              4
     Dist. from "FROM" Node / Offset dist                   0  mm.
     Height/Length of Liquid                             1200  mm.
     Liquid Density                                 0.0009996  kg./cm^3

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

 Element From Node                                         50
 Element To Node                                           60
 Element Type                                        Cylinder
 Description                                        SHELL 002
 Distance "FROM" to "TO"                                  200  mm.
 Inside Diameter                                         1200  mm.
 Element Thickness                                         20  mm.
 Internal Corrosion Allowance                               3  mm.
 Nominal Thickness                                         20  mm.
 External Corrosion Allowance                               0  mm.
 Design Internal Pressure                                  23  bars
 Design Temperature Internal Pressure                     125  °C
 Design External Pressure                              1.0342  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                           29.007  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                                50
     Detail Type                                  Saddle
     Detail ID                                   Lft Sdl
     Dist. from "FROM" Node / Offset dist            200  mm.
     Width of Saddle                                 172  mm.
     Height of Saddle at Bottom                      972  mm.
     Saddle Contact Angle                          120.0
     Height of Composite Ring Stiffener                0  mm.
     Width of Wear Plate                             332  mm.
     Thickness of Wear Plate                          12  mm.
     Contact Angle, Wear Plate (degrees)           140.0
     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                                50
     Detail Type                                  Liquid
     Detail ID                                         5
     Dist. from "FROM" Node / Offset dist              0  mm.
     Height/Length of Liquid                        1200  mm.
     Liquid Density                            0.0009996  kg./cm^3

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

 Element From Node                                    60
 Element To Node                                      70
 Element Type                                   Conical
 Description                                         CON
 Distance "FROM" to "TO"                             830  mm.
 Inside Diameter                                    1200  mm.
 Element Thickness                                    20  mm.
 Internal Corrosion Allowance                          3  mm.
 Nominal Thickness                                    20  mm.
 External Corrosion Allowance                          0  mm.
 Design Internal Pressure                             23  bars
 Design Temperature Internal Pressure                125  °C
 Design External Pressure                         1.0342  bars
 Design Temperature External Pressure                125  °C
 Effective Diameter Multiplier                       1.2
 Material Name                                 SA-516 70 [Impact Tested]
 Efficiency, Longitudinal Seam                       1.0
 Efficiency, Circumferential Seam                    1.0
 Cone Diameter at "To" End                          1656  mm.
 Design Length of Cone                               830  mm.
```

```
 Half Apex Angle of Cone                          28.784285  degrees
 Toriconical (Y/N)                                        N
 Weld is pre-Heated                                      No

     Element From Node                                   60
     Detail Type                                     Liquid
     Detail ID                                   Liquid: 60
     Dist. from "FROM" Node / Offset dist                 0  mm.
     Height/Length of Liquid                           1200  mm.
     Liquid Density                               0.0009996  kg./cm^3

     Element From Node                                   60
     Detail Type                                     Nozzle
     Detail ID                                           D4
     Dist. from "FROM" Node / Offset dist               400  mm.
     Nozzle Diameter                                      2  in.
     Nozzle Schedule                                   None
     Nozzle Class                                       300
     Layout Angle                                     270.0
     Blind Flange (Y/N)                                   N
     Weight of Nozzle ( Used if > 0 )                0.1015  kN
     Grade of Attached Flange                        GR 1.1
     Nozzle Matl                                SA-350 LF2 [Impact Tested]

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

 Element From Node                                       70
 Element To Node                                         80
 Element Type                                      Cylinder
 Description                                      SHELL 002
 Distance "FROM" to "TO"                               4000  mm.
 Inside Diameter                                       1656  mm.
 Element Thickness                                       18  mm.
 Internal Corrosion Allowance                             3  mm.
 Nominal Thickness                                       18  mm.
 External Corrosion Allowance                             0  mm.
 Design Internal Pressure                                23  bars
 Design Temperature Internal Pressure                   125  °C
 Design External Pressure                            1.0342  bars
 Design Temperature External Pressure                   125  °C
 Effective Diameter Multiplier                          1.2
 Material Name                                    SA-516 70 [Impact Tested]
 Efficiency, Longitudinal Seam                          1.0
 Efficiency, Circumferential Seam                       1.0
 Weld is pre-Heated                                      No

     Element From Node                                   70
     Detail Type                                     Saddle
     Detail ID                                      Lft Sdl
     Dist. from "FROM" Node / Offset dist              3500  mm.
     Width of Saddle                                    172  mm.
     Height of Saddle at Bottom                        1200  mm.
     Saddle Contact Angle                             120.0
     Height of Composite Ring Stiffener                   0  mm.
     Width of Wear Plate                                350  mm.
     Thickness of Wear Plate                             12  mm.
     Contact Angle, Wear Plate (degrees)              140.0
     Friction coefficient                        0.30000001
     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                                   70
     Detail Type                                     Liquid
     Detail ID                                   Liquid: 70
     Dist. from "FROM" Node / Offset dist                 0  mm.
     Height/Length of Liquid                           1200  mm.
     Liquid Density                               0.0009996  kg./cm^3

     Element From Node                                   70
     Detail Type                                     Nozzle
     Detail ID                                           S2
     Dist. from "FROM" Node / Offset dist               200  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 )                0.8591  kN
     Grade of Attached Flange                        GR 1.1
     Nozzle Matl                                   SA-333 6 [Impact Tested]

     Element From Node                                   70
     Detail Type                                     Nozzle
     Detail ID                                           S1
     Dist. from "FROM" Node / Offset dist              2800  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 )                0.8591  kN
     Grade of Attached Flange                        GR 1.1
     Nozzle Matl                                   SA-333 6 [Impact Tested]

     Element From Node                                   70
     Detail Type                                     Nozzle
     Detail ID                                           S3
     Dist. from "FROM" Node / Offset dist               600  mm.
     Nozzle Diameter                                      8  in.
     Nozzle Schedule                                     80
     Nozzle Class                                       300
     Layout Angle                                      90.0
     Blind Flange (Y/N)                                   N
     Weight of Nozzle ( Used if > 0 )                0.8591  kN
     Grade of Attached Flange                        GR 1.1
     Nozzle Matl                                   SA-333 6 [Impact Tested]

     Element From Node                                   70
     Detail Type                                     Nozzle
     Detail ID                                           D2
     Dist. from "FROM" Node / Offset dist               600  mm.
     Nozzle Diameter                                      2  in.
     Nozzle Schedule                                   None
     Nozzle Class                                       300
     Layout Angle                                     270.0
     Blind Flange (Y/N)                                   N
     Weight of Nozzle ( Used if > 0 )                0.1015  kN
     Grade of Attached Flange                        GR 1.1
     Nozzle Matl                                 SA-350 LF2 [Impact Tested]
```

```
Element From Node                                  70
Detail Type                                    Nozzle
Detail ID                                          D1
Dist. from "FROM" Node / Offset dist             2400  mm.
Nozzle Diameter                                     2  in.
Nozzle Schedule                                  None
Nozzle Class                                      300
Layout Angle                                    270.0
Blind Flange (Y/N)                                  N
Weight of Nozzle ( Used if > 0 )               0.1015  kN
Grade of Attached Flange                       GR 1.1
Nozzle Matl                              SA-350 LF2 [Impact Tested]

Element From Node                                  70
Detail Type                                    Nozzle
Detail ID                                          D3
Dist. from "FROM" Node / Offset dist             3200  mm.
Nozzle Diameter                                     2  in.
Nozzle Schedule                                  None
Nozzle Class                                      300
Layout Angle                                    270.0
Blind Flange (Y/N)                                  N
Weight of Nozzle ( Used if > 0 )               0.1015  kN
Grade of Attached Flange                       GR 1.1
Nozzle Matl                              SA-350 LF2 [Impact Tested]

Element From Node                                  70
Detail Type                                    Nozzle
Detail ID                                          TT
Dist. from "FROM" Node / Offset dist             3800  mm.
Nozzle Diameter                                     2  in.
Nozzle Schedule                                  None
Nozzle Class                                      300
Layout Angle                                    270.0
Blind Flange (Y/N)                                  N
Weight of Nozzle ( Used if > 0 )               0.1015  kN
Grade of Attached Flange                       GR 1.1
Nozzle Matl                              SA-350 LF2 [Impact Tested]

Element From Node                                  70
Detail Type                                    Nozzle
Detail ID                                           V
Dist. from "FROM" Node / Offset dist              200  mm.
Nozzle Diameter                                     2  in.
Nozzle Schedule                                  None
Nozzle Class                                      300
Layout Angle                                     90.0
Blind Flange (Y/N)                                  N
Weight of Nozzle ( Used if > 0 )               0.1015  kN
Grade of Attached Flange                       GR 1.1
Nozzle Matl                              SA-350 LF2 [Impact Tested]

Element From Node                                  70
Detail Type                                    Nozzle
Detail ID                                          S4
Dist. from "FROM" Node / Offset dist             2800  mm.
Nozzle Diameter                                     8  in.
Nozzle Schedule                                    80
Nozzle Class                                      300
Layout Angle                                     90.0
```

```
     Blind Flange (Y/N)                                    N
     Weight of Nozzle ( Used if > 0 )                 0.8591  kN
     Grade of Attached Flange                         GR 1.1
     Nozzle Matl                                    SA-333 6 [Impact Tested]

     Element From Node                                    70
     Detail Type                                      Nozzle
     Detail ID                                           LG1
     Dist. from "FROM" Node / Offset dist               2200  mm.
     Nozzle Diameter                                       2  in.
     Nozzle Schedule                                    None
     Nozzle Class                                        300
     Layout Angle                                      270.0
     Blind Flange (Y/N)                                    N
     Weight of Nozzle ( Used if > 0 )                 0.1015  kN
     Grade of Attached Flange                         GR 1.1
     Nozzle Matl                                  SA-350 LF2 [Impact Tested]

     Element From Node                                    70
     Detail Type                                      Nozzle
     Detail ID                                           LG2
     Dist. from "FROM" Node / Offset dist               2200  mm.
     Nozzle Diameter                                       2  in.
     Nozzle Schedule                                    None
     Nozzle Class                                        300
     Layout Angle                                       90.0
     Blind Flange (Y/N)                                    N
     Weight of Nozzle ( Used if > 0 )                 0.1015  kN
     Grade of Attached Flange                         GR 1.1
     Nozzle Matl                                  SA-350 LF2 [Impact Tested]

     Element From Node                                    70
     Detail Type                                      Nozzle
     Detail ID                                           LT1
     Dist. from "FROM" Node / Offset dist               1000  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 )                 0.2227  kN
     Grade of Attached Flange                         GR 1.1
     Nozzle Matl                                  SA-350 LF2 [Impact Tested]

     Element From Node                                    70
     Detail Type                                      Nozzle
     Detail ID                                           LT3
     Dist. from "FROM" Node / Offset dist               1500  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 )                 0.2227  kN
     Grade of Attached Flange                         GR 1.1
     Nozzle Matl                                  SA-350 LF2 [Impact Tested]

     Element From Node                                    70
     Detail Type                                      Nozzle
     Detail ID                                           LT2
     Dist. from "FROM" Node / Offset dist               1000  mm.
```

```
     Nozzle Diameter                                   2  in.
     Nozzle Schedule                                 160
     Nozzle Class                                    300
     Layout Angle                                  270.0
     Blind Flange (Y/N)                                N
     Weight of Nozzle ( Used if > 0 )             0.2227  kN
     Grade of Attached Flange                     GR 1.1
     Nozzle Matl                            SA-350 LF2 [Impact Tested]

     Element From Node                                70
     Detail Type                                  Nozzle
     Detail ID                                       LT4
     Dist. from "FROM" Node / Offset dist           1500  mm.
     Nozzle Diameter                                   2  in.
     Nozzle Schedule                                 160
     Nozzle Class                                    300
     Layout Angle                                  270.0
     Blind Flange (Y/N)                                N
     Weight of Nozzle ( Used if > 0 )             0.2227  kN
     Grade of Attached Flange                     GR 1.1
     Nozzle Matl                            SA-350 LF2 [Impact Tested]

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

 Element From Node                                    80
 Element To Node                                      90
 Element Type                                   Elliptical
 Description                                    HEAD 002
 Distance "FROM" to "TO"                              50  mm.
 Inside Diameter                                    1656  mm.
 Element Thickness                                    17  mm.
 Internal Corrosion Allowance                          3  mm.
 Nominal Thickness                                    20  mm.
 External Corrosion Allowance                          0  mm.
 Design Internal Pressure                             23  bars
 Design Temperature Internal Pressure                125  °C
 Design External Pressure                         1.0342  bars
 Design Temperature External Pressure                125  °C
 Effective Diameter Multiplier                       1.2
 Material Name                               SA-516 70 [Impact Tested]
 Efficiency, Longitudinal Seam                       1.0
 Efficiency, Circumferential Seam                    1.0
 Elliptical Head Factor                              2.0
 Weld is pre-Heated                                   No

     Element From Node                                80
     Detail Type                                  Liquid
     Detail ID                                Liquid: 80
     Dist. from "FROM" Node / Offset dist              0  mm.
     Height/Length of Liquid                        1200  mm.
     Liquid Density                            0.0009996  kg./cm^3
```

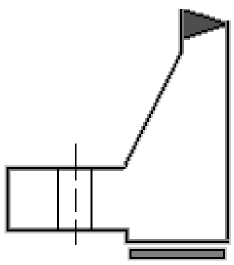
XY Coordinate Calculations:

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
HEAD 001		50	...	50	...
SHELL 001		850	...	800	...
BODY FLANGE 001		1005	...	155	...
body flange 02		1315.53	...	155	...
SHELL 002		1515.53	...	200	...
CON		2345.53	...	830	...
SHELL 002		6345.53	...	4000	...
HEAD 002		6395.52	...	50	...

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

BODY FLANGE 001

```
 Description of Flange Geometry (Type)          Integral Weld Neck
 Design Pressure                            P            23.12  bars
 Design Temperature                                        125  °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         1200.000  mm.
 Flange Outside Diameter                    A         1360.000  mm.
 Flange Thickness                           t         110.0000  mm.
 Thickness of Hub at Small End              go         15.0000  mm.
 Thickness of Hub at Large End              g1         23.0000  mm.
 Length of Hub                              h          45.0000  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         1310.000  mm.
 Nominal Bolt Diameter                      a          22.2250  mm.
 Type of Threads                            TEMA Thread Series
 Number of Bolts                                            72

 Flange Face Outside Diameter              Fod        1269.000  mm.
 Flange Face Inside Diameter               Fid        1200.000  mm.
 Flange Facing Sketch                       1, Code Sketch 1a

 Gasket Outside Diameter                    Go        1266.000  mm.
 Gasket Inside Diameter                     Gi        1226.000  mm.
 Gasket Factor                              m           3.0000
 Gasket Design Seating Stress               y            68.95  N./mm^2

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



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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)
  = (23.12*(1200.0/2+3.0))/(137.9*1.0-0.6*23.12)+Ca
```

```
  = 13.2120 mm.
```

Hub Small End Hub MAWP:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9 * 1.0 * 12.0)/(603.0 + 0.6 * 12.0 )
  = 27.117 bars
```

```
 Corroded Flange Thickness, tc = T-ci                   107.000  mm.
 Corroded Flange ID,      Bcor = B+2*Fcor              1206.000  mm.
 Corroded Large Hub,     g1Cor = g1-ci                   20.000  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            1250.063  mm.
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.785 * 1250.0626² * 23.118
  = 2837.167 kN
```
Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * Pi * G * m * P
  = 2 * 7.9687 * 3.1416 * 1250.0626 * 3.0 * 23.12
  = 434.062 kN
```
Hydrostatic End Load at Flange ID [Hd]:
```
  = Pi * Bcor² * P  / 4
  = 3.1416 * 1206.0² *23.1176/4
  = 2640.681 kN
```
Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 2837 - 2641
  = 196.486 kN
```
Operating Bolt Load [Wm1]:
```
  = max( H + Hp + H'p, 0 )
  = max( 2837 + 434 + 0, 0 )
  = 3271.229 kN
```
Gasket Seating Bolt Load [Wm2]:
```
  = y * b * Pi * G  + yPart * bPart * lp
  = 68.95*7.9687*3.141*1250.063+0.0*0.0*0.0
  = 2157.577 kN
```
Required Bolt Area [Am]:
```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 3271/172, 2158/172
  = 189.790 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/(3.0 + 0.5)
  = 227.879 mm.
```

Actual Circumferential Bolt Spacing [Bs]:
```
  = C * sin( pi / n )
  = 1310.0 * sin( 3.142/72 )
  = 57.141 mm.
```

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

```
  = max( sqrt( 57.141/( 2 * 22.225 + 107.0 )), 1 )
  = 1.0000
```

Bolting Information for TEMA Imperial Thread Series (Non Mandatory):

	Minimum	Actual	Maximum
Bolt Area, cm^2	189.790	194.632	
Radial Distance between Hub and Bolts:	31.750	32.000	
Radial Distance between Bolts and Edge:	23.812	25.000	
Circ. Spacing between the Bolts:	52.400	57.141	227.879

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

```
  = Ab * Sa/( y * Pi * (Go + Gi) )
  = 194.632 * 172.38/(68.95 * 3.14 * (1266.0 + 1226.0) )
  = 6.215 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 * ( 189.7901 + 194.6319 )/2
  = 3312.96 kN
```

Gasket Load for the Operating Condition [HG]:

```
  = Wm1 - H
  = 3271 - 2837
  = 434.06 kN
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
  = (C - G ) / 2
  = ( 1310.0 - 1250.0626 )/2
  = 29.9687 mm.
```

Distance to Face Pressure Reaction [ht]:

```
  = ( R + g1 + hg ) / 2
  = ( 32.0 + 20.0 + 29.9687 )/2
  = 40.9843 mm.
```

Distance to End Pressure Reaction [hd]:

```
  = R + ( g1 / 2 )
  = 32.0 + ( 20.0/2.0 )
  = 42.0000 mm.
```

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

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	2641.	42.0000	1.0000	110954.
Face Pressure,	Mt	196.	40.9843	1.0000	8056.
Gasket Load,	Mg	434.	29.9687	1.0000	13014.
Gasket Seating,	Matm	3313.	29.9687	1.0000	99325.

```
 Total Moment for Operation,      Mop                          132023. N-m
 Total Moment for Gasket seating, Matm                          99325. N-m

 Effective Hub Length, ho = sqrt(Bcor*goCor)         120.300  mm.
 Hub Ratio,           h/h0 = HL / H0                   0.374
 Thickness Ratio,    g1/g0 = (g1Cor/goCor)             1.667
```

Flange Factors for Integral Flange:

```
 Factor F                                              0.861
 Factor V                                              0.313
 Factor f                                              1.178
 Factors from Figure 2-7.1                     K =     1.128
                    T =      1.867             U =    17.771
                    Y =     16.171             Z =     8.361
                    d = 0.98424E+06 mm.³        e =     0.0072 mm.^-1
 Stress Factors                            ALPHA =     1.766
                 BETA =      2.021         GAMMA =     0.946
                DELTA =      1.245         Lamda =     2.191
```

Longitudinal Hub Stress, Operating [SHo]:
= (f * Mop / Bcor) / (L * g1²)
= (1.1782*132023/1206.0)/(2.1905*20.0²)
= 147.16 N./mm^2

Longitudinal Hub Stress, Seating [SHa]:
= (f * Matm / Bcor) / (L * g1²)
= (1.1782*99325/1206.0)/(2.1905*20.0²)
= 110.71 N./mm^2

Radial Flange Stress, Operating [SRo]:
= (Beta * Mop / Bcor) / (L * t²)
= (2.0214*132023/1206.0)/(2.1905*107.0²)
= 8.82 N./mm^2

Radial Flange Stress, Seating [SRa]:
= (Beta * Matm/Bcor) / (L * t²)
= (2.0214*99325/1206.0)/(2.1905*107.0²)
= 6.64 N./mm^2

Tangential Flange Stress, Operating [STo]:
= (Y * Mo / (t² * Bcor)) - Z * SRo
= (16.1715*132023/(107.0²*1206.0))-8.3612*9
= 80.83 N./mm^2

Tangential Flange Stress, Seating [STa]:
= (y * Matm / (t² * Bcor)) - Z * SRa
= (16.1715*99325/(107.0²*1206.0))-8.3612*7
= 60.81 N./mm^2

Average Flange Stress, Operating [SAo]:
= (SHo + max(SRo, STo)) / 2
= (147+max(9,81))/2
= 113.99 N./mm^2

Average Flange Stress, Seating [SAa]:
= (SHa + max(SRa, STa)) / 2
= (111+max(7,61))/2
= 85.76 N./mm^2

Bolt Stress, Operating [BSo]:
= Wm1 / Ab
= 3271/194.6319
= 168.09 N./mm^2

Bolt Stress, Seating [BSa]:
= (Wm2 / Ab)
= (2158/194.6319)
= 110.86 N./mm^2

Flange Stress Analysis Results: N./mm^2

	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed

Longitudinal Hub	147.	207.	111.	207.
Radial Flange	9.	138.	7.	138.
Tangential Flange	81.	138.	61.	138.
Maximum Average	114.	138.	86.	138.
Bolting	168.	172.	111.	172.

Minimum Required Flange Thickness [Rigidity]	107.798	mm.
Estimated M.A.W.P. (Operating)	23.707	bars
Estimated Finished Weight of Flange at given Thk.	299.6	kg.
Estimated Unfinished Weight of Forging at given Thk	386.5	kg.

Flange Rigidity Based on Required Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
= 52.14 * Ma / Bsc * Cnv_fac * V / (Lambda * Eamb * go^2 * ho * Ki)
= 52.14 * 99325.1/1.0 * 999.68 * 0.313/(2.107 * 202713 * 12.0^2 * 120.3 * 0.3)
= 0.730 (should be <= 1)

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:
= 52.14 * Mo / Bsc * Cnv_fac * V / (Lambda * Eop * goc^2 * ho * Ki)
= 52.14 * 132023.1/1.0 * 999.68 * 0.313/(2.107 * 196612 * 12.0^2 * 120.3 * 0.3)
= 1.000 (should be <= 1)

Flange Rigidity Based on Given Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
= 52.14 * Ma / Bsc * Cnv_fac * V / (Lambda * Eamb * go^2 * ho * Ki)
= 52.14 * 99325.1/1.0 * 999.68 * 0.313/(2.191 * 202713 * 12.0^2 * 120.3 * 0.3)
= 0.702 (should be <= 1)

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:
= 52.14 * Mo / Bsc * Cnv_fac * V / (Lambda * Eop * goc^2 * ho * Ki)
= 52.14 * 132023.1/1.0 * 999.68 * 0.313/(2.191 * 196612 * 12.0^2 * 120.3 * 0.3)
= 0.962 (should be <= 1)

Minimum Design Metal Temperature Results:

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

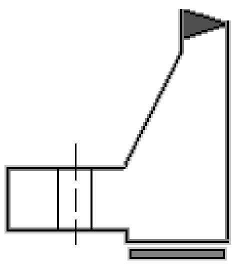
Impact Test Temperature provided per Specification -46 °C

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

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

body flange 02

Description of Flange Geometry (Type)		Integral Weld Neck	
Design Pressure	P	23.12	bars
Design Temperature		125	°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	1200.000	mm.
Flange Outside Diameter	A	1360.000	mm.
Flange Thickness	t	110.0000	mm.
Thickness of Hub at Small End	go	18.0000	mm.
Thickness of Hub at Large End	g1	23.0000	mm.
Length of Hub	h	45.0000	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	1310.000	mm.
Nominal Bolt Diameter	a	22.2250	mm.
Type of Threads		TEMA Thread Series	
Number of Bolts		72	
Flange Face Outside Diameter	Fod	1269.000	mm.
Flange Face Inside Diameter	Fid	1200.000	mm.
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	1266.000	mm.
Gasket Inside Diameter	Gi	1226.000	mm.
Gasket Factor	m	3.0000	
Gasket Design Seating Stress	y	68.95	N./mm^2
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	3.0000	mm.



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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)
  = (23.12*(1200.0/2+3.0))/(137.9*1.0-0.6*23.12)+Ca

```
  = 13.2120 mm.
```

Hub Small End Hub MAWP:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9 * 1.0 * 15.0)/(603.0 + 0.6 * 15.0 )
  = 33.797 bars

 Corroded Flange Thickness, tc = T-ci                     107.000  mm.
 Corroded Flange ID,      Bcor = B+2*Fcor                1206.000  mm.
 Corroded Large Hub,     g1Cor = g1-ci                     20.000  mm.
 Corroded Small Hub,     g0Cor = go-ci                     15.000  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              1250.063  mm.
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.785 * 1250.0626² * 23.118
  = 2837.167 kN
```
Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * Pi * G * m * P
  = 2 * 7.9687 * 3.1416 * 1250.0626 * 3.0 * 23.12
  = 434.062 kN
```
Hydrostatic End Load at Flange ID [Hd]:
```
  = Pi * Bcor² * P  / 4
  = 3.1416 * 1206.0² *23.1176/4
  = 2640.681 kN
```
Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 2837 - 2641
  = 196.486 kN
```
Operating Bolt Load [Wm1]:
```
  = max( H + Hp + H'p, 0 )
  = max( 2837 + 434 + 0, 0 )
  = 3271.229 kN
```
Gasket Seating Bolt Load [Wm2]:
```
  = y * b * Pi * G  + yPart * bPart * lp
  = 68.95*7.9687*3.141*1250.063+0.0*0.0*0.0
  = 2157.577 kN
```
Required Bolt Area [Am]:
```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 3271/172, 2158/172
  = 189.790 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/(3.0 + 0.5)
  = 227.879 mm.
```

Actual Circumferential Bolt Spacing [Bs]:
```
  = C * sin( pi / n )
  = 1310.0 * sin( 3.142/72 )
  = 57.141 mm.
```

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

```
  = max( sqrt( 57.141/( 2 * 22.225 + 107.0 )), 1 )
  = 1.0000
```

Bolting Information for TEMA Imperial Thread Series (Non Mandatory):

	Minimum	Actual	Maximum
Bolt Area, cm^2	189.790	194.632	
Radial Distance between Hub and Bolts:	31.750	32.000	
Radial Distance between Bolts and Edge:	23.812	25.000	
Circ. Spacing between the Bolts:	52.400	57.141	227.879

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

```
  = Ab * Sa/( y * Pi * (Go + Gi) )
  = 194.632 * 172.38/(68.95 * 3.14 * (1266.0 + 1226.0) )
  = 6.215 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 * ( 189.7901 + 194.6319 )/2
  = 3312.96 kN
```

Gasket Load for the Operating Condition [HG]:

```
  = Wm1 - H
  = 3271 - 2837
  = 434.06 kN
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
  = (C - G ) / 2
  = ( 1310.0 - 1250.0626 )/2
  = 29.9687 mm.
```

Distance to Face Pressure Reaction [ht]:

```
  = ( R + g1 + hg ) / 2
  = ( 32.0 + 20.0 + 29.9687 )/2
  = 40.9843 mm.
```

Distance to End Pressure Reaction [hd]:

```
  = R + ( g1 / 2 )
  = 32.0 + ( 20.0/2.0 )
  = 42.0000 mm.
```

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

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	2641.	42.0000	1.0000	110954.
Face Pressure,	Mt	196.	40.9843	1.0000	8056.
Gasket Load,	Mg	434.	29.9687	1.0000	13014.
Gasket Seating,	Matm	3313.	29.9687	1.0000	99325.

```
 Total Moment for Operation,      Mop                            132023. N-m
 Total Moment for Gasket seating, Matm                            99325. N-m

 Effective Hub Length, ho = sqrt(Bcor*goCor)          134.499  mm.
 Hub Ratio,           h/h0 = HL / H0                    0.335
 Thickness Ratio,    g1/g0 = (g1Cor/goCor)              1.333
```

Flange Factors for Integral Flange:

```
 Factor F                                                  0.881
 Factor V                                                  0.400
 Factor f                                                  1.000
 Factors from Figure 2-7.1                         K =     1.128
                    T =      1.867                 U =    17.771
                    Y =     16.171                 Z =     8.361
                    d = 0.13452E+07 mm.³            e =     0.0066 mm.^-1
 Stress Factors                                ALPHA =     1.701
                 BETA =      1.935             GAMMA =     0.911
                DELTA =      0.911             Lamda =     1.822
```

Longitudinal Hub Stress, Operating [SHo]:
```
  = ( f * Mop / Bcor ) / ( L * g1² )
  = (1.0*132023/1206.0)/(1.8218*20.0²)
  = 150.18 N./mm^2
```
Longitudinal Hub Stress, Seating [SHa]:
```
  = ( f * Matm / Bcor ) / ( L * g1² )
  = (1.0*99325/1206.0)/(1.8218*20.0²)
  = 112.98 N./mm^2
```

Radial Flange Stress, Operating [SRo]:
```
  = ( Beta * Mop / Bcor ) / ( L * t² )
  = (1.9349*132023/1206.0)/(1.8218*107.0²)
  = 10.15 N./mm^2
```
Radial Flange Stress, Seating [SRa]:
```
  = ( Beta * Matm/Bcor ) / ( L * t² )
  = (1.9349*99325/1206.0)/(1.8218*107.0²)
  = 7.64 N./mm^2
```

Tangential Flange Stress, Operating [STo]:
```
  = ( Y * Mo / (t² * Bcor) ) - Z * SRo
  = (16.1715*132023/(107.0²*1206.0))-8.3612*10
  = 69.69 N./mm^2
```
Tangential Flange Stress, Seating [STa]:
```
  = ( y * Matm / (t² * Bcor) ) - Z * SRa
  = (16.1715*99325/(107.0²*1206.0))-8.3612*8
  = 52.43 N./mm^2
```

Average Flange Stress, Operating [SAo]:
```
  = ( SHo + max( SRo, STo ) ) / 2
  = (150+max(10,70))/2
  = 109.93 N./mm^2
```
Average Flange Stress, Seating [SAa]:
```
  = ( SHa + max( SRa, STa ) ) / 2
  = (113+max(8,52))/2
  = 82.71 N./mm^2
```

Bolt Stress, Operating [BSo]:
```
  = Wm1 / Ab
  = 3271/194.6319
  = 168.09 N./mm^2
```
Bolt Stress, Seating [BSa]:
```
  = ( Wm2 / Ab )
  = (2158/194.6319)
  = 110.86 N./mm^2
```

Flange Stress Analysis Results: N./mm^2

```
                              Operating |      Gasket Seating |
                       Actual    Allowed |   Actual    Allowed |
 -----------------------------------------------------------------
```

Longitudinal Hub	150.	207.	113.	207.
Radial Flange	10.	138.	8.	138.
Tangential Flange	70.	138.	52.	138.
Maximum Average	110.	138.	83.	138.
Bolting	168.	172.	111.	172.

Minimum Required Flange Thickness [Rigidity]	99.466	mm.
Estimated M.A.W.P. (Operating)	23.707	bars
Estimated Finished Weight of Flange at given Thk.	301.7	kg.
Estimated Unfinished Weight of Forging at given Thk	386.5	kg.

Flange Rigidity Based on Required Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
= 52.14 * Ma / Bsc * Cnv_fac * V / (Lambda * Eamb * go^2 * ho * Ki)
= 52.14 * 99325.1/1.0 * 999.68 * 0.4/(1.541 * 202713 *
15.0^2 * 134.499 * 0.3)
= 0.730 (should be <= 1)

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:
= 52.14 * Mo / Bsc * Cnv_fac * V / (Lambda * Eop * goc^2 * ho * Ki)
= 52.14 * 132023.1/1.0 * 999.68 * 0.4/(1.541 * 196612
* 15.0^2 * 134.499 * 0.3)
= 1.000 (should be <= 1)

Flange Rigidity Based on Given Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
= 52.14 * Ma / Bsc * Cnv_fac * V / (Lambda * Eamb * go^2 * ho * Ki)
= 52.14 * 99325.1/1.0 * 999.68 * 0.4/(1.822 * 202713 *
15.0^2 * 134.499 * 0.3)
= 0.617 (should be <= 1)

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:
= 52.14 * Mo / Bsc * Cnv_fac * V / (Lambda * Eop * goc^2 * ho * Ki)
= 52.14 * 132023.1/1.0 * 999.68 * 0.4/(1.822 * 196612
* 15.0^2 * 134.499 * 0.3)
= 0.846 (should be <= 1)

Minimum Design Metal Temperature Results:

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

Impact Test Temperature provided per Specification -46 °C

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

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601 ------
Internal Pressure Calculations: Step: 7 11:47am Dec 23,2021

Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd bars	Nominal Thickness mm.	Total Corr Allowance mm.	Element Diameter mm.	Allowable Stress(SE) N./mm^2
HEAD 001		23.118	18	3	1200	137.9
SHELL 001		23.118	15	3	1200	137.9
BODY FLANGE 001		23.118	60	3	1200	137.9
body flange 02		23.118	60	3	1200	137.9
SHELL 002		23.118	20	3	1200	137.9
CON		23.118	20	3	1656	137.9
SHELL 002		23.118	18	3	1656	137.9
HEAD 002		23.118	20	3	1656	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 001		23	27.4499	34.387	15	13.0597
SHELL 001		23	26.9995	33.9635	15	13.2122
BODY FLANGE 001		23	23.5895	23.7071	110	107.798
body flange 02		23	23.5895	23.7071	110	99.4664
SHELL 002		23	38.1104	45.0627	20	13.2122
CON		23	24.33	28.8256	20	19.0657
SHELL 002		23	24.5056	29.5906	18	17.0735
HEAD 002		23	23.1853	28.2531	17	16.8885

Summary of Heat Exchanger Maximum Allowable Working Pressures :

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

```
Shell Side MAWP      =     23.589 bars
Shell Side MAPnc     =     23.707 bars
Channel Side  MAWP   =     23.161 bars  Governed by Cone Junction
Channel Side  MAPnc  =     23.707 bars
```

<u>Internal Pressure Calculation Results :</u>

ASME Code, Section VIII Division 1, 2017

<u>Elliptical Head From 10 To 20 SA-516 70 at 125 °C</u>

HEAD 001

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
```
  = (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
  = (23.118*1206.0*0.993)/(2*137.9*1.0-0.2*23.118)
  = 10.0597 + 3.0000 = 13.0597 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.118 bars

```
  = (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
  = (2*137.9*1.0*12.0)/(0.993*1206.0+0.2*12.0)
  = 27.568 - 0.118 = 27.450  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
  = (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
  = (2*137.9*1.0*15.0)/(1.0*1200.0+0.2*15.0)
  = 34.387 bars
```

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

```
  = (P*(Kcor*D+0.2*t))/(2*E*t)
  = (23.118*(0.993*1206.0+0.2*12.0))/(2*1.0*12.0)
  = 115.641 N./mm^2
```

Straight Flange Required Thickness:

```
  = (P*R)/(S*E-0.6*P) + c    per UG-27 (c)(1)
  = (23.118*603.0)/(137.9*1.0-0.6*23.118)+3.0
  = 13.212 mm.
```

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.118 bars

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9 * 1.0 * 15.0)/(603.0 + 0.6 * 15.0 )
  = 33.797 - 0.118 = 33.679  bars
```

Factor K, corroded condition [Kcor]:

```
  = ( 2 + ( Inside Diameter/( 2 * Inside Head Depth ))²)/6
  = ( 2 + ( 1206.0/( 2 * 303.0 ))²)/6
  = 0.993416
```

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 6.338 %
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

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

MDMT Calculations in the Head Straight Flange:

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

Cylindrical Shell From 20 To 30 SA-516 70 at 125 °C

SHELL 001

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (23.118*603.0)/(137.9*1.0-0.6*23.118)
  = 10.2122 + 3.0000 = 13.2122 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.118 bars

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9*1.0*12.0)/(603.0+0.6*12.0)
  = 27.117 - 0.118 = 26.999  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9*1.0*15.0)/(600.0+0.6*15.0)
  = 33.964 bars
```

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

```
  = (P*(R+0.6*t))/(E*t)
  = (23.118*(603.0+0.6*12.0))/(1.0*12.0)
  = 117.561 N./mm^2
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.235 %

Minimum Design Metal Temperature Results:

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

Cylindrical Shell From 50 To 60 SA-516 70 at 125 °C

SHELL 002

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (23.118*603.0)/(137.9*1.0-0.6*23.118)
  = 10.2122 + 3.0000 = 13.2122 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.118 bars

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9*1.0*17.0)/(603.0+0.6*17.0)
  = 38.228 - 0.118 = 38.110  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9*1.0*20.0)/(600.0+0.6*20.0)
  = 45.063 bars
```

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

```
  = (P*(R+0.6*t))/(E*t)
  = (23.118*(603.0+0.6*17.0))/(1.0*17.0)
  = 83.393 N./mm^2
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.639 %

Minimum Design Metal Temperature Results:

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

Conical Section From 60 To 70 SA-516 70 at 125 °C

CON

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
```
  = (P*D)/(2*cos(a)*(S*E-0.6*P)) per Appendix 1-4 (e)
  = (23.118*1662.8459)/(2*0.8764*(137.9*1.0-0.6*23.118))
  = 16.0657 + 3.0000 = 19.0657 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.118 bars
```
  = (2*S*E*t*cos(a))/(D+1.2*t*cos(a)) per App 1-4(e)
  = (2*137.9*1.0*17.0*0.876)/(1662.846+1.2*17.0*0.876)
  = 24.448 - 0.118 = 24.330  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (2*S*E*t*cos(a))/(D+1.2*t*cos(a)) per App 1-4(e)
  = (2*137.9*1.0*20.0*0.8764)/(1656.0+1.2*20.0*0.8764)
  = 28.826 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(D+1.2*t*cos(a)))/(2*E*t*cos(a))
  = (23.118*(1662.8459+1.2*17.0*0.8764))/(2*1.0*17.0*0.8764)
  = 130.398 N./mm^2
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.636 %

Minimum Design Metal Temperature Results:

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

Cylindrical Shell From 70 To 80 SA-516 70 at 125 °C

SHELL 002

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (23.118*831.0)/(137.9*1.0-0.6*23.118)
  = 14.0735 + 3.0000 = 17.0735 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.118 bars
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9*1.0*15.0)/(831.0+0.6*15.0)
  = 24.624 - 0.118 = 24.506  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9*1.0*18.0)/(828.0+0.6*18.0)
  = 29.591 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(R+0.6*t))/(E*t)
  = (23.118*(831.0+0.6*15.0))/(1.0*15.0)
  = 129.468 N./mm^2
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.075 %

Minimum Design Metal Temperature Results:

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

Elliptical Head From 80 To 90 SA-516 70 at 125 °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)
  = (23.118*1662.0*0.995)/(2*137.9*1.0-0.2*23.118)
  = 13.8885 + 3.0000 = 16.8885 mm.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 0.118 bars
```
  = (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
  = (2*137.9*1.0*14.0)/(0.995*1662.0+0.2*14.0)
  = 23.303 - 0.118 = 23.185  bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
  = (2*137.9*1.0*17.0)/(1.0*1656.0+0.2*17.0)
  = 28.253 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(Kcor*D+0.2*t))/(2*E*t)
  = (23.118*(0.995*1662.0+0.2*14.0))/(2*1.0*14.0)
  = 136.804 N./mm^2
```

Straight Flange Required Thickness:
```
  = (P*R)/(S*E-0.6*P) + c    per UG-27 (c)(1)
  = (23.118*831.0)/(137.9*1.0-0.6*23.118)+3.0
  = 17.073 mm.
```

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 0.118 bars
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9 * 1.0 * 17.0)/(831.0 + 0.6 * 17.0 )
  = 27.867 - 0.118 = 27.749  bars
```

Factor K, corroded condition [Kcor]:
```
  = ( 2 + ( Inside Diameter/( 2 * Inside Head Depth ))²)/6
  = ( 2 + ( 1662.0/( 2 * 417.0 ))²)/6
  = 0.995212
```

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 5.145 %
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

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

MDMT Calculations in the Head Straight Flange:

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DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601 ------
Internal Pressure Calculations: Step: 7 11:47am Dec 23,2021

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

Hydrostatic Test Pressure Results:

Exchanger Shell Side Hydrostatic Test Pressures:

```
Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S          30.666  bars
Pressure per UG99b[36] = 1.30 * Design Pres * Sa/S       29.900  bars
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)       30.657  bars
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S          25.948  bars
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)     32.890  bars
Pressure per App 27-4  = M.A.W.P.                        23.589  bars
```

Exchanger Channel Side Hydrostatic Test Pressures:

```
Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S          30.109  bars
Pressure per UG99b[36] = 1.30 * Design Pres * Sa/S       29.900  bars
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)       30.657  bars
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S          25.477  bars
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)     32.890  bars
Pressure per App 27-4  = M.A.W.P.                        23.161  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 001	150.2	235.8	0.637	30.02
SHELL 001	152.6	235.8	0.647	30.02
SHELL 002	108.3	235.8	0.459	30.02
CON	169.6	235.8	0.719	30.06
SHELL 002	168.4	235.8	0.714	30.06
HEAD 002	177.9	235.8	0.754	30.06

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

Description	Pad/Nozzle	Ambient	Operating	Ratio
T2	Nozzle	137.90	137.90	1.000
T2	Pad	137.90	137.90	1.000
T1	Nozzle	137.90	137.90	1.000
T1	Pad	137.90	137.90	1.000
D4	Nozzle	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
D2	Nozzle	137.90	137.90	1.000
D1	Nozzle	137.90	137.90	1.000
D3	Nozzle	137.90	137.90	1.000
TT	Nozzle	137.90	137.90	1.000
V	Nozzle	137.90	137.90	1.000
S4	Nozzle	117.90	117.90	1.000
S4	Pad	137.90	137.90	1.000
LG1	Nozzle	137.90	137.90	1.000
LG2	Nozzle	137.90	137.90	1.000
LT1	Nozzle	137.90	137.90	1.000
LT3	Nozzle	137.90	137.90	1.000
LT2	Nozzle	137.90	137.90	1.000
LT4	Nozzle	137.90	137.90	1.000
Minimum				1.000

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

Description	Ambient	Operating	Ratio
HEAD 001	137.90	137.90	1.000
SHELL 001	137.90	137.90	1.000
BODY FLANGE 001	137.90	137.90	1.000
body flange 02	137.90	137.90	1.000
SHELL 002	137.90	137.90	1.000
CON	137.90	137.90	1.000
SHELL 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
T2	43.65	235.80	0.185
T1	43.65	235.80	0.185
D4	8.08	223.40	0.036
S2	39.39	217.19	0.181
S1	39.39	217.19	0.181
S3	39.39	217.19	0.181
D2	8.08	223.40	0.036
D1	8.08	223.40	0.036
D3	8.08	223.40	0.036
TT	8.08	223.40	0.036
V	8.08	223.40	0.036
S4	39.39	217.19	0.181
LG1	8.08	223.40	0.036

LG2	8.08	223.40	0.036
LT1	18.32	223.40	0.082
LT3	18.32	223.40	0.082
LT2	18.32	223.40	0.082
LT4	18.32	223.40	0.082

Elements Suitable for Internal Pressure.

```
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External Pressure Calculations:       Step:    8  11:47am  Dec 23,2021
```

External Pressure Calculation Results :

External Pressure Calculations:

From	To	Section Length mm.	Outside Diameter mm.	Corroded Thickness mm.	Factor A	Factor B N./mm^2
10	20	No Calc	1230	12	0.001355	94.0922
20	30	950	1230	12	0.001708	100.056
30	40	No Calc	...	107	No Calc	No Calc
40	50	No Calc	...	107	No Calc	No Calc
50	60	5218	1240	17	0.00046617	46.6065
60	70	5218	1696	17	0.00040569	40.5597
70	80	5218	1692	15	0.00034124	34.1167
80	90	No Calc	1690	14	0.0011506	89.495

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	15	6.18473	1.03419	10.1991
20	30	15	6.52984	1.03419	13.0146
30	40	110	79.2734	1.03419	No Calc
40	50	110	65.4558	1.03419	No Calc
50	60	20	10.2323	1.03419	8.51898
60	70	20	11.6968	1.03419	5.4204
70	80	18	11.6842	1.03419	4.03247
80	90	17	7.37574	1.03419	8.23707
Minimum					4.032

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	950	20495	No Calc	No Calc
30	40	No Calc	No Calc	No Calc	No Calc
40	50	No Calc	No Calc	No Calc	No Calc
50	60	5218	112034	No Calc	No Calc
60	70	5218	115500	No Calc	No Calc
70	80	5218	46275.1	No Calc	No Calc
80	90	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

ASME Code, Section VIII Division 1, 2017

Elliptical Head From 10 to 20 Ext. Chart: CS-2 at 125 °C

HEAD 001

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

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External Pressure Calculations: Step: 8 11:47am Dec 23,2021

Results for Maximum Allowable External Pressure (MAEP):
```
     Tca          OD          D/t     Factor A           B
  12.000     1230.00      102.50    0.0013550       94.09
 EMAP = B/(K0*D/t) = 94.0922/( 0.9 *102.5 ) = 10.1991 bars
```

Results for Required Thickness (Tca):
```
     Tca          OD          D/t     Factor A           B
   3.185     1230.00      386.22    0.0003596       35.95
 EMAP = B/(K0*D/t) = 35.9532/( 0.9 *386.2177 ) = 1.0343 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)
  = (1.727*1206.0*0.993)/(2*137.9*1.0-0.2*1.727)
  = 0.7504 + 3.0000 = 3.7504 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*12.0)/(0.993*1206.0+0.2*12.0))/1.67
  = 16.508 bars
```

Maximum Allowable External Pressure [MAEP]:
```
  = min( MAEP, MAWP )
  = min( 10.2, 16.5077 )
  = 10.199 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 125 °C

SHELL 001

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     1230.00      950.00     102.50     0.7724   0.0017080   100.06
 EMAP = (4*B)/(3*(D/t)) = (4*100.0556)/(3*102.5) = 13.0146 bars
```

Results for Required Thickness (Tca):
```
     Tca          OD        SLEN        D/t        L/D    Factor A        B
   3.530     1230.00      950.00     348.46     0.7724   0.0002704    27.03
 EMAP = (4*B)/(3*(D/t)) = (4*27.0303)/(3*348.4581) = 1.0342 bars
```

Results for Maximum Stiffened Length (Slen):
```
     Tca          OD        SLEN        D/t        L/D    Factor A        B
  12.000     1230.00    20495.01     102.50    16.6626   0.0001081    10.81
 EMAP = (4*B)/(3*(D/t)) = (4*10.8077)/(3*102.5) = 1.4058 bars
```

Cylindrical Shell From 50 to 60 Ext. Chart: CS-2 at 125 °C

SHELL 002

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
17.000	1240.00	5218.00	72.94	4.2081	0.0004662	46.61

EMAP = (4*B)/(3*(D/t)) = (4*46.6065)/(3*72.9412) = 8.519 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
7.232	1240.00	5218.00	171.45	4.2081	0.0001330	13.30

EMAP = (4*B)/(3*(D/t)) = (4*13.3003)/(3*171.4528) = 1.0343 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
17.000	1240.00	112033.63	72.94	50.0000	0.0002131	21.31

EMAP = (4*B)/(3*(D/t)) = (4*21.3074)/(3*72.9412) = 3.8947 bars

Cylindrical Shell From 60 to 70 Ext. Chart: CS-2 at 125 °C

CON

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
17.000	1696.00	5218.00	99.76	3.0767	0.0004057	40.56

EMAP = (4*B)/(3*(D/t)) = (4*40.5597)/(3*99.7647) = 5.4204 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
8.697	1696.00	5218.00	195.01	3.0767	0.0001513	15.13

EMAP = (4*B)/(3*(D/t)) = (4*15.1274)/(3*195.0137) = 1.0342 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
17.000	1696.00	115500.43	99.76	50.0000	0.0001106	11.06

EMAP = (4*B)/(3*(D/t)) = (4*11.06)/(3*99.7647) = 1.4781 bars

Cylindrical Shell From 70 to 80 Ext. Chart: CS-2 at 125 °C

SHELL 002

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
15.000	1692.00	5218.00	112.80	3.0839	0.0003412	34.12

EMAP = (4*B)/(3*(D/t)) = (4*34.1167)/(3*112.8) = 4.0325 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
8.684	1692.00	5218.00	194.84	3.0839	0.0001512	15.11

EMAP = (4*B)/(3*(D/t)) = (4*15.1136)/(3*194.8375) = 1.0342 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
15.000	1692.00	46275.10	112.80	27.3493	0.0000884	8.84

EMAP = (4*B)/(3*(D/t)) = (4*8.8357)/(3*112.8) = 1.0444 bars

Elliptical Head From 80 to 90 Ext. Chart: CS-2 at 125 °C

HEAD 002

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

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	D/t	Factor A	B
14.000	1690.00	120.71	0.0011506	89.50

```
EMAP = B/(K0*D/t) = 89.495/( 0.9 *120.7143 ) = 8.2371 bars
```

Results for Required Thickness (Tca):

Tca	OD	D/t	Factor A	B
4.376	1690.00	386.22	0.0003596	35.95

```
EMAP = B/(K0*D/t) = 35.9529/( 0.9 *386.2208 ) = 1.0343 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)
= (1.727*1662.0*0.995)/(2*137.9*1.0-0.2*1.727)
= 1.0360 + 3.0000 = 4.0360 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*14.0)/(0.995*1662.0+0.2*14.0))/1.67
= 13.954 bars
```

Maximum Allowable External Pressure [MAEP]:

```
= min( MAEP, MAWP )
= min( 8.24, 13.954 )
= 8.237 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	274.398	282794	228.665	286772	54.8796
20	30	355.008	904941	284.707	914013	71.0015
30	40	299.644	176580	286.023	177090	59.9288
40	50	301.681	176580	288.06	177090	60.3362
50	60	118.823	127029	101.247	129297	23.7645
60	70	669.082	1340840	570.06	1353618	133.816
70	80	2934.72	8616848	2449.98	8679401	586.944
80	90	561.942	702273	477.651	709541	112.388
Total		5515	12327886.00	4686	12426824.00	1103

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	282.621	-100	0.36335E-04	1
20	Liqd	904.389	400	...	2
20	Nozl	366.74	400	854	T2
20	Nozl	366.74	400	854	T1
30	Liqd	176.472	77.5	...	3
40	Liqd	176.472	77.5	...	4
50	Sadl	212.848	200	770	Lft Sdl
50	Liqd	126.952	100	...	5
60	Liqd	1089.66	415	114	Liquid: 60
60	Nozl	12.4214	400	853.4	D4
70	Sadl	282.608	3500	999	Lft Sdl
70	Liqd	6683.29	2000	228	Liquid: 70
70	Nozl	105.134	200	937.537	S2
70	Nozl	105.134	2800	937.537	S1
70	Nozl	105.134	600	937.537	S3
70	Nozl	12.4214	600	853.4	D2
70	Nozl	12.4214	2400	853.4	D1
70	Nozl	12.4214	3200	853.4	D3
70	Nozl	12.4214	3800	853.4	TT
70	Nozl	12.4214	200	853.4	V
70	Nozl	105.134	2800	937.537	S4
70	Nozl	12.4214	2200	853.4	LG1
70	Nozl	12.4214	2200	853.4	LG2
70	Nozl	27.2525	1000	858.162	LT1
70	Nozl	27.2525	1500	858.162	LT3
70	Nozl	27.2525	1000	858.162	LT2
70	Nozl	27.2525	1500	858.162	LT4
80	Liqd	571.502	188	228	Liquid: 80
30	FTsh	1245.75	231	...	TUBE SHEET
30	Tube	8758.45	2261	...	

Total Weight of Each Detail Type:

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Element and Detail Weights: Step: 9 11:47am Dec 23,2021

Saddles	495.5
Liquid	10011.4
Nozzles	1362.4
Exchanger Components	10004.2
Liquid in Tubes	1550.0
Sum of the Detail Weights	23423.4 kg.

Weight Summation Results: (kg.)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	6618.4	6618.4	6618.4	6618.4	6618.4	6618.4
Saddles	495.5	495.5	495.5	495.5	495.5	495.5
Nozzles	1362.4	1362.4	1362.4	1362.4	1362.4	1362.4
Exchanger	10004.2	10004.2	10004.2	10004.2	10004.2	10004.2
Ope. Liquid	...	...	...	...	...	10011.4
Tube Ope Lqd	...	...	...	...	...	1550.0
Test Liquid	...	12320.4	...	...	...	...
Tube Tst Lqd	...	1550.0	...	...	...	...
Totals	18480.4	32350.8	18480.4	18480.4	18480.4	30041.8

Miscellaneous Weight Percent: 20.0 %

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	18480.4 kg.
Shop Test Wt.	- Fabricated Weight + Water (Full)	32350.8 kg.
Shipping Wt.	- Fab. Weight + removable Intls.+ Shipping App.	18480.4 kg.
Erected Wt.	- Fab. Wt + or - loose items (trays,platforms etc.)	18480.4 kg.
Ope. Wt. no Liq	- Fab. Weight + Internals. + Details + Weights	18480.4 kg.
Operating Wt.	- Empty Weight + Operating Liq. Uncorroded	30041.8 kg.
Oper. Wt. + CA	- Corr Wt. + Operating Liquid	29047.1 kg.
Field Test Wt.	- Empty Weight + Water (Full)	31455.0 kg.

Exchanger Tube Data

Volume of Exchanger tubes :	1550960.2 Cm3
Weight of Ope Liq in tubes :	1550.0 kg.
Weight of Water in tubes :	1550.0 kg.

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

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

Outside Surface Areas of Elements:

From	To	Surface Area cm^2
10	20	18501.5
20	30	30913.3
30	40	9678.31
40	50	9678.31

```
    50|  60|        7791.15 |
    60|  70|        39848.9 |
    70|  80|         212623 |
    80|  90|          33844 |
 ---------------------------
   Total       362878.469 cm^2
```

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Nozzle Flange MAWP: Step: 10 11:47am Dec 23,2021

Nozzle Flange MAWP Results:

Nozzle Description	Flange Rating Ope. bars	Ambient bars	Design Temp °C	Class	Grade/ Group	Equiv. Press	- - - - - - Max Pressure PVP	50%	DNV bars
T2	45.85	51.10	125	300	GR 1.1	...	...	...	...
T1	45.85	51.10	125	300	GR 1.1	...	...	...	...
D4	45.85	51.10	125	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	...	...	...	...
D2	45.85	51.10	125	300	GR 1.1	...	...	...	...
D1	45.85	51.10	125	300	GR 1.1	...	...	...	...
D3	45.85	51.10	125	300	GR 1.1	...	...	...	...
TT	45.85	51.10	125	300	GR 1.1	...	...	...	...
V	45.85	51.10	125	300	GR 1.1	...	...	...	...
S4	45.85	51.10	125	300	GR 1.1	...	...	...	...
LG1	45.85	51.10	125	300	GR 1.1	...	...	...	...
LG2	45.85	51.10	125	300	GR 1.1	...	...	...	...
LT1	45.85	51.10	125	300	GR 1.1	...	...	...	...
LT3	45.85	51.10	125	300	GR 1.1	...	...	...	...
LT2	45.85	51.10	125	300	GR 1.1	...	...	...	...
LT4	45.85	51.10	125	300	GR 1.1	...	...	...	...

Shellside Flange Rating

Channelside Flange Rating
Lowest Flange Pressure Rating was (Ope)[TubeSide]: 45.850 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

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Wind Load Calculation: Step: 11 11:47am Dec 23,2021

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] 0.559
Structure Height to Diameter ratio                       4.521
```

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
  = 1200.0 + 123000. = 124200.008 mm.
  = 407.48 ft. Imperial Units
```

Velocity Pressure coefficient evaluated at height z [Kz]:

  Because z (407.48 ft.) > 15 ft.
  $= 2.01 * (z / Zg)^{2 / Alpha}$
  $= 2.01 * (407.48/900.0)^{2/9.5}$
  = 1.701

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]:
$= \max(16, 0.00256 * Kz * Kzt * Kd * V(mph)^2)$
$= \max(16, 0.00256 * 1.701 * 1.0 * 0.95 * 121.171^2)$
= 60.7 psf [296.584] Kgs/m^2

Force on the first element [F]:
= qz * G * Cf * WindArea
= 60.744 * 0.85 * 0.559 * 4.07
= 117.4 lbs. [0.5] kN

Element	Hgt (z) mm.	K1	K2	K3	Kz	Kzt	qz Kgs/m^2
HEAD 001	*******	0.000	0.000	0.000	1.701	1.000	296.584
SHELL 001	*******	0.000	0.000	0.000	1.701	1.000	296.584
BODY FLANGE 001	*******	0.000	0.000	0.000	1.701	1.000	296.584
body flange 02	*******	0.000	0.000	0.000	1.701	1.000	296.584
SHELL 002	*******	0.000	0.000	0.000	1.701	1.000	296.584
CON	*******	0.000	0.000	0.000	1.701	1.000	296.584
SHELL 002	*******	0.000	0.000	0.000	1.701	1.000	296.584
HEAD 002	*******	0.000	0.000	0.000	1.701	1.000	296.584

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	124200	1476	3781.03	296.584	0.31332
20	30	124200	1476	11808	296.584	0.97847
30	40	124200	1440	2232	296.584	0.18495
40	50	124200	1440	2232	296.584	0.18495
50	60	124200	1488	2976	296.584	0.24661
60	70	124200	1761.6	14621.3	296.584	1.21159
70	80	124200	2030.4	81216	296.584	6.72997
80	90	124200	2028	6734.76	296.584	0.55808

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	1.000
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 * ($6.6535^{0.75}$)
= 0.083 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 * 0.083, 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 * 285 * 1.5
= 99.379 kN

Final Base Shear, V = 69.57 kN

Earthquake Load Calculation:

From	To	Earthquake Height mm.	Earthquake Weight kN	Element Ope Load kN
10	20	600	28.4836	6.24465

20	30	600	28.4836	6.24465
30	40	600	28.4836	6.24465
40	50	600	28.4836	6.24465
50	60	600	28.4836	6.24465
50	60	600	28.4836	6.24465
60	70	600	28.4836	6.24465
70	0	828	28.4836	8.61762
70	80	828	28.4836	8.61762
80	90	828	28.4836	8.61762

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	3985.356 mm.
Center of Gravity of Liquid	3577.988 mm.
Center of Gravity of Nozzles	2048.109 mm.
Center of Gravity of Tubesheet(s)	1081.000 mm.
Center of Gravity of Tubes	3111.000 mm.
Center of Gravity of Bare Shell New and Cold	3392.189 mm.
Center of Gravity of Bare Shell Corroded	3365.749 mm.
Vessel CG in the Operating Condition	3199.273 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition	3019.945 mm.
Vessel CG in the Test Condition	3283.736 mm.

```
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601    ------
Horizontal Vessel Analysis (Ope.):    Step:   14  11:47am  Dec 23,2021
```

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

*Warning - Distance to Saddle (a) > 0.25 * Tangent Distance (L) - 4.15.3.2*

Input and Calculated Values:

```
 Vessel Mean Radius                              Rm      611.50  mm.
 Stiffened Vessel Length per 4.15.6               L      355.00  mm.
 Distance from Saddle to Vessel tangent           a      352.00  mm.

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

 Wear Plate Width                                b1      332.00  mm.
 Wear Plate Bearing Angle                    theta1      140.00  degrees
 Wear Plate Thickness                            tr        12.0  mm.
 Wear Plate Allowable Stress                     Sr      137.90  N./mm^2

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

 Saddle Force Q, Operating Case                          264.30  kN

 Horizontal Vessel Analysis Results:        Actual |    Allowable |
                                           N./mm^2 |      N./mm^2 |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan           43.05 |       137.90 |
 Long. Stress at Bottom of Midspan           50.96 |       137.90 |
 Long. Stress at Top    of Saddles           19.42 |       137.90 |
 Long. Stress at Bottom of Saddles           53.70 |       137.90 |
 ----------------------------------------------------------------
 Tangential Shear in Shell                   29.26 |       110.32 |
 Circ. Stress at Horn of Saddle             131.68 |       172.37 |
 Circ. Compressive Stress in Shell            3.57 |       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 * ( 10.4/2 + 0 ) * 972.0/1094.6561
  = 13.9 kN
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 2.53, 0.0, 0 ) * 972.0/4330.0
  = 0.6 kN
```

Saddle Reaction Force due to Earthquake Fl or Friction [Fsl]:
```
  = max( Fl, Friction Force, Sum of X Forces ) * B / Ls
  = max( 69.57, 0.0, 0 ) * 972.0/4330.0
  = 15.6 kN
```

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

```
  = 3.0 * ( 70/2 + 0 ) * 972.0/1094.6561
  = 92.7 kN
```

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

```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 172 + Max( 0.6, 14, 16, 93 )
  = 264.3 kN
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)		266.39	kN
Transverse Shear Load Saddle	Ft	34.78	kN
Longitudinal Shear Load Saddle		69.57	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  = 0.0192     K8  = 0.3405
 K9  = 0.2711     K10 = 0.0581     K1* = 0.1923     K6p = 0.0379
 K7p = 0.0138
```

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

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

Moment per Equation 4.15.3 [M1]:

```
  = -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -264*352.0[1-(1-352.0/355.0+(611.5²-0.0²)/
    (2*352.0*355.0))/(1+(4*0.0)/(3*355.0))]
  = 46969.6 N-m
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 264*355/4(1+2(611²-0²)/(355²))/(1+(4*0)/
    (3*355))-4*352/355
  = 69649.5 N-m
```

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

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 23.059 * 611.5/(2*15.0) - 69649.5/(pi*611.5²*15.0)
  = 43.05 N./mm^2
```

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

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 23.059 * 611.5/(2 * 15.0) + 69649.5/(pi * 611.5² * 15.0 )
  = 50.96 N./mm^2
```

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

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 23.059*611.5/(2*17.0)-46969.6/(0.1066*pi*611.5²*17.0)
  = 19.42 N./mm^2
```

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

```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 23.059*611.5/(2*17.0)+46969.6/(0.1923*pi*611.5²*17.0)
  = 53.70 N./mm^2
```

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

```
  = Q(L-2a)/(L+(4*h2/3))
```

```
  = 264( 355.0 - 2 * 352.0)/(355.0 + ( 4 * 0.0/3))
  = -259.8 kN
```

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

```
  = K2 * T / ( Rm * t )
  = 1.1707 * -259.84/( 611.5 * 17.0 )
  = -29.26 N./mm^2
```

Decay Length (4.15.22) [x1,x2]:

```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 611.5 * 17.0 )
  = 79.527 mm.
```

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

```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 264 * 0.1/( 17.0 * ( 172.0 + 79.53 + 79.53 ) )
  = -3.57 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( 611.5 * 17.0 ), 2 * 352.0 )
  = 331.05 mm.
```

Wear Plate/Shell Stress ratio (4.15.29) [eta]:

```
  = min( Sr/S, 1 )
  = min( 137.9/137.9, 1 )
  = 1.0000
```

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [sigma6,r]:

```
  = -K5 * Q * k / ( B1( t + eta * tr ) )
  = - 0.7603 * 264 * 0.1/( 331.055( 17.0 + 1.0 * 12.0 ) )
  = -2.09 N./mm^2
```

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.28) [sigma7,r*]:

```
  = -Q/(4(t+eta*tr)b1) - 12*K7*Q*Rm/(L(t+eta*tr)²)
  = -264/(4(17.0+ 1.0* 12.0)331.055) -
     12*0.019*264*611.5/(355.0(17.0+1.0*12.0)²)
  = -131.68 N./mm^2
```

Free Un-Restrained Thermal Expansion between the Saddles [Exp]:

```
  = Alpha * Ls * ( Design Temperature - Ambient Temperature )
  = 0.000012 * 4330.0 * ( 125.0 - 21.1 )
  = 5.517 mm.
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1450.0000	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	326.0	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	489.9	17.0	8.5	83.3	70797.1	0.866E+04
Wearplate	332.0	12.0	23.0	39.8	91632.0	0.304E+04
Web	12.0	324.0	191.0	38.9	742607.5	0.593E+04
BasePlate	220.0	16.0	361.0	35.2	1270719.5	0.221E+05
Totals	...	...	...	197.2	2175756.0	0.398E+05

Distance to Centroid [C1]:
```
  = AY / A
  = 856.597/197.211
  = 110.326 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 * 264.302
  = 53.7912 kN

 Tension Stress, St = ( Fh/As )       =         4.7222  N./mm^2
 Allowed Stress, Sa = 0.6 * Yield Str =       124.1100  N./mm^2
```

Saddle Splitting Dimension [d]:
```
  = B - R * sin( theta )/ theta
  = 972.0 - 603.0 * sin( 1.0472 )/1.0472
  = 473.323 mm.

 Bending Moment, M  = Fh * d          =     25470.9512  N-m

 Bending Stress, Sb = ( M * C1 / I  ) =         7.0660  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(264 + 2)220.0/( 4 * 1450.0 * 137.9 ))½
  = 14.827 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 )( 600.0 + 20.0 + 12.0 )
  = 1094.656 mm.
```

Distance between Ribs [e]:
```
  = Web Length / ( Nribs - 1 )
  = 1094.656/( 4 - 1 )
  = 364.885 mm.
```

Baseplate Pressure Area [Ap]:
```
  = e * Bpwid / 2
  = 364.8853 * 220.0/2
  = 401.374 cm^2
```

Axial Load [P]:
```
  = Ap * Bp
  = 401.4 * 0.08
  = 33.255 kN
```

Area of the Rib and Web [Ar]:
```
  = Rib Area + Web Area
  = 19.2 + 21.893
  = 41.093 cm^2
```

Compressive Stress [Sc]:
```
  = P/Ar
  = 33.3/41.0931
  = 8.093 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
  = 0.0/41.093
  = 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( 508.8/41.093 )
  = 35.189 mm.
```

Length of Outer Rib [L]:
```
  = Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
  = 972.0 - cos( 120.0/2 )( 600.0 + 20.0 + 12.0 ) - 16.0
  = 640.000 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 * 640.0/35.189
  = 18.187
```

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * L / 2
```

```
  = 69.6/( 2 * 1450.0 ) * 364.885 * 640.0/2
  = 2802.062 N-m
```

Compressive Allowable, KL/r < Cc (18.1875 < 138.1347) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 18.19 )²/(2 * 138.13² ))207/
    ( 5/3+3*(18.19)/(8* 138.13)-( 18.19³)/(8*138.13³)
  = 119.5 N./mm^2
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 8.09/119.51 + ( 2802.06 * 86.0/5088449 )/137.9
  = 0.411
```

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	364.9	12.0	0.0	43.8	0.0	5.25
Totals	...	...	...	63.0	...	514.

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 0.0/62.986
  = 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
  = 972.0 - sqrt( (632.0 + 12.0)^2 - (364.885/2)^2 ) - 16.0
  = 350.906 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 513.9/62.986 )
  = 28.565 mm.
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 350.906/28.565
  = 12.285
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 69.565/( 2 * 1450.0 )
  = 0.024 kN/mm.
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 0.024 * 364.885 * 350.906
  = 3072.689 N-m
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 3072.689/59758.879
```

= 51.402 N./mm^2

Compressive Allowable, KL/r < Cc (12.2847 < 138.1347) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.28 )²/(2 * 138.13² ))207/
    ( 5/3+3*(12.28)/(8* 138.13)-( 12.28³)/(8*138.13³)
  = 121.2 N./mm^2
```

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

```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 10.12/121.2 + ( 3072.69 * 86.0/513.926 )/137.9
  = 0.456
```

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	75.0	mm.
Nominal Bolt Diameter	Bnd	22.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	2.7242	cm^2
Saddle Load QO (Weight)	QO	173.7	kN
Saddle Load QL (Wind/Seismic contribution)	QL	15.6	kN
Maximum Transverse Force	Ft	34.8	kN
Maximum Longitudinal Force	Fl	69.6	kN
Saddle Bolted to Steel Foundation		No	

Shear Stress in a Single Bolt [taub]:

```
  = Shear Force / ( 2 * Bolt Area * Number of Bolts )
  = 70/( 2 * 2.72 * 4 )
  = 31.9 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)
  = 69.57/(172.38 * 4.0)
  = 1.0090 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
  = B * Ft + Sum of X Moments
  = 972.0 * 34.78 + 0.0
  = 33822.50 N-m
```

Eccentricity (e):

```
  = Rmom / QO
  = 33822.5/173.73
  = 194.60 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, 1.009, 0.0]
  = 1.0090 cm^2
```

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

*Warning - Distance to Saddle (a) > 0.25 * Tangent Distance (L) - 4.15.3.2*

Input and Calculated Values:

```
 Vessel Mean Radius                              Rm       838.50  mm.
 Stiffened Vessel Length per 4.15.6               L       355.00  mm.
 Distance from Saddle to Vessel tangent           a       466.00  mm.

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

 Wear Plate Width                                b1       350.00  mm.
 Wear Plate Bearing Angle                    theta1       140.00  degrees
 Wear Plate Thickness                            tr         12.0  mm.
 Wear Plate Allowable Stress                     Sr       137.90  N./mm^2

 Inside Depth of Head                            h2       417.00  mm.

 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                           192.59  kN

 Horizontal Vessel Analysis Results:       Actual |    Allowable |
                                          N./mm^2 |      N./mm^2 |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan          65.21 |       137.90 |
 Long. Stress at Bottom of Midspan          63.57 |       137.90 |
 Long. Stress at Top    of Saddles          77.06 |       137.90 |
 Long. Stress at Bottom of Saddles          57.37 |       137.90 |
 ----------------------------------------------------------------
 Tangential Shear in Shell                  11.35 |       110.32 |
 Circ. Stress at Horn of Saddle            137.19 |       172.37 |
 Circ. Compressive Stress in Shell           2.81 |       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 * ( 10.4/2 + 0 ) * 1200.0/1486.0997
  = 12.6 kN
```

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

```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 4.71, 33.33, 0 ) * 1200.0/4330.0
  = 9.2 kN
```

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

```
  = max( Fl, Friction Force, Sum of X Forces ) * B / Ls
```

```
  = max( 69.57, 33.33, 0 ) * 1200.0/4330.0
  = 19.3 kN
```

Saddle Reaction Force due to Earthquake Ft [Fst]:

```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0 * ( 70/2 + 0 ) * 1200.0/1486.0997
  = 84.3 kN
```

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

```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 108 + Max( 9, 13, 19, 84 )
  = 192.6 kN
```

Summary of Loads at the base of this Saddle:

```
 Vertical Load (including saddle weight)            195.36  kN
 Transverse Shear Load Saddle          Ft            34.78  kN
 Longitudinal Shear Load Saddle                      69.57  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  = 0.0176     K8  = 0.3405
 K9  = 0.2711     K10 = 0.0581     K1* = 0.1923     K6p = 0.0379
 K7p = 0.0126
```

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

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

Moment per Equation 4.15.3 [M1]:

```
  = -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -193*466.0[1-(1-466.0/355.0+(838.5²-417.0²)/
    (2*466.0*355.0))/(1+(4*417.0)/(3*355.0))]
  = -44763.2 N-m
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 193*355/4(1+2(838²-417²)/(355²))/(1+(4*417)/
    (3*355))-4*466/355
  = -27160.3 N-m
```

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

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 23.036 * 838.5/(2*15.0) - -27160.3/(pi*838.5²*15.0)
  = 65.21 N./mm^2
```

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

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 23.036 * 838.5/(2 * 15.0) + -27160.3/(pi * 838.5² * 15.0 )
  = 63.57 N./mm^2
```

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

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 23.036*838.5/(2*15.0)--44763.2/(0.1066*pi*838.5²*15.0)
  = 77.06 N./mm^2
```

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

```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
```

```
  = 23.036*838.5/(2*15.0)+-44763.2/(0.1923*pi*838.5²*15.0)
  = 57.37 N./mm^2
```

Maximum Shear Force in the Saddle (4.15.5) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 193( 355.0 - 2 * 466.0)/(355.0 + ( 4 * 417.0/3))
  = -122.0 kN
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * -121.98/( 838.4999 * 15.0 )
  = -11.35 N./mm^2
```

Decay Length (4.15.22) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 838.5 * 15.0 )
  = 87.477 mm.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 193 * 0.1/( 15.0 * ( 172.0 + 87.48 + 87.48 ) )
  = -2.81 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( 838.5 * 15.0 ), 2 * 466.0 )
  = 346.95 mm.
```

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

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [sigma6,r]:
```
  = -K5 * Q * k / ( B1( t + eta * tr ) )
  = - 0.7603 * 193 * 0.1/( 346.953( 15.0 + 1.0 * 12.0 ) )
  = -1.56 N./mm^2
```

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.28) [sigma7,r*]:
```
  = -Q/(4(t+eta*tr)b1) - 12*K7*Q*Rm/(L(t+eta*tr)²)
  = -193/(4(15.0+ 1.0* 12.0)346.953) -
    12*0.018*193*838.5/(355.0(15.0+1.0*12.0)²)
  = -137.19 N./mm^2
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1450.0000	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	372.0	mm.
Friction Coefficient	mu	0.300	

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	524.2	15.0	7.5	78.6	58969.0	0.841E+04
Wearplate	350.0	12.0	21.0	42.0	88200.0	0.340E+04
Web	12.0	326.0	190.0	39.1	743279.8	0.591E+04
BasePlate	220.0	16.0	361.0	35.2	1270719.8	0.220E+05
Totals	...	...	...	194.9	2161168.5	0.398E+05

Distance to Centroid [C1]:
```
  = AY / A
  = 850.854/194.945
  = 110.860 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 * 192.59
  = 39.1963 kN

 Tension Stress, St = ( Fh/As )       =         3.3700  N./mm^2
 Allowed Stress, Sa = 0.6 * Yield Str =       124.1100  N./mm^2
```

Saddle Splitting Dimension [d]:
```
  = B - R * sin( theta )/ theta
  = 1200.0 - 831.0 * sin( 1.0472 )/1.0472
  = 512.768 mm.

 Bending Moment, M  = Fh * d          =     20106.7695  N-m

 Bending Stress, Sb = ( M * C1 / I  ) =         5.6047  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(193 + 3)220.0/( 4 * 1450.0 * 137.9 ))½
  = 12.697 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 )( 828.0 + 18.0 + 12.0 )
  = 1486.100 mm.
```

Distance between Ribs [e]:
```
  = Web Length / ( Nribs - 1 )
  = 1486.0997/( 4 - 1 )
  = 495.367 mm.
```

Baseplate Pressure Area [Ap]:
```
  = e * Bpwid / 2
  = 495.3665 * 220.0/2
```

```
  = 544.903 cm^2
```

Axial Load [P]:
```
  = Ap * Bp
  = 544.9 * 0.06
  = 32.898 kN
```

Area of the Rib and Web [Ar]:
```
  = Rib Area + Web Area
  = 19.2 + 29.722
  = 48.922 cm^2
```

Compressive Stress [Sc]:
```
  = P/Ar
  = 32.9/48.922
  = 6.725 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
  = 0.0/48.922
  = 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( 508.8/48.922 )
  = 32.251 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 * 353.914/32.251
  = 10.974
```

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 69.6/( 2 * 1450.0 ) * 495.367 * 353.91/2
  = 2103.616 N-m
```

Compressive Allowable, KL/r < Cc (10.9738 < 138.1347) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 10.97 )²/(2 * 138.13² ))207/
    ( 5/3+3*(10.97)/(8* 138.13)-( 10.97³)/(8*138.13³)
  = 121.6 N./mm^2
```

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

```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 6.73/121.55 + ( 2103.62 * 86.0/5088449 )/137.9
  = 0.313
```

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	495.4	12.0	0.0	59.4	0.0	7.13
Totals	...	...	...	78.6	...	516.

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 0.0/78.644
  = 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
  = 1200.0 - sqrt( (858.0 + 12.0)^2 - (495.367/2)^2 ) - 16.0
  = 362.527 mm.
```

Radius of Gyration [r]:

```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 515.8/78.644 )
  = 25.610 mm.
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 362.527/25.61
  = 14.156
```

Unit Force [Force,u]:

```
  = Fl / ( 2 * Baseplate Length )
  = 69.565/( 2 * 1450.0 )
  = 0.024 kN/mm.
```

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

```
  = Unit Force * e * L
  = 0.024 * 495.367 * 362.527
  = 4309.621 N-m
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:

```
  = Bending Moment / Section Modulus
  = 4309.621/59977.363
  = 71.831 N./mm^2
```

Compressive Allowable, KL/r < Cc (14.1557 < 138.1347) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
```

```
  = ( 1-( 14.16 )²/(2 * 138.13² ))207/
    ( 5/3+3*(14.16)/(8* 138.13)-( 14.16³)/(8*138.13³)
  = 120.7 N./mm^2
```

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

```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 8.09/120.69 + ( 4309.62 * 86.0/515.805 )/137.9
  = 0.588
```

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	75.0	mm.
Nominal Bolt Diameter	Bnd	22.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	2.7242	cm^2
Saddle Load QO (Weight)	QO	111.1	kN
Saddle Load QL (Wind/Seismic contribution)	QL	19.3	kN
Maximum Transverse Force	Ft	34.8	kN
Maximum Longitudinal Force	Fl	69.6	kN
Saddle Bolted to Steel Foundation		No	

Shear Stress in a Single Bolt [taub]:

```
  = Shear Force / ( 2 * Bolt Area * Number of Bolts )
  = 70/( 2 * 2.72 * 4 )
  = 31.9 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)
  = 69.57/(172.38 * 4.0)
  = 1.0090 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
  = B * Ft + Sum of X Moments
  = 1200.0 * 34.78 + 0.0
  = 41756.17 N-m
```

Eccentricity (e):

```
  = Rmom / QO
  = 41756.17/111.1
  = 375.68 mm. > Bplen/6 --> Uplift in Transverse direction

 f = Bplen / 2 - Edgedis
   = 1450.0/2 - 75.0
   = 650.00 mm.
```

Modular Ratio Of Steel/Concrete (n1):

```
  = ES / EC
  = 203402.5/21526.32
```

```
  = 9.45

 K1 = 3 (e - 0.5 * Bplen)
    = 3 (375.68 - 0.5*1450.0)
    = -1047.95 mm.

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 9.45 * 5.45/220.0 * (650.0 + 375.68)
    = 144011.04 mm.²

 K3 = -K2 * (0.5 * Bplen + f)
    = -144011.05 * (0.5 * 1450.0 + 650.0)
    = -198015174.66 mm.³
```

Iteratively Solving for the Effective Bearing Length:

```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + -1047.95 * Y² + 144011.05 * Y + -0.2E+09 = 0
 Y  = 1083.68 mm.

 Num = (Bplen / 2 - Y / 3 - e)
     = (1450.0/2 - 1083.68/3 - 375.68)
     = -11.91

 Denom = (Bplen / 2 - Y / 3 + f)
       = (1450.0/2 - 1083.68/3 + 650.0)
       = 1013.77
```

Total Bolt Tension Force [Tforce]:

```
  = - QO * Num / Denom
  = - 111.1 * -11.91/1013.77
  = 1.31 kN
```

Bolt Area Required due to Transverse Load [Bltareart]:

```
  = Tforce / (Stba * Nbt)
  = 1.31/( 172.38 * 2.0 )
  = 0.0379 cm^2
```

Required Area of a Single Bolt [Bltarear]:

```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0.0, 1.009, 0.0379]
  = 1.0090 cm^2
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)

```
  = 2(QO + Tforce) / (Y * Bpwid)
  = 2(111.1 + 1.31)/(1083.68 * 220.0)
  = 9.43 bars
```

Distance from Baseplate Edge to the Web [ADIST]:

```
  = (Bplen - Weblngth) / 2
  = (1450.0 - 1399.2)/2
  = 25.4000 mm.
```

Overturning Moment due To Bolt Tension [Mt]:

```
  = Tforce * Adist
  = 1.31 * 25.4
  = 33.16 N-m
```

Equivalent Bearing Pressure (f1):

```
  = fc * (Y - Adist) / Y
  = 9.43 * (1083.68 - 25.4)/1083.68
  = 9.21 bars
```

Overturning Moment due to Bearing Pressure [Mc]:

```
  = (Adist² * Bpwid / 6) * (f1 + 2 * fc)
  = (25.4² * 220.0/6) * (9.21 + 2 * 9.43)
  = 66.43 N-m
```

Baseplate Required Thickness [Treq]:

```
  = (6 * max(Mt,Mc) / (Bpwid * Sba))½
  = (6 *max(33.16,66.43/(220.0 * 162.38))½
  = 3.3396 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

*Warning - Distance to Saddle (a) > 0.25 * Tangent Distance (L) - 4.15.3.2*

Input and Calculated Values:

Vessel Mean Radius	Rm	611.50	mm.
Stiffened Vessel Length per 4.15.6	L	355.00	mm.
Distance from Saddle to Vessel tangent	a	352.00	mm.
Saddle Width	b	172.00	mm.
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	332.00	mm.
Wear Plate Bearing Angle	theta1	140.00	degrees
Wear Plate Thickness	tr	12.0	mm.
Wear Plate Allowable Stress	Sr	137.90	N./mm^2
Shell Allowable Stress used in Calculation		235.81	N./mm^2
Head Allowable Stress used in Calculation		235.81	N./mm^2
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Test Case, no Ext. Forces		189.83	kN

Horizontal Vessel Analysis Results:	Actual N./mm^2	Allowable N./mm^2
Long. Stress at Top of Midspan	58.23	235.81
Long. Stress at Bottom of Midspan	63.91	235.81
Long. Stress at Top of Saddles	38.05	235.81
Long. Stress at Bottom of Saddles	62.67	235.81
Tangential Shear in Shell	21.02	188.65
Circ. Stress at Horn of Saddle	94.58	353.71
Circ. Compressive Stress in Shell	2.56	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 * ( 3.4/2 + 0 ) * 972.0/1094.6561
  = 4.6 kN
```

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

```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 0.83, 0.0, 0 ) * 972.0/4330.0
  = 0.2 kN
```

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

```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 185 + Max( 0.2, 5, 0, 0 )
  = 189.8 kN
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight) 191.92 kN

```
 Transverse Shear Load Saddle          Ft              1.72  kN
 Longitudinal Shear Load Saddle                        0.83  kN
```

Hydrostatic Test Pressure at center of Vessel: 29.960 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  = 0.0192     K8  = 0.3405
 K9  = 0.2711     K10 = 0.0581     K1* = 0.1923     K6p = 0.0379
 K7p = 0.0138
```

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

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

Moment per Equation 4.15.3 [M1]:

```
  = -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -190*352.0[1-(1-352.0/355.0+(611.5²-0.0²)/
    (2*352.0*355.0))/(1+(4*0.0)/(3*355.0))]
  = 33735.3 N-m
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 190*355/4(1+2(611²-0²)/(355²))/(1+(4*0)/
    (3*355))-4*352/355
  = 50024.8 N-m
```

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

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 29.96 * 611.5/(2*15.0) - 50024.8/(pi*611.5²*15.0)
  = 58.23 N./mm^2
```

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

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 29.96 * 611.5/(2 * 15.0) + 50024.8/(pi * 611.5² * 15.0 )
  = 63.91 N./mm^2
```

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

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 29.96*611.5/(2*17.0)-33735.3/(0.1066*pi*611.5²*17.0)
  = 38.05 N./mm^2
```

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

```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 29.96*611.5/(2*17.0)+33735.3/(0.1923*pi*611.5²*17.0)
  = 62.67 N./mm^2
```

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

```
  = Q(L-2a)/(L+(4*h2/3))
  = 190( 355.0 - 2 * 352.0)/(355.0 + ( 4 * 0.0/3))
  = -186.6 kN
```

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

```
  = K2 * T / ( Rm * t )
  = 1.1707 * -186.62/( 611.5 * 17.0 )
  = -21.02 N./mm^2
```

Decay Length (4.15.22) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 611.5 * 17.0 )
  = 79.527 mm.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 190 * 0.1/( 17.0 * ( 172.0 + 79.53 + 79.53 ) )
  = -2.56 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( 611.5 * 17.0 ), 2 * 352.0 )
  = 331.05 mm.
```

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

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [sigma6,r]:
```
  = -K5 * Q * k / ( B1( t + eta * tr ) )
  = - 0.7603 * 190 * 0.1/( 331.055( 17.0 + 1.0 * 12.0 ) )
  = -1.50 N./mm^2
```

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.28) [sigma7,r*]:
```
  = -Q/(4(t+eta*tr)b1) - 12*K7*Q*Rm/(L(t+eta*tr)²)
  = -190/(4(17.0+ 1.0* 12.0)331.055) -
     12*0.019*190*611.5/(355.0(17.0+1.0*12.0)²)
  = -94.58 N./mm^2
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1450.0000	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	326.0	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	489.9	17.0	8.5	83.3	70797.1	0.866E+04
Wearplate	332.0	12.0	23.0	39.8	91632.0	0.304E+04
Web	12.0	324.0	191.0	38.9	742607.5	0.593E+04
BasePlate	220.0	16.0	361.0	35.2	1270719.5	0.221E+05
Totals	...	...	...	197.2	2175756.0	0.398E+05

Distance to Centroid [C1]:
```
  = AY / A
  = 856.597/197.211
  = 110.326 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 * 189.831
  = 38.6348 kN

 Tension Stress, St = ( Fh/As )       =          3.3917  N./mm^2
 Allowed Stress, Sa = 0.6 * Yield Str =        124.1100  N./mm^2
```

Saddle Splitting Dimension [d]:
```
  = B - R * sin( theta )/ theta
  = 972.0 - 603.0 * sin( 1.0472 )/1.0472
  = 473.323 mm.

 Bending Moment, M  = Fh * d          =      18294.1660  N-m

 Bending Stress, Sb = ( M * C1 / I  ) =          5.0751  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(190 + 2)220.0/( 4 * 1450.0 * 137.9 ))½
  = 12.585 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 )( 600.0 + 20.0 + 12.0 )
  = 1094.656 mm.
```

Distance between Ribs [e]:
```
  = Web Length / ( Nribs - 1 )
  = 1094.656/( 4 - 1 )
  = 364.885 mm.
```

Baseplate Pressure Area [Ap]:
```
  = e * Bpwid / 2
  = 364.8853 * 220.0/2
  = 401.374 cm^2
```

Axial Load [P]:
```
  = Ap * Bp
  = 401.4 * 0.06
  = 23.885 kN
```

Area of the Rib and Web [Ar]:
```
  = Rib Area + Web Area
  = 19.2 + 21.893
  = 41.093 cm^2
```

Compressive Stress [Sc]:
```
  = P/Ar
  = 23.9/41.0931
  = 5.813 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
  = 0.0/41.093
  = 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( 508.8/41.093 )
  = 35.189 mm.
```

Length of Outer Rib [L]:
```
  = Saddle Height - cos( theta/2 )( radius + shlthk + wpdthk ) - bpthk
  = 972.0 - cos( 120.0/2 )( 600.0 + 20.0 + 12.0 ) - 16.0
  = 640.000 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 * 640.0/35.189
  = 18.187
```

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 0.8/( 2 * 1450.0 ) * 364.885 * 640.0/2
  = 33.613 N-m
```

Compressive Allowable, KL/r < Cc (18.1875 < 138.1347) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 18.19 )²/(2 * 138.13² ))207/
    ( 5/3+3*(18.19)/(8* 138.13)-( 18.19³)/(8*138.13³)
  = 119.5 N./mm^2
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 5.81/119.51 + ( 33.61 * 86.0/5088449 )/137.9
  = 0.053
```

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	364.9	12.0	0.0	43.8	0.0	5.25
Totals	...	...	...	63.0	...	514.

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 0.0/62.986
  = 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
  = 972.0 - sqrt( (632.0 + 12.0)^2 - (364.885/2)^2 ) - 16.0
  = 350.906 mm.
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 513.9/62.986 )
  = 28.565 mm.
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 350.906/28.565
  = 12.285
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 0.834/( 2 * 1450.0 )
  = 0.000 kN/mm.
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 0. * 364.885 * 350.906
  = 36.859 N-m
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 36.859/59758.879
  = 0.617 N./mm^2
```

Compressive Allowable, KL/r < Cc (12.2847 < 138.1347) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.28 )²/(2 * 138.13² ))207/
    ( 5/3+3*(12.28)/(8* 138.13)-( 12.28³)/(8*138.13³)
  = 121.2 N./mm^2
```

AISC Unity Check of Inside Ribs (must be <= 1)
```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 7.27/121.2 + ( 36.86 * 86.0/513.926 )/137.9
  = 0.064
```

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	75.0	mm.
Nominal Bolt Diameter	Bnd	22.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	2.7242	cm^2
Saddle Load QO (Weight)	QO	187.3	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.2	kN
Maximum Transverse Force	Ft	1.7	kN
Maximum Longitudinal Force	Fl	1.6	kN
Saddle Bolted to Steel Foundation		No	

Shear Stress in a Single Bolt [taub]:
```
  = Shear Force / ( 2 * Bolt Area * Number of Bolts )
  = 2/( 2 * 2.72 * 4 )
  = 0.8 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)
  = 1.55/(172.38 * 4.0)
  = 0.0225 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 972.0 * 1.72 + 0.0
  = 1669.90 N-m
```

Eccentricity (e):
```
  = Rmom / QO
  = 1669.9/187.34
  = 8.91 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, 0.0225, 0.0]
  = 0.0225 cm^2
```

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

*Warning - Distance to Saddle (a) > 0.25 * Tangent Distance (L) - 4.15.3.2*

Input and Calculated Values:

Vessel Mean Radius	Rm	838.50	mm.
Stiffened Vessel Length per 4.15.6	L	355.00	mm.

```
 Distance from Saddle to Vessel tangent         a      466.00  mm.

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

 Wear Plate Width                              b1      350.00  mm.
 Wear Plate Bearing Angle                  theta1      140.00  degrees
 Wear Plate Thickness                          tr        12.0  mm.
 Wear Plate Allowable Stress                   Sr      137.90  N./mm^2

 Inside Depth of Head                          h2      417.00  mm.

 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             131.28  kN
```

Horizontal Vessel Analysis Results:	Actual N./mm^2	Allowable N./mm^2
Long. Stress at Top of Midspan	84.36	235.81
Long. Stress at Bottom of Midspan	83.25	235.81
Long. Stress at Top of Saddles	92.44	235.81
Long. Stress at Bottom of Saddles	79.02	235.81
Tangential Shear in Shell	7.74	188.65
Circ. Stress at Horn of Saddle	93.51	353.71
Circ. Compressive Stress in Shell	1.92	235.81

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:
```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.0 * ( 3.4/2 + 0 ) * 1200.0/1486.0997
  = 4.2 kN
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:
```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 1.55, 0.0, 0 ) * 1200.0/4330.0
  = 0.4 kN
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 127 + Max( 0.4, 4, 0, 0 )
  = 131.3 kN
```

Summary of Loads at the base of this Saddle:
```
 Vertical Load (including saddle weight)               134.05  kN
 Transverse Shear Load Saddle           Ft               1.72  kN
 Longitudinal Shear Load Saddle                          1.55  kN
```

Hydrostatic Test Pressure at center of Vessel: 29.982 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  = 0.0176     K8  = 0.3405
K9  = 0.2711     K10 = 0.0581     K1* = 0.1923     K6p = 0.0379
K7p = 0.0126
```

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

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

Moment per Equation 4.15.3 [M1]:
```
  = -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -131*466.0[1-(1-466.0/355.0+(838.5²-417.0²)/
    (2*466.0*355.0))/(1+(4*417.0)/(3*355.0))]
  = -30512.2 N-m
```

Moment per Equation 4.15.4 [M2]:
```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 131*355/4(1+2(838²-417²)/(355²))/(1+(4*417)/
    (3*355))-4*466/355
  = -18513.5 N-m
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:
```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 29.982 * 838.5/(2*15.0) - -18513.5/(pi*838.5²*15.0)
  = 84.36 N./mm^2
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:
```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 29.982 * 838.5/(2 * 15.0) + -18513.5/(pi * 838.5² * 15.0 )
  = 83.25 N./mm^2
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:
```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 29.982*838.5/(2*15.0)--30512.2/(0.1066*pi*838.5²*15.0)
  = 92.44 N./mm^2
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:
```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 29.982*838.5/(2*15.0)+-30512.2/(0.1923*pi*838.5²*15.0)
  = 79.02 N./mm^2
```

Maximum Shear Force in the Saddle (4.15.5) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 131( 355.0 - 2 * 466.0)/(355.0 + ( 4 * 417.0/3))
  = -83.1 kN
```

Shear Stress in the shell no rings, not stiffened (4.15.14) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * -83.15/( 838.4999 * 15.0 )
  = -7.74 N./mm^2
```

Decay Length (4.15.22) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 838.5 * 15.0 )
  = 87.477 mm.
```

Circumferential Stress in shell, no rings (4.15.23) [sigma6]:
```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = - 0.7603 * 131 * 0.1/( 15.0 * ( 172.0 + 87.48 + 87.48 ) )
  = -1.92 N./mm^2
```

Effective reinforcing plate width (4.15.1) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 172.0 + 1.56 * sqrt( 838.5 * 15.0 ), 2 * 466.0 )
  = 346.95 mm.
```

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

Circumferential Stress at Saddle Base with Wear Plate (4.15.26) [sigma6,r]:
```
  = -K5 * Q * k / ( B1( t + eta * tr ) )
  = - 0.7603 * 131 * 0.1/( 346.953( 15.0 + 1.0 * 12.0 ) )
  = -1.07 N./mm^2
```

Circ. Comp. Stress at Horn of Saddle, L<8Rm (4.15.28) [sigma7,r*]:
```
  = -Q/(4(t+eta*tr)b1) - 12*K7*Q*Rm/(L(t+eta*tr)²)
  = -131/(4(15.0+ 1.0* 12.0)346.953) -
     12*0.018*131*838.5/(355.0(15.0+1.0*12.0)²)
  = -93.51 N./mm^2
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	1450.0000	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	372.0	mm.
Friction Coefficient	mu	0.300	

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	524.2	15.0	7.5	78.6	58969.0	0.841E+04
Wearplate	350.0	12.0	21.0	42.0	88200.0	0.340E+04
Web	12.0	326.0	190.0	39.1	743279.8	0.591E+04
BasePlate	220.0	16.0	361.0	35.2	1270719.8	0.220E+05
Totals	...	...	...	194.9	2161168.5	0.398E+05

Distance to Centroid [C1]:
```
  = AY / A
  = 850.854/194.945
  = 110.860 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 * 131.276
  = 26.7176 kN

 Tension Stress, St = ( Fh/As )       =         2.2971  N./mm^2
 Allowed Stress, Sa = 0.6 * Yield Str =       124.1100  N./mm^2
```

Saddle Splitting Dimension [d]:

```
  = B - R * sin( theta )/ theta
  = 1200.0 - 831.0 * sin( 1.0472 )/1.0472
  = 512.768 mm.

 Bending Moment, M  = Fh * d          =      13705.4990  N-m

 Bending Stress, Sb = ( M * C1 / I  ) =         3.8204  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(131 + 3)220.0/( 4 * 1450.0 * 137.9 ))½
  = 10.518 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 )( 828.0 + 18.0 + 12.0 )
  = 1486.100 mm.
```

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 1486.0997/( 4 - 1 )
  = 495.367 mm.
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 495.3665 * 220.0/2
  = 544.903 cm^2
```

Axial Load [P]:

```
  = Ap * Bp
  = 544.9 * 0.04
  = 22.424 kN
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 19.2 + 29.722
  = 48.922 cm^2
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 22.4/48.922
  = 4.584 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
  = 0.0/48.922
  = 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( 508.8/48.922 )
  = 32.251 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 * 353.914/32.251
  = 10.974
```

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 1.6/( 2 * 1450.0 ) * 495.367 * 353.91/2
  = 46.984 N-m
```

Compressive Allowable, KL/r < Cc (10.9738 < 138.1347) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 10.97 )²/(2 * 138.13² ))207/
    ( 5/3+3*(10.97)/(8* 138.13)-( 10.97³)/(8*138.13³)
  = 121.6 N./mm^2
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 4.58/121.55 + ( 46.98 * 86.0/5088449 )/137.9
  = 0.043
```

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	495.4	12.0	0.0	59.4	0.0	7.13
Totals	...	...	...	78.6	...	516.

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 0.0/78.644
  = 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
  = 1200.0 - sqrt( (858.0 + 12.0)^2 - (495.367/2)^2 ) - 16.0
  = 362.527 mm.
```

Radius of Gyration [r]:

```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 515.8/78.644 )
  = 25.610 mm.
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 362.527/25.61
  = 14.156
```

Unit Force [Force,u]:

```
  = Fl / ( 2 * Baseplate Length )
  = 1.554/( 2 * 1450.0 )
  = 0.001 kN/mm.
```

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

```
  = Unit Force * e * L
  = 0.001 * 495.367 * 362.527
  = 96.255 N-m
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:

```
  = Bending Moment / Section Modulus
  = 96.255/59977.363
  = 1.604 N./mm^2
```

Compressive Allowable, KL/r < Cc (14.1557 < 138.1347) per AISC E2-1 [Sca]:

$$= (1-(Klr)^2/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)$$
$$= (1-(14.16)^2/(2 * 138.13^2))207/$$
$$(5/3+3*(14.16)/(8* 138.13)-(14.16^3)/(8*138.13^3)$$
$$= 120.7 N./mm^2$$

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

```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 5.51/120.69 + ( 96.25 * 86.0/515.805 )/137.9
  = 0.057
```

<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	75.0	mm.
Nominal Bolt Diameter	Bnd	22.0000	mm.
Thread Series	Series	TEMA Metric	
BasePlate Allowable Stress	S	108.25	N./mm^2
Area Available in a Single Bolt	BltArea	2.7242	cm^2
Saddle Load QO (Weight)	QO	129.9	kN
Saddle Load QL (Wind/Seismic contribution)	QL	0.4	kN
Maximum Transverse Force	Ft	1.7	kN
Maximum Longitudinal Force	Fl	1.6	kN

```
 Saddle Bolted to Steel Foundation                          No
```

Shear Stress in a Single Bolt [taub]:
```
  = Shear Force / ( 2 * Bolt Area * Number of Bolts )
  = 2/( 2 * 2.72 * 4 )
  = 0.8 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)
  = 1.55/(172.38 * 4.0)
  = 0.0225 cm^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 1200.0 * 1.72 + 0.0
  = 2061.61 N-m
```

Eccentricity (e):
```
  = Rmom / QO
  = 2061.61/129.89
  = 15.87 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, 0.0225, 0.0]
  = 0.0225 cm^2
```

Conical Reinforcement Calculations, ASME VIII Div. 1, App. 1

Conical Section From 60 To 70 SA-516 70

```
CON
 Elastic Modulus Data from ASME Section II Part D at 125 °C

 Elastic Modulus of Cone Material                0.197E+09 KPa. at 124 °C
 Elastic Modulus of Small Cylinder Material      0.197E+09 KPa. at 124 °C
 Elastic Modulus of Large Cylinder Material      0.197E+09 KPa. at 124 °C
 Elastic Modulus of Large End Reinforcement      0.197E+09 KPa. at 124 °C
 Elastic Modulus of Small End Reinforcement      0.197E+09 KPa. at 124 °C

 Elastic Modulus Data from ASME Section II Part D at 125 °C

 Elastic Modulus of Cone Material                0.197E+09 KPa. at 124 °C
 Elastic Modulus of Small Cylinder Material      0.197E+09 KPa. at 124 °C
 Elastic Modulus of Large Cylinder Material      0.197E+09 KPa. at 124 °C
 Elastic Modulus of Large End Reinforcement      0.197E+09 KPa. at 124 °C
 Elastic Modulus of Small End Reinforcement      0.197E+09 KPa. at 124 °C

 Axial Force on Small End of Cone                       0.00  kN
 Axial Force on Large End of Cone                       0.00  kN
 Moment on Small End of Cone                            0.00  N-m
 Moment on Large End of Cone                            0.00  N-m
```

Note: Axial forces and moments are not computed for Horizontal geometries.
Please compute them manually and input them as Miscellaneous Load on the ends of the cone.

Note: Neither end of Cone is a Line of Support

```
 Maximum Centroid Reinforcement Distance Large End    28.1625  mm.
 Maximum Centroid Reinforcement Distance Small End    25.6661  mm.
```

Note: No ring was found close enough to the large end to be considered.

Note: No ring was found close enough to the small end to be considered.

Reinforcement Calculations for Cone / Large Cylinder:

Required Area of Reinforcement for Large End Under Internal Pressure

```
 Large end ratio of pressure to allowable stress      0.01677
 Large end max. half apex angle w/o reinforcement      30.000  degrees
 Large end actual half apex angle                      28.784  degrees
```

Required Area of Reinforcement for Large End Under External Pressure

```
 Large end ratio of pressure to allowable stress      0.00075
 Large end max. half apex angle w/o reinforcement       1.875  degrees
 Large end actual half apex angle                      28.784  degrees
```

Intermediate Value [k]:

```
  = max( Y / ( Srl * Erl ), 1 )
  = max( 0.27111E+11/( 137.9 * 0.19660E+09 ), 1 )
  = 1.0000
```

where [Y] is:

```
   = Large End All. Stress * Large End Elastic Modulus (Ext. temp.)
   = 137.9 * 0.19660E+09
```

```
   = 27111170048.0 N./mm^2^2

 Allowable Stress of Large End Material (Ext. Temp)   137.9  N./mm^2
 Allowable Stress of Cone Material (Ext. Temp)        137.9  N./mm^2
```

Required Area of Reinforcement, Large End, External [Arl]:

```
  = (k*QL*Rl*tan(angle)/(Ss*E1))*(1-1/4((P*Rl-QL)/QL)*(delta/alpha)
  = (1.0*0.0437*846.0*0.549/(138*1.0))*
    (1-1/4((1.03*846.0-0.044)/0.044)*(1.875/28.784)
  = 1.451 cm^2
```

Force per Length, Cone Large End External Pressure [QL]:

```
  = Pext( Rl/2 ) + Faxial/(pi(Dl - Tl)) + Moment/(pi(Rl - Tl/2)(Rl - Tl/2))
  = 1.034( 846.0/2 ) + 0.0/(pi(1692.0 - 18.0)) +
    0.0/(pi(846.0 - 18.0/2)(846.0 - 18.0/2))
  = 0.044 kN/mm.
```

Available Area of Reinforcement, Large End, External [Ael]:

```
  = 0.55*( Dl*ts )½ * ( ts + tc/cos(alpha) )
  = 0.55 * ( 1692.0 * 15.0 )½ * ( 15.0 + 17.0/0.876 )
  = 30.1387 cm^2
```

<u>Summary of Reinforcement Area, Large End, External Pressure:</u>

```
 Area of reinforcement required per App. 1-8(1)       1.4505  cm^2
 Area of reinforcement in shell per App. 1-8(2)      30.1387  cm^2
 Area of reinforcement in stiffening ring             0.0000  cm^2
```

<u>Reinforcement Calculations for Cone / Small Cylinder:</u>

Required Area of Reinforcement for Small End under Internal Pressure

```
 Small end ratio of pressure to allowable stress     0.01677
 Small end max. half apex angle w/o reinforcement     11.368  degrees
 Small end actual half apex angle                     28.784  degrees
```

Intermediate Value [k]:

```
  = max( Y / ( Sr * Ers ), 1 )
  = max( 0.27111E+11/( 137.9 * 0.19660E+09 ), 1 )
  = 1.0000
```

where [Y] is:

```
   = Small End All. Stress * Small End Elastic Modulus (Int. temp.)
   = 137.9 * 0.19660E+09
   = 27111170048.0 N./mm^2^2
```

Decay Length, Cone Small End:

```
  = 1.4 * sqrt( Rs( ts - ca ) )
  = 1.4 * sqrt( 603.0( 20.0 - 3.0 ) )
  = 141.746 mm.
```

Required Area of Reinforcement, Small End, Internal [Ars]:

```
  = k*QS*Rs/(Ss*E1)*(1-delta/alpha)*tan(alpha)
  = 1.0 * 0.697 * 603.0/( 138 * 1.0 ) *
    ( 1 - 11.37/28.78 ) 0.5494
  = 10.13 cm^2
```

Force per Length, Cone Small End [QS]:

```
  = P( Rs/2 ) - Faxial/(pi(Ds + Ts)) + Moment/(pi(Rs + Ts/2)(Rs + Ts/2))
  = 23.118( 603.0/2 ) - 0.0/(pi(1206.0 + 20.0)) +
    0.0/(pi(603.0 + 20.0/2)(603.0 + 20.0/2))
  = 0.697 kN/mm.
```

Area of Reinforcement Available in Small End Shell [Aes]:

```
  = 0.78(Rs*Ts)½*((Ts-t)+(Tc-Tr)/cos(alpha) ))
  = 0.78(603.0*17.0)½*(( 17.0-10.212 )+( 17.0-11.652 )/0.88)
  = 10.1795 cm^2
```

Summary of Reinforcement Area, Small End, Internal Pressure:

```
 Area of reinforcement required per App. 1-5(3)       10.1322  cm^2
 Area of reinforcement in shell per App. 1-5(4)       10.1795  cm^2
 Area of reinforcement in stiffening ring              0.0000  cm^2
```

Required Area of Reinforcement for Small End Under External Pressure

```
 Allowable Stress of Small End Material (Ext. Temp)    137.9  N./mm^2
 Allowable Stress of Cone Material (Ext. Temp)         137.9  N./mm^2
```

Intermediate Value [k]:

```
  = max( Y / ( Srs * Ers ), 1 )
  = max( 0.27111E+11/( 137.9 * 0.19660E+09 ), 1 )
  = 1.0000
```

where [Y] is:

```
   = Small End All. Stress * Small End Elastic Modulus (Ext. temp.)
   = 137.9 * 0.19660E+09
   = 27111170048.0 N./mm^2^2
```

Area of Reinforcement Required in Small End Shell [Ars]:

```
  = k * QS * Rs * tan(alpha) / ( Ss * E1 )
  = (1.0*0.0321*620.0*0.5494/(138*1.0))
  = 0.792 cm^2
```

Force per Length, Cone Small End [QS]:

```
  = Pext( Rs/2 ) + Faxial/(pi(Ds - Ts)) + Moment/(pi(Rs - Ts/2)(Rs - Ts/2))
  = 1.034( 620.0/2 ) + 0.0/(pi(1240.0 - 20.0)) +
    0.0/(pi(620.0 - 20.0/2)(620.0 - 20.0/2))
  = 0.032 kN/mm.
```

Area of Reinforcement Available in Small End Shell [Aes]:

```
  = 0.55*(Ds*ts)½*[(ts-t)+(tc-tr)/cos(alpha))]
  = 0.55*(1240.0*17.0)½*[(17.0-7.232)+(17.0-3.633)/0.876]
  = 19.9791 cm^2
```

Summary of Reinforcement Area, Small End, External Pressure:

```
 Area of reinforcement required per App. 1-8(3)        0.7920  cm^2
 Area of reinforcement in shell per App. 1-8(4)       19.9791  cm^2
 Area of reinforcement in stiffening ring              0.0000  cm^2
```

Note: The following calculations are only required per 1-5(g)(1) and do include external loads due to wind or seismic. These discontinuity stresses are computed at the shell/cone junction and do not include effects of local stiffening from a junction ring.

Results for Discontinuity Stresses per Bednar p. 236 2nd Edition

Stress Type	Stress	Allowable	Location
Tensile Stress	196.23	413.70	Small Cyl. Long.
Compres. Stress	-113.07	-413.70	Small Cyl. Long.
Membrane Stress	168.29	-206.85	Small End Tang.
Tensile Stress	202.10	413.70	Cone Longitudinal
Compres. Stress	-107.21	-413.70	Cone Longitudinal
Compres Stress	180.01	-206.85	Cone Tangential

Tensile Stress	371.50	413.70	Large Cyl. Long.
Compres. Stress	-242.27	-413.70	Large Cyl. Long.
Membrane Stress	-20.95	-206.85	Large End Tang.
Tensile Stress	303.98	413.70	Cone Longitudinal
Compres. Stress	-173.87	-413.70	Cone Longitudinal
Compres Stress	-20.08	-206.85	Cone Tangential

Note: An asterisk (*) denotes that this stress was not applicable
for this combination of loads.

Maximum Allowable Pressure Calculations for Cone to Shell Junction:

Pressure Case	Pressure bars	Reason for Failure at this Pressure
MAWP	23.161	Small End Reinforcement
MAPnc	28.825	Small End Reinforcement

These pressures were determined by iteration.

Nozzle Calculation Summary:

Description	MAWP bars	Ext	MAPNC bars	UG-45	[tr] mm.	Weld Path	Areas or Stresses
T2	24.91	OK	...	OK	11.33	OK	Passed
T1	24.79	OK	...	OK	11.33	OK	Passed
D4	24.33	OK	...	OK	7.80	OK	Passed
S2	24.51	OK	...	OK	10.16	OK	Passed
S1	24.51	OK	...	OK	10.16	OK	Passed
S3	24.51	OK	...	OK	10.16	OK	Passed
D2	24.51	OK	...	OK	7.80	OK	Passed
D1	24.51	OK	...	OK	7.80	OK	Passed
D3	24.51	OK	...	OK	7.80	OK	Passed
TT	24.51	OK	...	OK	7.80	OK	Passed
V	24.51	OK	...	OK	7.80	OK	Passed
S4	24.51	OK	...	OK	10.16	OK	Passed
LG1	24.51	OK	...	OK	7.80	OK	Passed
LG2	24.51	OK	...	OK	7.80	OK	Passed
LT1	24.51	OK	...	OK	6.42	OK	Passed
LT3	24.51	OK	...	OK	6.42	OK	Passed
LT2	24.51	OK	...	OK	6.42	OK	Passed
LT4	24.51	OK	...	OK	6.42	OK	Passed

MAWP Summary:

Minimum MAWP Nozzles : 24.330 Nozzle : D4

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

Check the Spatial Relationship between the Nozzles

From Node	Nozzle Description	X Coordinate mm.	Layout Angle deg	Dia. Limit mm.
20	T2	450.000	90.000	948.000
20	T1	450.000	270.000	948.000
60	D4	1915.525	270.000	118.000
70	S2	2545.525	270.000	405.700
70	S1	5145.525	270.000	405.700
70	S3	2945.525	90.000	405.700
70	D2	2945.525	270.000	114.000
70	D1	4745.525	270.000	114.000
70	D3	5545.525	270.000	114.000
70	TT	6145.525	270.000	114.000
70	V	2545.525	90.000	114.000
70	S4	5145.525	90.000	405.700
70	LG1	4545.525	270.000	114.000
70	LG2	4545.525	90.000	114.000
70	LT1	3345.525	90.000	115.034
70	LT3	3845.525	90.000	115.034
70	LT2	3345.525	270.000	115.034
70	LT4	3845.525	270.000	115.034

The nozzle spacing is computed by the following:

= $\mathrm{Sqrt}(ll^2 + lc^2)$ 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

```
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601    ------
Nozzle Summary:                       Step:   36  11:47am  Dec 23,2021
```

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

Input, Nozzle Desc: T2 From: 20

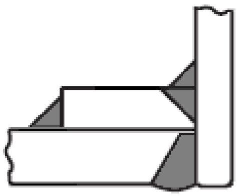
```
Pressure for Reinforcement Calculations       P      23.000  bars
Temperature for Internal Pressure          Temp         125  °C
Design External Pressure                   Pext        1.03  bars
Temperature for External Pressure        Tempex         125  °C

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     1200.00  mm.
Design Length of Section                      L    949.9999  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                    450.00  mm.

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

Type of Element Connected to the Shell : Nozzle

```
Material        [Normalized]                      SA-516 70
Material UNS Number                                  K02700
Material Specification/Type                           Plate
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)                      OD
Layout Angle                                          90.00  deg
Diameter                                            20.0000  in.

Size and Thickness Basis                              Actual
Actual Thickness                             tn     20.0000  mm.

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    150.0000  mm.
Weld leg size between Nozzle and Pad/Shell   Wo     18.0000  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    748.0000  mm.
Thickness of Pad                             te     20.0000  mm.
Weld leg size between Pad and Shell          Wp     12.0000  mm.
Groove weld depth between Pad and Nozzle   Wgpn     15.0000  mm.
Reinforcing Pad Width                              120.0000  mm.

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


The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: T2

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

```
Actual Outside Diameter Used in Calculation          20.000  in.
Actual Thickness Used in Calculation                  0.787  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*603.0)/(138*1.0-0.6*23.0)
  = 10.1595 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*254.0)/(138*1.0+0.4*23.0)
  = 4.2086 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.9797 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)             Dl   948.0001  mm.
Parallel to Vessel Wall, opening length               d   474.0000  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp    30.0000  mm.
```

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

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

Weld Strength Reduction Factor [fr4]:
```
  = min( 1, Sp/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	48.156	8.366	NA
Area in Shell	A1	8.724	40.149	NA
Area in Nozzle Wall	A2	7.675	9.612	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	4.040	4.040	NA
Area in Element	A5	36.000	36.000	NA
TOTAL AREA AVAILABLE	Atot	56.439	89.801	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:	692.7844	20.0000	mm.
Based on given Pad Diameter:	748.0001	15.3987	mm.
Based on Shell or Nozzle Thickness:	754.3792	15.0000	mm.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (474.0*10.1595*1.0+2*17.0*10.1595*1.0*(1-1.0))
  = 48.156 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 )
  = 474.0( 1.0 * 12.0 - 1.0 * 10.16 ) - 2 * 17.0
    ( 1.0 * 12.0 - 1.0 * 10.1595 ) * ( 1 - 1.0 )
  = 8.724 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 30.0 ) * ( 17.0 - 4.21 ) * 1.0
  = 7.675 cm^2
```

Area Available in Welds [A41 + A42 + A43]:
```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
  = (2.6 ) * 1.0 + (0.0 ) * 1.0 + 304.8² * 1.0
  = 4.040 cm^2
```

Area Available in Element, also see UG-37(h) [A5]:
```
  = (min(Dp,DL)-(Nozzle OD))(min(tp,Tlwp,te)) * fr4 * 0.75
  = ( 748.0 - 508.0 )20.0 * 1.0 * 0.75
  = 36.000 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures       ta = 7.2086 mm.
 Wall Thickness per UG16(b),                        tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 13.1595 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 13.1595 mm.
```

```
Wall Thickness, shell/head, external pressure      trb2 = 3.4525 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( 13.1595, 4.5 ) ]
= 11.3312 mm.
```

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

```
= max( ta, tb )
= max( 7.2086, 11.3312 )
= 11.3312 mm.
```

Available Nozzle Neck Thickness = 20.0000 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    :     32.6,  Allowable :    137.9 N./mm^2  Passed
Expansion    :      0.0,  Allowable :    312.2 N./mm^2  Passed
Occasional   :     15.5,  Allowable :    183.4 N./mm^2  Passed
Shear        :     11.0,  Allowable :     96.5 N./mm^2  Passed
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: D

Govrn. thk, tg = 20.0, tr = 4.209, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.248, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve D              -40 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C
```

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

Govrn. thk, tg = 20.0, tr = 4.209, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.248, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve D              -40 °C
Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C
```

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

Govrn. thk, tg = 20.0, tr = 4.209, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.248, Temp. Reduction = 78 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve D              -40 °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 = 10.16, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.847, 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 = 10.16, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.847, 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                        :   -48 °C
Governing MDMT of the Reinforcement Pad             :   -48 °C
Governing MDMT of all the sub-joints of this Junction  :   -48 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 23.00/51.10 = 0.450

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

Weld Size Calculations, Description: T2

```
Intermediate Calc. for nozzle/shell Welds   Tmin      17.0000  mm.
Intermediate Calc. for pad/shell Welds   TminPad      12.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness     Actual Thickness
Nozzle Weld         11.9000 = 0.7 * tmin. 12.7260 = 0.7 * Wo mm.
Pad Weld             6.0000 = 0.5*TminPad  8.4840 = 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, (48.1563 - 8.7237 + 2 * 17.0 * 1.0 *
    (1.0 * 12.0 - 10.1595 ) )138)
  = 552.36 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 7.6749 + 36.0 + 4.04 - 0.0 * 1.0 ) * 138
  = 657.93 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 7.6749 + 0.0 + 3.24 + ( 4.08 ) ) * 138
  = 206.76 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 7.6749 + 0.0 + 4.04 + 36.0 + ( 4.08 ) ) * 138
  = 714.19 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 508.0 * 18.0 * 0.49 * 138
  = 970. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 748.0 * 12.0 * 0.49 * 138
  = 953. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 245.5) * ( 20.0 - 3.0 ) * 0.7 * 138
  = 1266. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 508.0 * 15.0 * 0.74 * 138
  = 1221. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 508.0 * ( 15.0 - 3.0 ) * 0.74 * 138
  = 977. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 953 + 1266 ) = 2218 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 970 + 1221 + 977 + 0 ) = 3169 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 953 + 977 + 0 ) = 1930 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 2218 kN , must exceed W = 552 kN  or W1 = 657 kN
 Path 2-2 = 3168 kN , must exceed W = 552 kN  or W2 = 206 kN
 Path 3-3 = 1929 kN , must exceed W = 552 kN  or W3 = 714 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case       24.907   bars

 Nozzle is O.K. for the External Pressure                1.034   bars
```

The Drop for this Nozzle is : 56.4156 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 221.4156 mm.

Percent Elongation Calculations:

```
 % Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro))  4.098 %
```

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    1200.000  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
```

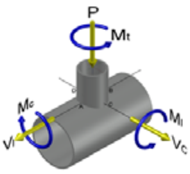

Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

```
 Attachment Type                                Type       Round

 Diameter Basis for Nozzle                    Nbasis       OD
 Corrosion Allowance for Nozzle                  Can       3.0000  mm.
 Nozzle Diameter                                  Dn      508.000  mm.
 Nozzle Thickness                                 Tn       20.000  mm.
 Nozzle Material                                        SA-516 70
 Nozzle UNS Number                                         K02700
 Nozzle Cold S.I. Allowable                     SNmc       137.90  N./mm^2
 Nozzle Hot  S.I. Allowable                     SNmh       137.90  N./mm^2

 Thickness of Reinforcing Pad                   Tpad       20.000  mm.
 Diameter  of Reinforcing Pad                   Dpad      748.000  mm.

 Design Internal Pressure                         Dp       23.000  bars
 Include Pressure Thrust                                       No
```

External Forces and Moments in WRC 107/537 Convention:

```
 Radial Load              (SUS)                    P         20.0  kN
 Longitudinal Shear       (SUS)                   Vl         20.0  kN
 Circumferential Shear    (SUS)                   Vc         20.0  kN
 Circumferential Moment   (SUS)                   Mc      28000.0  N-m
 Longitudinal Moment      (SUS)                   Ml      42500.1  N-m
 Torsional Moment         (SUS)                   Mt      52500.1  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 ) )
  = 508.0 + 2 * 1.65 * sqrt( 609.0 ( 15.0 - 3.0 ) )
  = 790.107 mm.
```

WRC 107 Stress Calculation for SUStained loads:

```
 Radial Load                                     P         20.0  kN
 Circumferential Shear                          VC         20.0  kN
```

Longitudinal Shear	VL	20.0	kN
Circumferential Moment	MC	28000.0	N-m
Longitudinal Moment	ML	42500.1	N-m
Torsional Moment	MT	52500.1	N-m

Dimensionless Parameters used : Gamma = 19.34

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.359	4C	2.373	(A,B)
N(PHI) / (P/Rm)	0.359	3C	1.389	(C,D)
M(PHI) / (P)	0.359	2C1	0.023	(A,B)
M(PHI) / (P)	0.359	1C !	0.057	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.359	3A	0.798	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.359	1A	0.075	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.359	3B	1.693	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.359	1B	0.019	(A,B,C,D)
N(x) / (P/Rm)	0.359	3C	1.389	(A,B)
N(x) / (P/Rm)	0.359	4C	2.373	(C,D)
M(x) / (P)	0.359	1C1	0.045	(A,B)
M(x) / (P)	0.359	2C !	0.030	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.359	4A	1.812	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.359	2A	0.034	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.359	4B	0.768	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.359	2B	0.032	(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	-2.4	-2.4	-2.4	-2.4	-1.4	-1.4	-1.4	-1.4
Circ. Bend.	P	-2.7	2.7	-2.7	2.7	-6.7	6.7	-6.7	6.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-5.1	-5.1	5.1	5.1
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-55.3	55.3	55.3	-55.3
Circ. Memb.	ML	-16.3	-16.3	16.3	16.3	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-20.9	20.9	20.9	-20.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-42.4	4.9	32.1	-4.2	-68.5	55.5	52.3	-44.9
Long. Memb.	P	-1.4	-1.4	-1.4	-1.4	-2.4	-2.4	-2.4	-2.4
Long. Bend.	P	-5.3	5.3	-5.3	5.3	-3.5	3.5	-3.5	3.5
Long. Memb.	MC	0.0	0.0	0.0	0.0	-11.5	-11.5	11.5	11.5
Long. Bend.	MC	0.0	0.0	0.0	0.0	-24.9	24.9	24.9	-24.9
Long. Memb.	ML	-7.4	-7.4	7.4	7.4	0.0	0.0	0.0	0.0
Long. Bend.	ML	-35.6	35.6	35.6	-35.6	0.0	0.0	0.0	0.0
Tot. Long. Str.		-49.7	32.1	36.4	-24.4	-42.3	14.5	30.5	-12.2
Shear	VC	0.8	0.8	-0.8	-0.8	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-0.8	-0.8	0.8	0.8

Shear MT	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Tot. Shear	4.8	4.8	3.3	3.3	3.3	3.3	4.8	4.8
Str. Int.	52.1	32.9	38.1	24.9	68.9	55.8	53.3	45.6

WARNING: Ratio of Pad Radius/Rm (.614) is not between 0.01 and 0.571.

Dimensionless Parameters used : Gamma = 50.75

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.537	4C !	2.960	(A,B)
N(PHI) / (P/Rm)	0.537	3C !	1.042	(C,D)
M(PHI) / (P)	0.537	2C1 !	0.004	(A,B)
M(PHI) / (P)	0.537	1C !	0.065	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.537	3A !	0.947	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.537	1A !	0.057	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.537	3B !	1.547	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.537	1B !	0.003	(A,B,C,D)
N(x) / (P/Rm)	0.537	3C !	1.042	(A,B)
N(x) / (P/Rm)	0.537	4C !	2.960	(C,D)
M(x) / (P)	0.537	1C1 !	0.010	(A,B)
M(x) / (P)	0.537	2C !	0.033	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.537	4A !	4.440	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.537	2A !	0.023	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.537	4B !	0.987	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.537	2B !	0.006	(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	-8.1	-8.1	-8.1	-8.1	-2.9	-2.9	-2.9	-2.9
Circ. Bend. P	-3.5	3.5	-3.5	3.5	-54.4	54.4	-54.4	54.4
Circ. Memb. MC	0.0	0.0	0.0	0.0	-11.1	-11.1	11.1	11.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	-203.2	203.2	203.2	-203.2
Circ. Memb. ML	-27.5	-27.5	27.5	27.5	0.0	0.0	0.0	0.0
Circ. Bend. ML	-18.6	18.6	18.6	-18.6	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-57.7	-13.5	34.4	4.3	-271.5	243.6	157.0	-140.6
Long. Memb. P	-2.9	-2.9	-2.9	-2.9	-8.1	-8.1	-8.1	-8.1
Long. Bend. P	-8.7	8.7	-8.7	8.7	-27.9	27.9	-27.9	27.9
Long. Memb. MC	0.0	0.0	0.0	0.0	-52.0	-52.0	52.0	52.0
Long. Bend. MC	0.0	0.0	0.0	0.0	-81.4	81.4	81.4	-81.4
Long. Memb. ML	-17.5	-17.5	17.5	17.5	0.0	0.0	0.0	0.0
Long. Bend. ML	-31.0	31.0	31.0	-31.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-60.1	19.4	37.0	-7.6	-169.4	49.2	97.4	-9.6

Shear VC	1.4	1.4	-1.4	-1.4	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.4	-1.4	1.4	1.4
Shear MT	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Tot. Shear	6.4	6.4	3.6	3.6	3.6	3.6	6.4	6.4
Str. Int.	65.4	35.2	39.5	13.9	271.6	243.7	157.7	140.9

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	42.2	44.5	42.2	44.5	42.2	44.5	42.2	44.5
Circ. Pl (SUS)	-18.7	-18.7	13.9	13.9	-6.5	-6.5	3.7	3.7
Circ. Q (SUS)	-23.6	23.6	18.2	-18.2	-62.0	62.0	48.6	-48.6
Long. Pm (SUS)	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1
Long. Pl (SUS)	-8.8	-8.8	6.0	6.0	-13.9	-13.9	9.1	9.1
Long. Q (SUS)	-40.9	40.9	30.4	-30.4	-28.4	28.4	21.3	-21.3
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.8	0.8	-0.8	-0.8	-0.8	-0.8	0.8	0.8
Shear Q (SUS)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Pm (SUS)	42.2	44.5	42.2	44.5	42.2	44.5	42.2	44.5
Pm+Pl (SUS)	23.5	25.8	56.2	58.5	35.8	38.1	45.9	48.2
Pm+Pl+Q (Total)	30.1	56.5	75.0	44.0	27.8	100.2	95.0	13.4

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	44.52	137.90	Passed
Pm+Pl (SUS)	58.48	206.85	Passed
Pm+Pl+Q (TOTAL)	100.21	413.70	Passed

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

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	114.4	116.7	114.4	116.7	114.4	116.7	114.4	116.7
Circ. Pl (SUS)	-35.6	-35.6	19.4	19.4	-13.9	-13.9	8.2	8.2
Circ. Q (SUS)	-22.1	22.1	15.0	-15.0	-257.6	257.6	148.8	-148.8

Long. Pm (SUS)	57.2	57.2	57.2	57.2	57.2	57.2	57.2	57.2
Long. Pl (SUS)	-20.4	-20.4	14.7	14.7	-60.1	-60.1	43.9	43.9
Long. Q (SUS)	-39.7	39.7	22.3	-22.3	-109.3	109.3	53.5	-53.5
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.4	1.4	-1.4	-1.4	-1.4	-1.4	1.4	1.4
Shear Q (SUS)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Pm (SUS)	114.4	116.7	114.4	116.7	114.4	116.7	114.4	116.7
Pm+Pl (SUS)	78.9	81.2	133.9	136.2	103.4	105.7	122.8	125.1
Pm+Pl+Q (Total)	61.0	104.7	149.1	121.3	157.3	360.4	271.8	72.5

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	116.74	137.90	Passed
Pm+Pl (SUS)	136.16	206.85	Passed
Pm+Pl+Q (TOTAL)	360.40	413.70	Passed

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

Input, Nozzle Desc: T1 From: 20

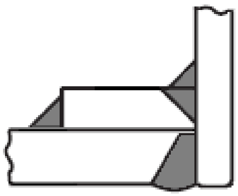
Pressure for Reinforcement Calculations	P	23.118	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1200.00	mm.
Design Length of Section	L	949.9999	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		450.00	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Normalized]		SA-516 70	
Material UNS Number		K02700	
Material Specification/Type		Plate	
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)		OD	
Layout Angle		270.00	deg
Diameter		20.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	20.0000	mm.
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	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	18.0000	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	748.0000	mm.
Thickness of Pad	te	20.0000	mm.
Weld leg size between Pad and Shell	Wp	12.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	15.0000	mm.
Reinforcing Pad Width		120.0000	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

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

```
Actual Outside Diameter Used in Calculation           20.000  in.
Actual Thickness Used in Calculation                   0.787  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*603.0)/(138*1.0-0.6*23.12)
  = 10.2120 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*254.0)/(138*1.0+0.4*23.12)
  = 4.2299 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.9797 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl   948.0001  mm.
Parallel to Vessel Wall, opening length              d   474.0000  mm.
Normal to Vessel Wall (Thickness Limit), pad side Tlwp    30.0000  mm.
```

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

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

Weld Strength Reduction Factor [fr4]:
```
  = min( 1, Sp/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	48.405	8.366	NA
Area in Shell	A1	8.475	40.149	NA
Area in Nozzle Wall	A2	7.662	9.612	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	4.040	4.040	NA
Area in Element	A5	36.000	36.000	NA
TOTAL AREA AVAILABLE	Atot	56.177	89.801	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:	696.1868	20.0000	mm.
Based on given Pad Diameter:	748.0001	15.6822	mm.
Based on Shell or Nozzle Thickness:	758.9158	15.0000	mm.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (474.0*10.212*1.0+2*17.0*10.212*1.0*(1-1.0))
  = 48.405 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 )
  = 474.0( 1.0 * 12.0 - 1.0 * 10.212 ) - 2 * 17.0
    ( 1.0 * 12.0 - 1.0 * 10.212 ) * ( 1 - 1.0 )
  = 8.475 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 30.0 ) * ( 17.0 - 4.23 ) * 1.0
  = 7.662 cm^2
```

Area Available in Welds [A41 + A42 + A43]:
```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Wp²*fr4
  = (2.6 ) * 1.0 + (0.0 ) * 1.0 + 304.8² * 1.0
  = 4.040 cm^2
```

Area Available in Element, also see UG-37(h) [A5]:
```
  = (min(Dp,DL)-(Nozzle OD))(min(tp,Tlwp,te)) * fr4 * 0.75
  = ( 748.0 - 508.0 )20.0 * 1.0 * 0.75
  = 36.000 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 7.2299 mm.
 Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 13.2120 mm.
 Wall Thickness                 tb1 = max(trb1, tr16b) = 13.2120 mm.
```

```
 Wall Thickness, shell/head, external pressure      trb2 = 3.4525 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( 13.212, 4.5 ) ]
  = 11.3312 mm.
```

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

```
  = max( ta, tb )
  = max( 7.2299, 11.3312 )
  = 11.3312 mm.
```

Available Nozzle Neck Thickness = 20.0000 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   :     32.7,  Allowable :    137.9 N./mm^2  Passed
 Expansion   :      0.0,  Allowable :    312.1 N./mm^2  Passed
 Occasional  :     15.6,  Allowable :    183.4 N./mm^2  Passed
 Shear       :     11.0,  Allowable :     96.5 N./mm^2  Passed
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: D

Govrn. thk, tg = 20.0, tr = 4.23, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.249, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D              -40 °C
 Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C
```

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

Govrn. thk, tg = 20.0, tr = 4.23, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.249, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D              -40 °C
 Min Metal Temp. at Required thickness (UCS 66.1)           -104 °C
```

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

Govrn. thk, tg = 20.0, tr = 4.23, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.249, Temp. Reduction = 78 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D              -40 °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 = 10.212, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.851, Temp. Reduction = 8 °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 = 10.212, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.851, Temp. Reduction = 8 °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                        :   -48 °C
Governing MDMT of the Reinforcement Pad             :   -48 °C
Governing MDMT of all the sub-joints of this Junction  :   -48 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 23.12/51.10 = 0.452

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

Weld Size Calculations, Description: T1

```
Intermediate Calc. for nozzle/shell Welds   Tmin      17.0000  mm.
Intermediate Calc. for pad/shell Welds    TminPad     12.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld         11.9000 = 0.7 * tmin. 12.7260 = 0.7 * Wo mm.
Pad Weld             6.0000 = 0.5*TminPad  8.4840 = 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, (48.405 - 8.475 + 2 * 17.0 * 1.0 *
  (1.0 * 12.0 - 10.212 ) )138)
= 558.97 kN
```

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

Weld Load [W1]:
```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 7.662 + 36.0 + 4.04 - 0.0 * 1.0 ) * 138
= 657.76 kN
```

Weld Load [W2]:
```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 7.662 + 0.0 + 3.24 + ( 4.08 ) ) * 138
= 206.58 kN
```

Weld Load [W3]:
```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 7.662 + 0.0 + 4.04 + 36.0 + ( 4.08 ) ) * 138
= 714.01 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 ) * 508.0 * 18.0 * 0.49 * 138
  = 970. kN
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 748.0 * 12.0 * 0.49 * 138
  = 953. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 245.5) * ( 20.0 - 3.0 ) * 0.7 * 138
  = 1266. kN
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  =  (3.1416/2 ) * 508.0 * 15.0 * 0.74 * 138
  = 1221. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 508.0 * ( 15.0 - 3.0 ) * 0.74 * 138
  = 977. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 953 + 1266 ) = 2218 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 970 + 1221 + 977 + 0 ) = 3169 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 953 + 977 + 0 ) = 1930 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 2218 kN , must exceed W = 558 kN  or W1 = 657 kN
 Path 2-2 = 3168 kN , must exceed W = 558 kN  or W2 = 206 kN
 Path 3-3 = 1929 kN , must exceed W = 558 kN  or W3 = 714 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case       24.907   bars

 Nozzle is O.K. for the External Pressure                1.034   bars
```

The Drop for this Nozzle is : 56.4156 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 221.4156 mm.

Percent Elongation Calculations:

```
 % Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro))  4.098 %
```

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    1200.000  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:Evaporator E-PK1601
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601 ------
Nozzle Calcs.: T1 Nozl: 20 11:47am Dec 23,2021

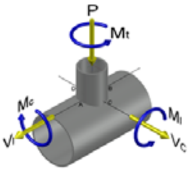
Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

```
 Attachment Type                              Type      Round

 Diameter Basis for Nozzle                  Nbasis      OD
 Corrosion Allowance for Nozzle                Can      3.0000  mm.
 Nozzle Diameter                                Dn    508.000  mm.
 Nozzle Thickness                               Tn     20.000  mm.
 Nozzle Material                                   SA-516 70
 Nozzle UNS Number                                  K02700
 Nozzle Cold S.I. Allowable                   SNmc     137.90  N./mm^2
 Nozzle Hot  S.I. Allowable                   SNmh     137.90  N./mm^2

 Thickness of Reinforcing Pad                 Tpad     20.000  mm.
 Diameter  of Reinforcing Pad                 Dpad    748.000  mm.

 Design Internal Pressure                       Dp     23.118  bars
 Include Pressure Thrust                                   No
```

External Forces and Moments in WRC 107/537 Convention:

```
 Radial Load            (SUS)                    P       20.0  kN
 Longitudinal Shear     (SUS)                   Vl       20.0  kN
 Circumferential Shear  (SUS)                   Vc       20.0  kN
 Circumferential Moment (SUS)                   Mc    28000.0  N-m
 Longitudinal Moment    (SUS)                   Ml    42500.1  N-m
 Torsional Moment       (SUS)                   Mt    52500.1  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 ) )
  = 508.0 + 2 * 1.65 * sqrt( 609.0 ( 15.0 - 3.0 ) )
  = 790.107 mm.
```

WRC 107 Stress Calculation for SUStained loads:

```
 Radial Load                                   P         20.0  kN
 Circumferential Shear                        VC         20.0  kN
```

Longitudinal Shear	VL	20.0	kN
Circumferential Moment	MC	28000.0	N-m
Longitudinal Moment	ML	42500.1	N-m
Torsional Moment	MT	52500.1	N-m

Dimensionless Parameters used : Gamma = 19.34

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.359	4C	2.373	(A,B)
N(PHI) / (P/Rm)	0.359	3C	1.389	(C,D)
M(PHI) / (P)	0.359	2C1	0.023	(A,B)
M(PHI) / (P)	0.359	1C !	0.057	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.359	3A	0.798	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.359	1A	0.075	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.359	3B	1.693	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.359	1B	0.019	(A,B,C,D)
N(x) / (P/Rm)	0.359	3C	1.389	(A,B)
N(x) / (P/Rm)	0.359	4C	2.373	(C,D)
M(x) / (P)	0.359	1C1	0.045	(A,B)
M(x) / (P)	0.359	2C !	0.030	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.359	4A	1.812	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.359	2A	0.034	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.359	4B	0.768	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.359	2B	0.032	(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	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-2.4	-2.4	-2.4	-2.4	-1.4	-1.4	-1.4	-1.4
Circ. Bend.	P	-2.7	2.7	-2.7	2.7	-6.7	6.7	-6.7	6.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-5.1	-5.1	5.1	5.1
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-55.3	55.3	55.3	-55.3
Circ. Memb.	ML	-16.3	-16.3	16.3	16.3	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-20.9	20.9	20.9	-20.9	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-42.4	4.9	32.1	-4.2	-68.5	55.5	52.3	-44.9
Long. Memb.	P	-1.4	-1.4	-1.4	-1.4	-2.4	-2.4	-2.4	-2.4
Long. Bend.	P	-5.3	5.3	-5.3	5.3	-3.5	3.5	-3.5	3.5
Long. Memb.	MC	0.0	0.0	0.0	0.0	-11.5	-11.5	11.5	11.5
Long. Bend.	MC	0.0	0.0	0.0	0.0	-24.9	24.9	24.9	-24.9
Long. Memb.	ML	-7.4	-7.4	7.4	7.4	0.0	0.0	0.0	0.0
Long. Bend.	ML	-35.6	35.6	35.6	-35.6	0.0	0.0	0.0	0.0
Tot. Long. Str.		-49.7	32.1	36.4	-24.4	-42.3	14.5	30.5	-12.2
Shear	VC	0.8	0.8	-0.8	-0.8	0.0	0.0	0.0	0.0
Shear	VL	0.0	0.0	0.0	0.0	-0.8	-0.8	0.8	0.8

Shear MT	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Tot. Shear	4.8	4.8	3.3	3.3	3.3	3.3	4.8	4.8
Str. Int.	52.1	32.9	38.1	24.9	68.9	55.8	53.3	45.6

WARNING: Ratio of Pad Radius/Rm (.614) is not between 0.01 and 0.571.

Dimensionless Parameters used : Gamma = 50.75

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.537	4C !	2.960	(A,B)
N(PHI) / (P/Rm)	0.537	3C !	1.042	(C,D)
M(PHI) / (P)	0.537	2C1 !	0.004	(A,B)
M(PHI) / (P)	0.537	1C !	0.065	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.537	3A !	0.947	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.537	1A !	0.057	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.537	3B !	1.547	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.537	1B !	0.003	(A,B,C,D)
N(x) / (P/Rm)	0.537	3C !	1.042	(A,B)
N(x) / (P/Rm)	0.537	4C !	2.960	(C,D)
M(x) / (P)	0.537	1C1 !	0.010	(A,B)
M(x) / (P)	0.537	2C !	0.033	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.537	4A !	4.440	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.537	2A !	0.023	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.537	4B !	0.987	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.537	2B !	0.006	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
		Stress Intensity Values at							
Circ. Memb.	P	-8.1	-8.1	-8.1	-8.1	-2.9	-2.9	-2.9	-2.9
Circ. Bend.	P	-3.5	3.5	-3.5	3.5	-54.4	54.4	-54.4	54.4
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-11.1	-11.1	11.1	11.1
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-203.2	203.2	203.2	-203.2
Circ. Memb.	ML	-27.5	-27.5	27.5	27.5	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-18.6	18.6	18.6	-18.6	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-57.7	-13.5	34.4	4.3	-271.5	243.6	157.0	-140.6
Long. Memb.	P	-2.9	-2.9	-2.9	-2.9	-8.1	-8.1	-8.1	-8.1
Long. Bend.	P	-8.7	8.7	-8.7	8.7	-27.9	27.9	-27.9	27.9
Long. Memb.	MC	0.0	0.0	0.0	0.0	-52.0	-52.0	52.0	52.0
Long. Bend.	MC	0.0	0.0	0.0	0.0	-81.4	81.4	81.4	-81.4
Long. Memb.	ML	-17.5	-17.5	17.5	17.5	0.0	0.0	0.0	0.0
Long. Bend.	ML	-31.0	31.0	31.0	-31.0	0.0	0.0	0.0	0.0
Tot. Long. Str.		-60.1	19.4	37.0	-7.6	-169.4	49.2	97.4	-9.6

Shear VC	1.4	1.4	-1.4	-1.4	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.4	-1.4	1.4	1.4
Shear MT	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Tot. Shear	6.4	6.4	3.6	3.6	3.6	3.6	6.4	6.4
Str. Int.	65.4	35.2	39.5	13.9	271.6	243.7	157.7	140.9

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	42.4	44.8	42.4	44.8	42.4	44.8	42.4	44.8
Circ. Pl (SUS)	-18.7	-18.7	13.9	13.9	-6.5	-6.5	3.7	3.7
Circ. Q (SUS)	-23.6	23.6	18.2	-18.2	-62.0	62.0	48.6	-48.6
Long. Pm (SUS)	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2
Long. Pl (SUS)	-8.8	-8.8	6.0	6.0	-13.9	-13.9	9.1	9.1
Long. Q (SUS)	-40.9	40.9	30.4	-30.4	-28.4	28.4	21.3	-21.3
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.8	0.8	-0.8	-0.8	-0.8	-0.8	0.8	0.8
Shear Q (SUS)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Pm (SUS)	42.4	44.8	42.4	44.8	42.4	44.8	42.4	44.8
Pm+Pl (SUS)	23.8	26.1	56.4	58.7	36.0	38.3	46.1	48.5
Pm+Pl+Q (Total)	30.2	56.6	75.2	44.1	27.7	100.4	95.3	13.3

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	44.75	137.90	Passed
Pm+Pl (SUS)	58.71	206.85	Passed
Pm+Pl+Q (TOTAL)	100.44	413.70	Passed

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

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	115.0	117.3	115.0	117.3	115.0	117.3	115.0	117.3
Circ. Pl (SUS)	-35.6	-35.6	19.4	19.4	-13.9	-13.9	8.2	8.2
Circ. Q (SUS)	-22.1	22.1	15.0	-15.0	-257.6	257.6	148.8	-148.8

Long. Pm (SUS)	57.5	57.5	57.5	57.5	57.5	57.5	57.5	57.5
Long. Pl (SUS)	-20.4	-20.4	14.7	14.7	-60.1	-60.1	43.9	43.9
Long. Q (SUS)	-39.7	39.7	22.3	-22.3	-109.3	109.3	53.5	-53.5
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	1.4	1.4	-1.4	-1.4	-1.4	-1.4	1.4	1.4
Shear Q (SUS)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Pm (SUS)	115.0	117.3	115.0	117.3	115.0	117.3	115.0	117.3
Pm+Pl (SUS)	79.5	81.8	134.4	136.8	103.7	106.0	123.4	125.7
Pm+Pl+Q (Total)	61.2	105.3	149.7	121.9	156.7	361.0	272.4	72.2

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	117.34	137.90	Passed
Pm+Pl (SUS)	136.76	206.85	Passed
Pm+Pl+Q (TOTAL)	361.00	413.70	Passed

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

Input, Nozzle Desc: D4 From: 60

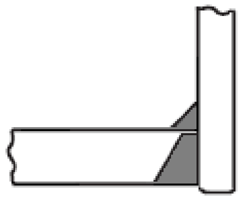
```
Pressure for Reinforcement Calculations         P      23.051  bars
Temperature for Internal Pressure            Temp         125  °C
Design External Pressure                     Pext        1.03  bars
Temperature for External Pressure          Tempex         125  °C

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 Cone at Nozzle Location      D     1419.76  mm.
Equivalent Length of Conical Section           Le   5217.9990  mm.
Cone Half Apex Angle                        Alpha       28.78  Degrees
Shell Finished (Minimum) Thickness              t     20.0000  mm.
Shell Internal Corrosion Allowance              c      3.0000  mm.
Shell External Corrosion Allowance             co      0.0000  mm.

Distance from Bottom/Left Tangent                     1915.53  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                                               2.0000  in.

Size and Thickness Basis                               Actual
Actual Thickness                               tn     16.6000  mm.

Flange Material [Normalized]                       SA-350 LF2
Flange Type                                    Long Weld Neck

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

Outside Projection                             ho    150.0000  mm.
Weld leg size between Nozzle and Pad/Shell     Wo     10.0000  mm.
Groove weld depth between Nozzle and Vessel Wgnv      20.0000  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: D4

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

```
 Actual Inside Diameter Used in Calculation              2.000  in.
 Actual Thickness Used in Calculation                    0.654  in.
```

Nozzle input data check completed without errors.

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

```
  = (P*D)/(2*cos(a)*(Sv*E-0.6*P)) Appendix 1-4(e)
  = (23.05*(1426.605+2*0.0))/( 2*0.8764*(138*1.0-0.6*23.05))
  = 13.7432 mm.
```

Reqd Cone thickness at Nozzle Location under External Pres. : 11.6968 mm.

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

```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (23.05*28.4)/(138*1.0-0.6*23.05)
  = 0.4796 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3431 mm.

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

```
 Parallel to Vessel Wall (Diameter Limit)            Dl   118.0000  mm.
 Parallel to Vessel Wall                        Rn+tn+t    59.0000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    34.0000  mm.
```

Weld Strength Reduction Factor [fr1]:

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

Weld Strength Reduction Factor [fr2]:

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

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 1.0, 1.0 )
  = 1.000
```

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

```
 AREA AVAILABLE, A1 to A5     |     Design|  External|     Mapnc|
 ---------------------------------------------------------------
```

Area Required	Ar	7.806	2.470	NA
Area in Shell	A1	1.993	5.082	NA
Area in Nozzle Wall	A2	8.922	9.015	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	11.915	15.096	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (56.8*13.7432*1.0+2*13.6*13.7432*1.0*(1-1.0))
  = 7.806 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 )
  = 61.2( 1.0 * 17.0 - 1.0 * 13.743 ) - 2 * 13.6
    ( 1.0 * 17.0 - 1.0 * 13.7432 ) * ( 1 - 1.0 )
  = 1.993 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 34.0 )( 13.6 - 0.48 )1.0
  = 8.922 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 = 3.4796 mm.
 Wall Thickness per UG16(b),                         tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure        trb1 = 16.7432 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 16.7432 mm.
 Wall Thickness, shell/head, external pressure        trb2 = 3.6107 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                        tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 16.7432, 4.5 ) ]
  = 7.8000 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.4796, 7.8 )
  = 7.8000 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

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

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

 Calculated Minimum Design Metal Temperature                -104 °C

 Governing MDMT of all the sub-joints of this Junction   :  -104 °C
```

Weld Size Calculations, Description: D4

```
 Intermediate Calc. for nozzle/shell Welds   Tmin     13.6000  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, (7.8061 - 1.9932 + 2 * 13.6 * 1.0 *
    (1.0 * 17.0 - 13.7432 ) )138)
  = 92.37 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 8.9219 + 0.0 + 1. - 0.0 * 1.0 ) * 138
  = 136.81 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 8.9219 + 0.0 + 1. + ( 4.624 ) ) * 138
  = 200.57 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.9219 + 0.0 + 1. + 0.0 + ( 4.624 ) ) * 138
  = 200.57 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 138
  = 145. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 84.0 * ( 20.0 - 3.0 ) * 0.74 * 138
  = 229. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89 + 145 ) = 234 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89 + 0 + 229 + 0 ) = 318 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89 + 229 + 0 ) = 318 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 234 kN , must exceed W = 92 kN  or W1 = 136 kN
 Path 2-2 = 318 kN , must exceed W = 92 kN  or W2 = 200 kN
 Path 3-3 = 318 kN , must exceed W = 92 kN  or W3 = 200 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case       24.381   bars
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
 Nozzle is O.K. for the External Pressure                1.034   bars
```

The Drop for this Nozzle is : 1.2436 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 171.2436 mm.

Input, Nozzle Desc: S2 From: 70

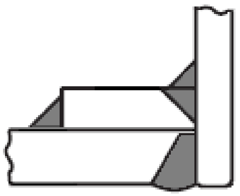
Pressure for Reinforcement Calculations	P	23.118	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		2545.53	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	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	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	18.0000	mm.
Weld leg size between Pad and Shell	Wp	14.0000	mm.
Groove weld depth between Pad and Nozzle	Wgpn	18.0000	mm.
Reinforcing Pad Width		80.0000	mm.
Class of attached Flange		300	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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



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

Reinforcement CALCULATION, Description: S2

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

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

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.12*831.0)/(138*1.0-0.6*23.12)
  = 14.0733 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)
  = 2.1311 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.5985 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     37.5000   mm.
```

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

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

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

Weld Strength Reduction Factor [fr3]:

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	28.879	8.910	NA
Area in Shell	A1	1.858	12.663	NA
Area in Nozzle Wall	A2	3.836	4.818	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	2.810	2.810	NA
Area in Element	A5	28.800	28.800	NA
TOTAL AREA AVAILABLE	Atot	37.304	49.092	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:	332.2690	18.0000	mm.
Based on given Pad Diameter:	379.0750	12.7343	mm.
Based on Shell or Nozzle Thickness:	402.4264	11.1125	mm.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (202.85*14.0733*1.0+2*8.1125*14.0733*1.0*(1-0.86))
  = 28.879 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 * 15.0 - 1.0 * 14.073 ) - 2 * 8.113
    ( 1.0 * 15.0 - 1.0 * 14.0733 ) * ( 1 - 0.855 )
  = 1.858 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 37.5 ) * ( 8.11 - 2.13 ) * 0.855
  = 3.836 cm^2
```

Area Available in Welds [A41 + A42 + A43]:
```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Trapfr4
  = ( 1. ) * 0.86 + (0.0 ) * 0.86 + 195.5274² * 1.0
  = 2.810 cm^2
```

Area Available in Element [A5]:
```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 379.075 - 219.075 ) * 18.0 * 1.0
  = 28.800 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 5.1311 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 17.0733 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 17.0733 mm.
```

```
 Wall Thickness, shell/head, external pressure     trb2 = 3.6235 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( 17.0733, 4.5 ) ]
  = 10.1600 mm.
```

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

```
  = max( ta, tb )
  = max( 5.1311, 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 = 18.0, tr = 14.073, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.938, Temp. Reduction = 3 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D              -43 °C
 Min Metal Temp. at Required thickness (UCS 66.1)            -46 °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                :    -46 °C
Governing MDMT of all the sub-joints of this Junction  :    -46 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ANSI B16.5/47 flange per Matl. Specification        -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)            -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      15.0000  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             7.5000 = 0.5*TminPad   9.8980 = 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, (28.8788 - 1.858 + 2 * 8.1125 * 0.855 *
  (1.0 * 15.0 - 14.0733 ) )138)
= 374.36 kN
```

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

Weld Load [W1]:
```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 3.8356 + 28.8 + 2.8103 - 0.0 * 0.86 ) * 138
= 488.76 kN
```

Weld Load [W2]:
```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 3.8356 + 0.0 + 0.855 + ( 2.0809 ) ) * 138
= 93.37 kN
```

Weld Load [W3]:
```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 3.8356 + 0.0 + 2.8103 + 28.8 + ( 2.0809 ) ) * 138
= 517.45 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 * 14.0 * 0.49 * 138
  = 563. 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 * 18.0 * 0.74 * 138
  = 632. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 219.075 * ( 18.0 - 3.0 ) * 0.74 * 138
  = 527. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 563 + 222 ) = 785 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 199 + 632 + 527 + 0 ) = 1358 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 563 + 527 + 0 ) = 1090 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 785 kN , must exceed W = 374 kN  or W1 = 488 kN
 Path 2-2 = 1357 kN , must exceed W = 374 kN  or W2 = 93 kN
 Path 3-3 = 1089 kN , must exceed W = 374 kN  or W3 = 517 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case      24.623  bars
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
 Nozzle is O.K. for the External Pressure               1.034  bars
```

The Drop for this Nozzle is : 7.2775 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 175.2774 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	1656.000	mm.
Vessel Thickness	Tv	18.000	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
```

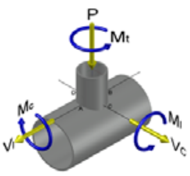
Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

```
 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      18.000  mm.
 Diameter  of Reinforcing Pad                 Dpad     379.075  mm.

 Design Internal Pressure                       Dp      23.118  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( 838.5 ( 18.0 - 3.0 ) )
  = 589.168 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 = 25.68

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.113	4C	4.590	(A,B)
N(PHI) / (P/Rm)	0.113	3C	3.985	(C,D)
M(PHI) / (P)	0.113	2C1	0.097	(A,B)
M(PHI) / (P)	0.113	1C	0.134	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.113	3A	0.723	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.113	1A	0.098	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.113	3B	2.471	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.113	1B	0.047	(A,B,C,D)
N(x) / (P/Rm)	0.113	3C	3.985	(A,B)
N(x) / (P/Rm)	0.113	4C	4.590	(C,D)
M(x) / (P)	0.113	1C1	0.136	(A,B)
M(x) / (P)	0.113	2C	0.097	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.113	4A	1.032	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.113	2A	0.054	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.113	4B	0.691	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.113	2B	0.078	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-1.3	-1.3	-1.3	-1.3	-1.1	-1.1	-1.1	-1.1
Circ. Bend. P	-4.3	4.3	-4.3	4.3	-5.9	5.9	-5.9	5.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	-1.8	-1.8	1.8	1.8
Circ. Memb. MC	0.0	0.0	0.0	0.0	-38.3	38.3	38.3	-38.3
Circ. Memb. ML	-6.3	-6.3	6.3	6.3	0.0	0.0	0.0	0.0
Circ. Bend. ML	-18.5	18.5	18.5	-18.5	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-30.3	15.1	19.1	-9.2	-47.1	41.2	33.1	-31.7
Long. Memb. P	-1.1	-1.1	-1.1	-1.1	-1.3	-1.3	-1.3	-1.3
Long. Bend. P	-6.0	6.0	-6.0	6.0	-4.3	4.3	-4.3	4.3
Long. Memb. MC	0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Long. Bend. MC	0.0	0.0	0.0	0.0	-21.2	21.2	21.2	-21.2
Long. Memb. ML	-1.8	-1.8	1.8	1.8	0.0	0.0	0.0	0.0
Long. Bend. ML	-30.7	30.7	30.7	-30.7	0.0	0.0	0.0	0.0
Tot. Long. Str.	-39.5	33.8	25.3	-24.0	-29.4	21.5	18.3	-15.6
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	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4

Tot. Shear	4.1	4.1	2.7	2.7	2.7	2.7	4.1	4.1
Str. Int.	41.1	34.6	26.3	24.5	47.5	41.5	34.1	32.7

Dimensionless Parameters used : Gamma = 55.90

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.198	4C	7.314	(A,B)
N(PHI) / (P/Rm)	0.198	3C	4.343	(C,D)
M(PHI) / (P)	0.198	2C1	0.028	(A,B)
M(PHI) / (P)	0.198	1C !	0.066	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.198	3A	2.187	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.198	1A	0.069	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.198	3B	5.207	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.198	1B	0.020	(A,B,C,D)
N(x) / (P/Rm)	0.198	3C	4.343	(A,B)
N(x) / (P/Rm)	0.198	4C	7.314	(C,D)
M(x) / (P)	0.198	1C1	0.058	(A,B)
M(x) / (P)	0.198	2C !	0.034	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.198	4A	4.611	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.198	2A	0.032	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.198	4B	2.241	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.198	2B	0.028	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-4.7	-4.7	-4.7	-4.7	-2.8	-2.8	-2.8	-2.8
Circ. Bend. P	-6.0	6.0	-6.0	6.0	-14.0	14.0	-14.0	14.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	-7.1	-7.1	7.1	7.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	-75.4	75.4	75.4	-75.4
Circ. Memb. ML	-17.0	-17.0	17.0	17.0	0.0	0.0	0.0	0.0
Circ. Bend. ML	-22.0	22.0	22.0	-22.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-49.6	6.4	28.4	-3.8	-99.4	79.6	65.7	-57.0
Long. Memb. P	-2.8	-2.8	-2.8	-2.8	-4.7	-4.7	-4.7	-4.7
Long. Bend. P	-12.4	12.4	-12.4	12.4	-7.2	7.2	-7.2	7.2
Long. Memb. MC	0.0	0.0	0.0	0.0	-15.0	-15.0	15.0	15.0
Long. Bend. MC	0.0	0.0	0.0	0.0	-34.8	34.8	34.8	-34.8
Long. Memb. ML	-7.3	-7.3	7.3	7.3	0.0	0.0	0.0	0.0
Long. Bend. ML	-30.8	30.8	30.8	-30.8	0.0	0.0	0.0	0.0
Tot. Long. Str.	-53.3	33.1	22.9	-13.8	-61.7	22.4	37.9	-17.2
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	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5

Tot. Shear	3.4	3.4	1.6	1.6	1.6	1.6	3.4	3.4
Str. Int.	55.3	33.5	28.8	14.0	99.4	79.6	66.1	57.3

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)	57.1	59.4	57.1	59.4	57.1	59.4	57.1	59.4
Circ. Pl (SUS)	-7.6	-7.6	5.0	5.0	-3.0	-3.0	0.7	0.7
Circ. Q (SUS)	-22.7	22.7	14.2	-14.2	-44.2	44.2	32.4	-32.4
Long. Pm (SUS)	28.5	28.5	28.5	28.5	28.5	28.5	28.5	28.5
Long. Pl (SUS)	-2.9	-2.9	0.6	0.6	-3.9	-3.9	1.3	1.3
Long. Q (SUS)	-36.7	36.7	24.7	-24.7	-25.5	25.5	16.9	-16.9
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)	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Pm (SUS)	57.1	59.4	57.1	59.4	57.1	59.4	57.1	59.4
Pm+Pl (SUS)	49.5	51.8	62.1	64.4	54.1	56.4	57.8	60.1
Pm+Pl+Q (Total)	38.7	75.8	76.5	50.3	12.1	100.7	90.6	28.7

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	59.40	137.90	Passed
Pm+Pl (SUS)	64.36	206.85	Passed
Pm+Pl+Q (TOTAL)	100.73	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)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Circ. Pl (SUS)	-21.6	-21.6	12.3	12.3	-9.9	-9.9	4.4	4.4
Circ. Q (SUS)	-28.0	28.0	16.1	-16.1	-89.5	89.5	61.4	-61.4
Long. Pm (SUS)	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5
Long. Pl (SUS)	-10.1	-10.1	4.5	4.5	-19.7	-19.7	10.4	10.4
Long. Q (SUS)	-43.2	43.2	18.3	-18.3	-42.1	42.1	27.6	-27.6

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)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Pm (SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Pm+Pl (SUS)	105.3	107.6	139.3	141.6	117.1	119.4	131.3	133.6
Pm+Pl+Q (Total)	77.5	135.9	155.4	125.5	27.7	208.8	192.8	72.7

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	129.25	137.90	Passed
Pm+Pl (SUS)	141.57	206.85	Passed
Pm+Pl+Q (TOTAL)	208.84	413.70	Passed

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

Input, Nozzle Desc: S1 From: 70

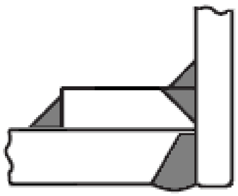
```
Pressure for Reinforcement Calculations        P      23.118  bars
Temperature for Internal Pressure           Temp         125  °C
Design External Pressure                    Pext        1.03  bars
Temperature for External Pressure         Tempex         125  °C

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     1656.00  mm.
Design Length of Section                       L   5217.9990  mm.
Shell Finished (Minimum) Thickness             t     18.0000  mm.
Shell Internal Corrosion Allowance             c      3.0000  mm.
Shell External Corrosion Allowance            co      0.0000  mm.

Distance from Bottom/Left Tangent                    5145.53  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    150.0000  mm.
Weld leg size between Nozzle and Pad/Shell    Wo     10.0000  mm.
Groove weld depth between Nozzle and Vessel Wgnv     18.0000  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     18.0000  mm.
Weld leg size between Pad and Shell           Wp     14.0000  mm.
Groove weld depth between Pad and Nozzle    Wgpn     18.0000  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: S1

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*831.0)/(138*1.0-0.6*23.12)
  = 14.0733 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)
  = 2.1311 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.5985 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    37.5000  mm.
```

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

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

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

Weld Strength Reduction Factor [fr3]:

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	28.879	8.910	NA
Area in Shell	A1	1.858	12.663	NA
Area in Nozzle Wall	A2	3.836	4.818	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	2.810	2.810	NA
Area in Element	A5	28.800	28.800	NA
TOTAL AREA AVAILABLE	Atot	37.304	49.092	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:	332.2690	18.0000	mm.
Based on given Pad Diameter:	379.0750	12.7343	mm.
Based on Shell or Nozzle Thickness:	402.4264	11.1125	mm.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (202.85*14.0733*1.0+2*8.1125*14.0733*1.0*(1-0.86))
  = 28.879 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 * 15.0 - 1.0 * 14.073 ) - 2 * 8.113
    ( 1.0 * 15.0 - 1.0 * 14.0733 ) * ( 1 - 0.855 )
  = 1.858 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 37.5 ) * ( 8.11 - 2.13 ) * 0.855
  = 3.836 cm^2
```

Area Available in Welds [A41 + A42 + A43]:
```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Trapfr4
  = ( 1. ) * 0.86 + (0.0 ) * 0.86 + 195.5274² * 1.0
  = 2.810 cm^2
```

Area Available in Element [A5]:
```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 379.075 - 219.075 ) * 18.0 * 1.0
  = 28.800 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures       ta = 5.1311 mm.
 Wall Thickness per UG16(b),                        tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 17.0733 mm.
 Wall Thickness                   tb1 = max(trb1, tr16b) = 17.0733 mm.
```

```
 Wall Thickness, shell/head, external pressure     trb2 = 3.6235 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( 17.0733, 4.5 ) ]
  = 10.1600 mm.
```

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

```
  = max( ta, tb )
  = max( 5.1311, 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 = 18.0, tr = 14.073, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.938, Temp. Reduction = 3 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D              -43 °C
 Min Metal Temp. at Required thickness (UCS 66.1)            -46 °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                :    -46 °C
Governing MDMT of all the sub-joints of this Junction  :    -46 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ANSI B16.5/47 flange per Matl. Specification        -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)            -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: S1

```
Intermediate Calc. for nozzle/shell Welds   Tmin       8.1125  mm.
Intermediate Calc. for pad/shell Welds    TminPad     15.0000  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	7.5000 = 0.5*TminPad	9.8980 = 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, (28.8788 - 1.858 + 2 * 8.1125 * 0.855 *
    (1.0 * 15.0 - 14.0733 ) )138)
  = 374.36 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.8356 + 28.8 + 2.8103 - 0.0 * 0.86 ) * 138
  = 488.76 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.8356 + 0.0 + 0.855 + ( 2.0809 ) ) * 138
  = 93.37 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.8356 + 0.0 + 2.8103 + 28.8 + ( 2.0809 ) ) * 138
  = 517.45 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 * 14.0 * 0.49 * 138
  = 563. 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 * 18.0 * 0.74 * 138
  = 632. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 219.075 * ( 18.0 - 3.0 ) * 0.74 * 138
  = 527. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 563 + 222 ) = 785 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 199 + 632 + 527 + 0 ) = 1358 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 563 + 527 + 0 ) = 1090 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 785 kN , must exceed W = 374 kN  or W1 = 488 kN
 Path 2-2 = 1357 kN , must exceed W = 374 kN  or W2 = 93 kN
 Path 3-3 = 1089 kN , must exceed W = 374 kN  or W3 = 517 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case       24.623   bars
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
 Nozzle is O.K. for the External Pressure                1.034   bars
```

The Drop for this Nozzle is : 7.2775 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 175.2774 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	1656.000	mm.
Vessel Thickness	Tv	18.000	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

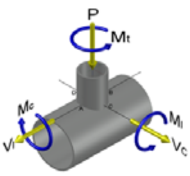
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	219.075	mm.
Nozzle Thickness	Tn	11.113	mm.
Nozzle Material		SA-333 6	
Nozzle UNS Number		K03006	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm^2
Thickness of Reinforcing Pad	Tpad	18.000	mm.
Diameter of Reinforcing Pad	Dpad	379.075	mm.
Design Internal Pressure	Dp	23.118	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(838.5 (18.0 - 3.0))
= 589.168 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 = 25.68

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.113	4C	4.590	(A,B)
N(PHI) / (P/Rm)	0.113	3C	3.985	(C,D)
M(PHI) / (P)	0.113	2C1	0.097	(A,B)
M(PHI) / (P)	0.113	1C	0.134	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.113	3A	0.723	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.113	1A	0.098	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.113	3B	2.471	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.113	1B	0.047	(A,B,C,D)
N(x) / (P/Rm)	0.113	3C	3.985	(A,B)
N(x) / (P/Rm)	0.113	4C	4.590	(C,D)
M(x) / (P)	0.113	1C1	0.136	(A,B)
M(x) / (P)	0.113	2C	0.097	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.113	4A	1.032	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.113	2A	0.054	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.113	4B	0.691	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.113	2B	0.078	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-1.3	-1.3	-1.3	-1.3	-1.1	-1.1	-1.1	-1.1
Circ. Bend. P	-4.3	4.3	-4.3	4.3	-5.9	5.9	-5.9	5.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	-1.8	-1.8	1.8	1.8
Circ. Memb. MC	0.0	0.0	0.0	0.0	-38.3	38.3	38.3	-38.3
Circ. Memb. ML	-6.3	-6.3	6.3	6.3	0.0	0.0	0.0	0.0
Circ. Bend. ML	-18.5	18.5	18.5	-18.5	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-30.3	15.1	19.1	-9.2	-47.1	41.2	33.1	-31.7
Long. Memb. P	-1.1	-1.1	-1.1	-1.1	-1.3	-1.3	-1.3	-1.3
Long. Bend. P	-6.0	6.0	-6.0	6.0	-4.3	4.3	-4.3	4.3
Long. Memb. MC	0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Long. Bend. MC	0.0	0.0	0.0	0.0	-21.2	21.2	21.2	-21.2
Long. Memb. ML	-1.8	-1.8	1.8	1.8	0.0	0.0	0.0	0.0
Long. Bend. ML	-30.7	30.7	30.7	-30.7	0.0	0.0	0.0	0.0
Tot. Long. Str.	-39.5	33.8	25.3	-24.0	-29.4	21.5	18.3	-15.6
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	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4

Tot. Shear	4.1	4.1	2.7	2.7	2.7	2.7	4.1	4.1
Str. Int.	41.1	34.6	26.3	24.5	47.5	41.5	34.1	32.7

Dimensionless Parameters used : Gamma = 55.90

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.198	4C	7.314	(A,B)
N(PHI) / (P/Rm)	0.198	3C	4.343	(C,D)
M(PHI) / (P)	0.198	2C1	0.028	(A,B)
M(PHI) / (P)	0.198	1C !	0.066	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.198	3A	2.187	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.198	1A	0.069	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.198	3B	5.207	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.198	1B	0.020	(A,B,C,D)
N(x) / (P/Rm)	0.198	3C	4.343	(A,B)
N(x) / (P/Rm)	0.198	4C	7.314	(C,D)
M(x) / (P)	0.198	1C1	0.058	(A,B)
M(x) / (P)	0.198	2C !	0.034	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.198	4A	4.611	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.198	2A	0.032	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.198	4B	2.241	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.198	2B	0.028	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-4.7	-4.7	-4.7	-4.7	-2.8	-2.8	-2.8	-2.8
Circ. Bend. P	-6.0	6.0	-6.0	6.0	-14.0	14.0	-14.0	14.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	-7.1	-7.1	7.1	7.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	-75.4	75.4	75.4	-75.4
Circ. Memb. ML	-17.0	-17.0	17.0	17.0	0.0	0.0	0.0	0.0
Circ. Bend. ML	-22.0	22.0	22.0	-22.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-49.6	6.4	28.4	-3.8	-99.4	79.6	65.7	-57.0
Long. Memb. P	-2.8	-2.8	-2.8	-2.8	-4.7	-4.7	-4.7	-4.7
Long. Bend. P	-12.4	12.4	-12.4	12.4	-7.2	7.2	-7.2	7.2
Long. Memb. MC	0.0	0.0	0.0	0.0	-15.0	-15.0	15.0	15.0
Long. Bend. MC	0.0	0.0	0.0	0.0	-34.8	34.8	34.8	-34.8
Long. Memb. ML	-7.3	-7.3	7.3	7.3	0.0	0.0	0.0	0.0
Long. Bend. ML	-30.8	30.8	30.8	-30.8	0.0	0.0	0.0	0.0
Tot. Long. Str.	-53.3	33.1	22.9	-13.8	-61.7	22.4	37.9	-17.2
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	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5

Tot. Shear	3.4	3.4	1.6	1.6	1.6	1.6	3.4	3.4
Str. Int.	55.3	33.5	28.8	14.0	99.4	79.6	66.1	57.3

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	57.1	59.4	57.1	59.4	57.1	59.4	57.1	59.4
Circ. Pl (SUS)	-7.6	-7.6	5.0	5.0	-3.0	-3.0	0.7	0.7
Circ. Q (SUS)	-22.7	22.7	14.2	-14.2	-44.2	44.2	32.4	-32.4
Long. Pm (SUS)	28.5	28.5	28.5	28.5	28.5	28.5	28.5	28.5
Long. Pl (SUS)	-2.9	-2.9	0.6	0.6	-3.9	-3.9	1.3	1.3
Long. Q (SUS)	-36.7	36.7	24.7	-24.7	-25.5	25.5	16.9	-16.9
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)	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Pm (SUS)	57.1	59.4	57.1	59.4	57.1	59.4	57.1	59.4
Pm+Pl (SUS)	49.5	51.8	62.1	64.4	54.1	56.4	57.8	60.1
Pm+Pl+Q (Total)	38.7	75.8	76.5	50.3	12.1	100.7	90.6	28.7

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	59.40	137.90	Passed
Pm+Pl (SUS)	64.36	206.85	Passed
Pm+Pl+Q (TOTAL)	100.73	413.70	Passed

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

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Circ. Pl (SUS)	-21.6	-21.6	12.3	12.3	-9.9	-9.9	4.4	4.4
Circ. Q (SUS)	-28.0	28.0	16.1	-16.1	-89.5	89.5	61.4	-61.4
Long. Pm (SUS)	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5
Long. Pl (SUS)	-10.1	-10.1	4.5	4.5	-19.7	-19.7	10.4	10.4
Long. Q (SUS)	-43.2	43.2	18.3	-18.3	-42.1	42.1	27.6	-27.6

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)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Pm (SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Pm+Pl (SUS)	105.3	107.6	139.3	141.6	117.1	119.4	131.3	133.6
Pm+Pl+Q (Total)	77.5	135.9	155.4	125.5	27.7	208.8	192.8	72.7

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	129.25	137.90	Passed
Pm+Pl (SUS)	141.57	206.85	Passed
Pm+Pl+Q (TOTAL)	208.84	413.70	Passed

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

Input, Nozzle Desc: S3 From: 70

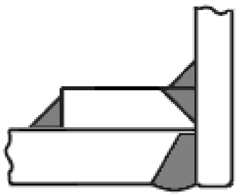
```
Pressure for Reinforcement Calculations        P       23.000  bars
Temperature for Internal Pressure            Temp        125  °C
Design External Pressure                     Pext        1.03  bars
Temperature for External Pressure          Tempex        125  °C

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     1656.00  mm.
Design Length of Section                       L   5217.9990  mm.
Shell Finished (Minimum) Thickness             t     18.0000  mm.
Shell Internal Corrosion Allowance             c      3.0000  mm.
Shell External Corrosion Allowance            co      0.0000  mm.

Distance from Bottom/Left Tangent                    2945.53  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                                              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    150.0000  mm.
Weld leg size between Nozzle and Pad/Shell    Wo     10.0000  mm.
Groove weld depth between Nozzle and Vessel Wgnv     18.0000  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     18.0000  mm.
Weld leg size between Pad and Shell           Wp     14.0000  mm.
Groove weld depth between Pad and Nozzle    Wgpn     18.0000  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: S3

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)
  = (23.0*831.0)/(138*1.0-0.6*23.0)
  = 14.0010 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*109.5375)/(118*1.0+0.4*23.0)
  = 2.1204 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.5985 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    37.5000  mm.
```

Weld Strength Reduction Factor [fr1]:

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

Weld Strength Reduction Factor [fr2]:

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

Weld Strength Reduction Factor [fr4]:

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

Weld Strength Reduction Factor [fr3]:

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	28.730	8.910	NA
Area in Shell	A1	2.003	12.663	NA
Area in Nozzle Wall	A2	3.842	4.818	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	2.810	2.810	NA
Area in Element	A5	28.800	28.800	NA
TOTAL AREA AVAILABLE	Atot	37.456	49.092	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:            330.6005    18.0000  mm.
 Based on given Pad Diameter:             379.0750    12.5466  mm.
 Based on Shell or Nozzle Thickness:      399.7238    11.1125  mm.
```

Area Required [A]:

```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (202.85*14.001*1.0+2*8.1125*14.001*1.0*(1-0.86))
  = 28.730 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 * 15.0 - 1.0 * 14.001 ) - 2 * 8.113
    ( 1.0 * 15.0 - 1.0 * 14.001 ) * ( 1 - 0.855 )
  = 2.003 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 37.5 ) * ( 8.11 - 2.12 ) * 0.855
  = 3.842 cm^2
```

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

```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Trapfr4
  = ( 1. ) * 0.86 + (0.0 ) * 0.86 + 195.5274² * 1.0
  = 2.810 cm^2
```

Area Available in Element [A5]:

```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 379.075 - 219.075 ) * 18.0 * 1.0
  = 28.800 cm^2
```

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

```
 Wall Thickness for Internal/External pressures      ta = 5.1204 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 17.0010 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 17.0010 mm.
```

```
Wall Thickness, shell/head, external pressure     trb2 = 3.6235 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( 17.001, 4.5 ) ]
= 10.1600 mm.
```

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

```
= max( ta, tb )
= max( 5.1204, 10.16 )
= 10.1600 mm.
```

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

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

```
Sustained    :     50.5,  Allowable :    117.9 N./mm^2  Passed
Expansion    :      0.0,  Allowable :    244.3 N./mm^2  Passed
Occasional   :     13.8,  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 = 2.12, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.261, 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 = 18.0, tr = 14.001, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.933, Temp. Reduction = 4 °C

```
Min Metal Temp. w/o impact per UCS-66, Curve D              -43 °C
Min Metal Temp. at Required thickness (UCS 66.1)            -46 °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                :   -46 °C
Governing MDMT of all the sub-joints of this Junction  :   -46 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ANSI B16.5/47 flange per Matl. Specification       -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)           -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       8.1125  mm.
Intermediate Calc. for pad/shell Welds    TminPad     15.0000  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	7.5000 = 0.5*TminPad	9.8980 = 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, (28.7304 - 2.003 + 2 * 8.1125 * 0.855 *
    (1.0 * 15.0 - 14.001 ) )138)
  = 370.45 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.8425 + 28.8 + 2.8103 - 0.0 * 0.86 ) * 138
  = 488.85 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.8425 + 0.0 + 0.855 + ( 2.0809 ) ) * 138
  = 93.47 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.8425 + 0.0 + 2.8103 + 28.8 + ( 2.0809 ) ) * 138
  = 517.54 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 * 14.0 * 0.49 * 138
  = 563. 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 * 18.0 * 0.74 * 138
  = 632. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 219.075 * ( 18.0 - 3.0 ) * 0.74 * 138
  = 527. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 563 + 222 ) = 785 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 199 + 632 + 527 + 0 ) = 1358 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 563 + 527 + 0 ) = 1090 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 785 kN , must exceed W = 370 kN  or W1 = 488 kN
 Path 2-2 = 1357 kN , must exceed W = 370 kN  or W2 = 93 kN
 Path 3-3 = 1089 kN , must exceed W = 370 kN  or W3 = 517 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case       24.506   bars
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
 Nozzle is O.K. for the External Pressure                1.034   bars
```

The Drop for this Nozzle is : 7.2775 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 175.2774 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	1656.000	mm.
Vessel Thickness	Tv	18.000	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

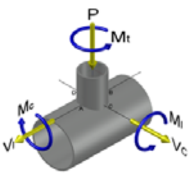
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	219.075	mm.
Nozzle Thickness	Tn	11.113	mm.
Nozzle Material		SA-333 6	
Nozzle UNS Number		K03006	
Nozzle Cold S.I. Allowable	SNmc	117.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	117.90	N./mm^2
Thickness of Reinforcing Pad	Tpad	18.000	mm.
Diameter of Reinforcing Pad	Dpad	379.075	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	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(838.5 (18.0 - 3.0))
= 589.168 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 = 25.68

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.113	4C	4.590	(A,B)
N(PHI) / (P/Rm)	0.113	3C	3.985	(C,D)
M(PHI) / (P)	0.113	2C1	0.097	(A,B)
M(PHI) / (P)	0.113	1C	0.134	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.113	3A	0.723	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.113	1A	0.098	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.113	3B	2.471	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.113	1B	0.047	(A,B,C,D)
N(x) / (P/Rm)	0.113	3C	3.985	(A,B)
N(x) / (P/Rm)	0.113	4C	4.590	(C,D)
M(x) / (P)	0.113	1C1	0.136	(A,B)
M(x) / (P)	0.113	2C	0.097	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.113	4A	1.032	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.113	2A	0.054	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.113	4B	0.691	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.113	2B	0.078	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
Circ. Memb. P	-1.3	-1.3	-1.3	-1.3	-1.1	-1.1	-1.1	-1.1
Circ. Bend. P	-4.3	4.3	-4.3	4.3	-5.9	5.9	-5.9	5.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	-1.8	-1.8	1.8	1.8
Circ. Memb. MC	0.0	0.0	0.0	0.0	-38.3	38.3	38.3	-38.3
Circ. Memb. ML	-6.3	-6.3	6.3	6.3	0.0	0.0	0.0	0.0
Circ. Bend. ML	-18.5	18.5	18.5	-18.5	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-30.3	15.1	19.1	-9.2	-47.1	41.2	33.1	-31.7
Long. Memb. P	-1.1	-1.1	-1.1	-1.1	-1.3	-1.3	-1.3	-1.3
Long. Bend. P	-6.0	6.0	-6.0	6.0	-4.3	4.3	-4.3	4.3
Long. Memb. MC	0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Long. Bend. MC	0.0	0.0	0.0	0.0	-21.2	21.2	21.2	-21.2
Long. Memb. ML	-1.8	-1.8	1.8	1.8	0.0	0.0	0.0	0.0
Long. Bend. ML	-30.7	30.7	30.7	-30.7	0.0	0.0	0.0	0.0
Tot. Long. Str.	-39.5	33.8	25.3	-24.0	-29.4	21.5	18.3	-15.6
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	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4

Tot. Shear	4.1	4.1	2.7	2.7	2.7	2.7	4.1	4.1
Str. Int.	41.1	34.6	26.3	24.5	47.5	41.5	34.1	32.7

Dimensionless Parameters used : Gamma = 55.90

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.198	4C	7.314	(A,B)
N(PHI) / (P/Rm)	0.198	3C	4.343	(C,D)
M(PHI) / (P)	0.198	2C1	0.028	(A,B)
M(PHI) / (P)	0.198	1C !	0.066	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.198	3A	2.187	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.198	1A	0.069	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.198	3B	5.207	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.198	1B	0.020	(A,B,C,D)
N(x) / (P/Rm)	0.198	3C	4.343	(A,B)
N(x) / (P/Rm)	0.198	4C	7.314	(C,D)
M(x) / (P)	0.198	1C1	0.058	(A,B)
M(x) / (P)	0.198	2C !	0.034	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.198	4A	4.611	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.198	2A	0.032	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.198	4B	2.241	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.198	2B	0.028	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
Circ. Memb. P	-4.7	-4.7	-4.7	-4.7	-2.8	-2.8	-2.8	-2.8
Circ. Bend. P	-6.0	6.0	-6.0	6.0	-14.0	14.0	-14.0	14.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	-7.1	-7.1	7.1	7.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	-75.4	75.4	75.4	-75.4
Circ. Memb. ML	-17.0	-17.0	17.0	17.0	0.0	0.0	0.0	0.0
Circ. Bend. ML	-22.0	22.0	22.0	-22.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-49.6	6.4	28.4	-3.8	-99.4	79.6	65.7	-57.0
Long. Memb. P	-2.8	-2.8	-2.8	-2.8	-4.7	-4.7	-4.7	-4.7
Long. Bend. P	-12.4	12.4	-12.4	12.4	-7.2	7.2	-7.2	7.2
Long. Memb. MC	0.0	0.0	0.0	0.0	-15.0	-15.0	15.0	15.0
Long. Bend. MC	0.0	0.0	0.0	0.0	-34.8	34.8	34.8	-34.8
Long. Memb. ML	-7.3	-7.3	7.3	7.3	0.0	0.0	0.0	0.0
Long. Bend. ML	-30.8	30.8	30.8	-30.8	0.0	0.0	0.0	0.0
Tot. Long. Str.	-53.3	33.1	22.9	-13.8	-61.7	22.4	37.9	-17.2
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	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5

Tot. Shear	3.4	3.4	1.6	1.6	1.6	1.6	3.4	3.4
Str. Int.	55.3	33.5	28.8	14.0	99.4	79.6	66.1	57.3

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	56.8	59.1	56.8	59.1	56.8	59.1	56.8	59.1
Circ. Pl (SUS)	-7.6	-7.6	5.0	5.0	-3.0	-3.0	0.7	0.7
Circ. Q (SUS)	-22.7	22.7	14.2	-14.2	-44.2	44.2	32.4	-32.4
Long. Pm (SUS)	28.4	28.4	28.4	28.4	28.4	28.4	28.4	28.4
Long. Pl (SUS)	-2.9	-2.9	0.6	0.6	-3.9	-3.9	1.3	1.3
Long. Q (SUS)	-36.7	36.7	24.7	-24.7	-25.5	25.5	16.9	-16.9
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)	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Pm (SUS)	56.8	59.1	56.8	59.1	56.8	59.1	56.8	59.1
Pm+Pl (SUS)	49.2	51.5	61.8	64.1	53.8	56.1	57.5	59.8
Pm+Pl+Q (Total)	38.5	75.5	76.3	50.0	11.9	100.4	90.3	28.5

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	59.09	137.90	Passed
Pm+Pl (SUS)	64.06	206.85	Passed
Pm+Pl+Q (TOTAL)	100.43	413.70	Passed

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

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Circ. Pl (SUS)	-21.6	-21.6	12.3	12.3	-9.9	-9.9	4.4	4.4
Circ. Q (SUS)	-28.0	28.0	16.1	-16.1	-89.5	89.5	61.4	-61.4
Long. Pm (SUS)	63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.1
Long. Pl (SUS)	-10.1	-10.1	4.5	4.5	-19.7	-19.7	10.4	10.4
Long. Q (SUS)	-43.2	43.2	18.3	-18.3	-42.1	42.1	27.6	-27.6

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)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Pm (SUS)	126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Pm+Pl (SUS)	104.7	107.0	138.6	140.9	116.4	118.7	130.7	133.0
Pm+Pl+Q (Total)	76.9	135.2	154.7	124.9	27.0	208.2	192.1	72.0

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	128.59	137.90	Passed
Pm+Pl (SUS)	140.91	206.85	Passed
Pm+Pl+Q (TOTAL)	208.18	413.70	Passed

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

Input, Nozzle Desc: D2 From: 70

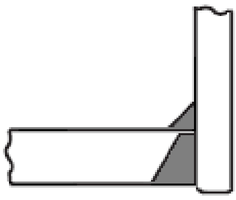
Pressure for Reinforcement Calculations	P	23.118	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		2945.53	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		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	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: D2

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

```
 Actual Inside Diameter Used in Calculation              2.000  in.
 Actual Thickness Used in Calculation                    0.654  in.
```

Nozzle input data check completed without errors.

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

```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.12*831.0)/(138*1.0-0.6*23.12)
  = 14.0733 mm.
```

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

```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (23.12*28.4)/(138*1.0-0.6*23.12)
  = 0.4810 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3431 mm.

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

```
 Parallel to Vessel Wall (Diameter Limit)            Dl    114.0000   mm.
 Parallel to Vessel Wall                        Rn+tn+t     57.0000   mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     34.0000   mm.
```

Weld Strength Reduction Factor [fr1]:

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

Weld Strength Reduction Factor [fr2]:

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

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 1.0, 1.0 )
  = 1.000
```

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.994	2.466	NA
Area in Shell	A1	0.530	3.613	NA

Area in Nozzle Wall	A2	8.921	9.015	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	10.451	13.627	NA

The Internal Pressure Case Governs the Analysis.

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

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (56.8*14.0733*1.0+2*13.6*14.0733*1.0*(1-1.0))
  = 7.994 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 )
  = 57.2( 1.0 * 15.0 - 1.0 * 14.073 ) - 2 * 13.6
    ( 1.0 * 15.0 - 1.0 * 14.0733 ) * ( 1 - 1.0 )
  = 0.530 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 34.0 )( 13.6 - 0.48 )1.0
  = 8.921 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 = 3.4810 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 17.0733 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 17.0733 mm.
 Wall Thickness, shell/head, external pressure      trb2 = 3.6235 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 17.0733, 4.5 ) ]
  = 7.8000 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.481, 7.8 )
  = 7.8000 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):
```
 Sustained  :      14.9,  Allowable :    137.9 N./mm^2  Passed
 Expansion  :       0.0,  Allowable :    329.9 N./mm^2  Passed
 Occasional :       1.9,  Allowable :    183.4 N./mm^2  Passed
```

```
 Shear      :      9.6,  Allowable :     96.5 N./mm^2  Passed
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

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

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

 Calculated Minimum Design Metal Temperature                -104 °C

 Governing MDMT of all the sub-joints of this Junction  :  -104 °C
```

Weld Size Calculations, Description: D2

```
 Intermediate Calc. for nozzle/shell Welds   Tmin     13.6000  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, (7.9936 - 0.5301 + 2 * 13.6 * 1.0 *
    (1.0 * 15.0 - 14.0733 ) )138)
  = 106.39 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 8.9209 + 0.0 + 1. - 0.0 * 1.0 ) * 138
  = 136.80 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 8.9209 + 0.0 + 1. + ( 4.08 ) ) * 138
  = 193.06 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.9209 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138
  = 193.06 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 138
```

```
  = 145. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 84.0 * ( 18.0 - 3.0 ) * 0.74 * 138
  = 202. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89 + 145 ) = 234 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89 + 0 + 202 + 0 ) = 291 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89 + 202 + 0 ) = 291 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 234 kN , must exceed W = 106 kN  or W1 = 136 kN
 Path 2-2 = 291 kN , must exceed W = 106 kN  or W2 = 193 kN
 Path 3-3 = 291 kN , must exceed W = 106 kN  or W3 = 193 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case       24.623  bars
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
 Nozzle is O.K. for the External Pressure                1.034  bars
```

The Drop for this Nozzle is : 1.0659 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 169.0659 mm.

Input Echo, WRC107/537 Item 1, Description: D2 :

```
 Diameter Basis for Vessel                    Vbasis       ID
 Cylindrical or Spherical Vessel              Cylsph       Cylindrical
 Internal Corrosion Allowance                    Cas       3.0000  mm.
 Vessel Diameter                                  Dv     1656.000  mm.
 Vessel Thickness                                 Tv       18.000  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

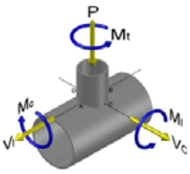
```
 Attachment Type                                Type       Round

 Diameter Basis for Nozzle                    Nbasis       ID
 Corrosion Allowance for Nozzle                  Can       3.0000  mm.
 Nozzle Diameter                                  Dn       50.800  mm.
 Nozzle Thickness                                 Tn       16.600  mm.
 Nozzle Material                                     SA-350 LF2
 Nozzle UNS Number                                         K03011
 Nozzle Cold S.I. Allowable                     SNmc       137.90  N./mm^2
 Nozzle Hot  S.I. Allowable                     SNmh       137.90  N./mm^2
```

```
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601    ------
Nozzle Calcs.: D2                        Nozl:   25  11:47am  Dec 23,2021

 Design Internal Pressure                     Dp      23.118  bars
 Include Pressure Thrust                                  No
```

External Forces and Moments in WRC 107/537 Convention:

```
 Radial Load            (SUS)                  P         2.0  kN
 Longitudinal Shear     (SUS)                 Vl         2.0  kN
 Circumferential Shear  (SUS)                 Vc         2.0  kN
 Circumferential Moment (SUS)                 Mc       400.0  N-m
 Longitudinal Moment    (SUS)                 Ml       400.0  N-m
 Torsional Moment       (SUS)                 Mt       500.0  N-m


 Use Interactive Control                          No
 WRC107 Version                          Version  March  1979

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

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



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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 84.0 + 2 * 1.65 * sqrt( 838.5 ( 18.0 - 3.0 ) )
  = 454.093 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 =   55.90
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

```
 -------------------------------------------------------------------
 Curves read for 1979                  Beta  Figure     Value   Location
 -------------------------------------------------------------------
 N(PHI) / ( P/Rm )                    0.044   4C       10.449   (A,B)
 N(PHI) / ( P/Rm )                    0.044   3C       10.482   (C,D)
 M(PHI) / ( P )                       0.044   2C1       0.147   (A,B)
 M(PHI) / ( P )                       0.044   1C        0.187   (C,D)
 N(PHI) / ( MC/(Rm**2 * Beta) )       0.044   3A        0.763   (A,B,C,D)
 M(PHI) / ( MC/(Rm    * Beta) )       0.044   1A        0.103   (A,B,C,D)
 N(PHI) / ( ML/(Rm**2 * Beta) )       0.044   3B        3.111   (A,B,C,D)
 M(PHI) / ( ML/(Rm    * Beta) )       0.044   1B        0.059   (A,B,C,D)

 N(x)   / ( P/Rm )                    0.044   3C       10.482   (A,B)
```

```
 N(x)   / ( P/Rm )                  0.044   4C       10.449   (C,D)
 M(x)   / ( P )                     0.044   1C1       0.194   (A,B)
 M(x)   / ( P )                     0.044   2C        0.146   (C,D)
 N(x)   / ( MC/(Rm**2 * Beta) )   0.044   4A        1.005   (A,B,C,D)
 M(x)   / ( MC/(Rm    * Beta) )   0.044   2A        0.062   (A,B,C,D)
 N(x)   / ( ML/(Rm**2 * Beta) )   0.044   4B        0.781   (A,B,C,D)
 M(x)   / ( ML/(Rm    * Beta) )   0.044   2B        0.096   (A,B,C,D)
```

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend. P	-7.8	7.8	-7.8	7.8	-10.0	10.0	-10.0	10.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb. MC	0.0	0.0	0.0	0.0	-29.8	29.8	29.8	-29.8
Circ. Memb. ML	-2.7	-2.7	2.7	2.7	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.	-29.2	20.5	10.2	-8.1	-42.1	37.5	18.8	-20.9
Long. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend. P	-10.3	10.3	-10.3	10.3	-7.8	7.8	-7.8	7.8
Long. Memb. MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend. MC	0.0	0.0	0.0	0.0	-17.9	17.9	17.9	-17.9
Long. Memb. ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend. ML	-28.0	28.0	28.0	-28.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-40.7	36.0	16.7	-18.7	-28.2	23.2	9.3	-10.9
Shear VC	1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear MT	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Tot. Shear	4.0	4.0	2.0	2.0	2.0	2.0	4.0	4.0
Str. Int.	41.9	37.0	17.2	19.0	42.4	37.8	20.3	22.3

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Circ. Pl (SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q (SUS)	-24.8	24.8	9.2	-9.2	-39.8	39.8	19.9	-19.9
Long. Pm (SUS)	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5
Long. Pl (SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q (SUS)	-38.3	38.3	17.7	-17.7	-25.7	25.7	10.1	-10.1

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)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pm (SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Pm+Pl (SUS)	122.6	124.9	128.0	130.3	124.6	126.9	125.9	128.3
Pm+Pl+Q (Total)	98.0	150.0	137.2	121.2	84.9	166.8	146.0	108.7

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	129.25	137.90	Passed
Pm+Pl (SUS)	130.29	206.85	Passed
Pm+Pl+Q (TOTAL)	166.77	413.70	Passed

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

Input, Nozzle Desc: D1 From: 70

Pressure for Reinforcement Calculations	P	23.118	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	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	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		4745.53	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		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	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)

```
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
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Tag no:Evaporator E-PK1601
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601    ------
Nozzle Calcs.: D1                        Nozl:    26   11:47am  Dec 23,2021
```

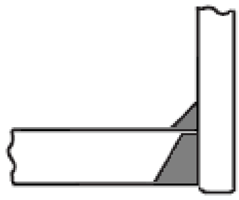

Insert/Set-in Nozzle No Pad, no Inside projection

Reinforcement CALCULATION, Description: D1

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

```
 Actual Inside Diameter Used in Calculation              2.000  in.
 Actual Thickness Used in Calculation                    0.654  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.12*831.0)/(138*1.0-0.6*23.12)
  = 14.0733 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (23.12*28.4)/(138*1.0-0.6*23.12)
  = 0.4810 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3431 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl   114.0000  mm.
 Parallel to Vessel Wall                         Rn+tn+t    57.0000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad    Tlnp    34.0000  mm.
```

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

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

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.994	2.466	NA
Area in Shell	A1	0.530	3.613	NA

Area in Nozzle Wall	A2	8.921	9.015	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	10.451	13.627	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (56.8*14.0733*1.0+2*13.6*14.0733*1.0*(1-1.0))
  = 7.994 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 )
  = 57.2( 1.0 * 15.0 - 1.0 * 14.073 ) - 2 * 13.6
    ( 1.0 * 15.0 - 1.0 * 14.0733 ) * ( 1 - 1.0 )
  = 0.530 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 34.0 )( 13.6 - 0.48 )1.0
  = 8.921 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 = 3.4810 mm.
 Wall Thickness per UG16(b),                         tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure        trb1 = 17.0733 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 17.0733 mm.
 Wall Thickness, shell/head, external pressure        trb2 = 3.6235 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                        tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 17.0733, 4.5 ) ]
  = 7.8000 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.481, 7.8 )
  = 7.8000 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):
```
 Sustained  :     14.9,  Allowable :    137.9 N./mm^2  Passed
 Expansion  :      0.0,  Allowable :    329.9 N./mm^2  Passed
 Occasional :      1.9,  Allowable :    183.4 N./mm^2  Passed
```

```
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DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
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FileName : Calculation Book for Evaporator E-PK1601    ------
Nozzle Calcs.: D1                          Nozl:   26  11:47am  Dec 23,2021
```

```
 Shear      :      9.6,  Allowable :     96.5 N./mm^2  Passed
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

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

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

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

 Calculated Minimum Design Metal Temperature                -104 °C

 Governing MDMT of all the sub-joints of this Junction  :  -104 °C
```

Weld Size Calculations, Description: D1

```
 Intermediate Calc. for nozzle/shell Welds   Tmin     13.6000  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, (7.9936 - 0.5301 + 2 * 13.6 * 1.0 *
    (1.0 * 15.0 - 14.0733 ) )138)
  = 106.39 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 8.9209 + 0.0 + 1. - 0.0 * 1.0 ) * 138
  = 136.80 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 8.9209 + 0.0 + 1. + ( 4.08 ) ) * 138
  = 193.06 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.9209 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138
  = 193.06 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 138
```

```
  = 145. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 84.0 * ( 18.0 - 3.0 ) * 0.74 * 138
  = 202. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89 + 145 ) = 234 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89 + 0 + 202 + 0 ) = 291 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89 + 202 + 0 ) = 291 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 234 kN , must exceed W = 106 kN  or W1 = 136 kN
 Path 2-2 = 291 kN , must exceed W = 106 kN  or W2 = 193 kN
 Path 3-3 = 291 kN , must exceed W = 106 kN  or W3 = 193 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case       24.623  bars
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
 Nozzle is O.K. for the External Pressure                1.034  bars
```

The Drop for this Nozzle is : 1.0659 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 169.0659 mm.

Input Echo, WRC107/537 Item 1, Description: D1 :

```
 Diameter Basis for Vessel                   Vbasis       ID
 Cylindrical or Spherical Vessel             Cylsph       Cylindrical
 Internal Corrosion Allowance                   Cas       3.0000   mm.
 Vessel Diameter                                 Dv     1656.000   mm.
 Vessel Thickness                                Tv       18.000   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

```
 Attachment Type                               Type       Round

 Diameter Basis for Nozzle                   Nbasis       ID
 Corrosion Allowance for Nozzle                 Can       3.0000   mm.
 Nozzle Diameter                                 Dn       50.800   mm.
 Nozzle Thickness                                Tn       16.600   mm.
 Nozzle Material                                       SA-350 LF2
 Nozzle UNS Number                                        K03011
 Nozzle Cold S.I. Allowable                    SNmc       137.90   N./mm^2
 Nozzle Hot  S.I. Allowable                    SNmh       137.90   N./mm^2
```

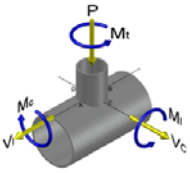
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601 ------
Nozzle Calcs.: D1 Nozl: 26 11:47am Dec 23,2021

```
 Design Internal Pressure                       Dp      23.118  bars
 Include Pressure Thrust                                    No
```

External Forces and Moments in WRC 107/537 Convention:

```
 Radial Load            (SUS)                   P          2.0  kN
 Longitudinal Shear     (SUS)                   Vl         2.0  kN
 Circumferential Shear  (SUS)                   Vc         2.0  kN
 Circumferential Moment (SUS)                   Mc       400.0  N-m
 Longitudinal Moment    (SUS)                   Ml       400.0  N-m
 Torsional Moment       (SUS)                   Mt       500.0  N-m


 Use Interactive Control                            No
 WRC107 Version                         Version  March  1979

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

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



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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 84.0 + 2 * 1.65 * sqrt( 838.5 ( 18.0 - 3.0 ) )
  = 454.093 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 =    55.90
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

```
 -------------------------------------------------------------------
 Curves read for 1979                 Beta  Figure     Value   Location
 -------------------------------------------------------------------
 N(PHI) / ( P/Rm )                   0.044   4C       10.449   (A,B)
 N(PHI) / ( P/Rm )                   0.044   3C       10.482   (C,D)
 M(PHI) / ( P )                      0.044   2C1       0.147   (A,B)
 M(PHI) / ( P )                      0.044   1C        0.187   (C,D)
 N(PHI) / ( MC/(Rm**2 * Beta) )      0.044   3A        0.763   (A,B,C,D)
 M(PHI) / ( MC/(Rm    * Beta) )      0.044   1A        0.103   (A,B,C,D)
 N(PHI) / ( ML/(Rm**2 * Beta) )      0.044   3B        3.111   (A,B,C,D)
 M(PHI) / ( ML/(Rm    * Beta) )      0.044   1B        0.059   (A,B,C,D)

 N(x)   / ( P/Rm )                   0.044   3C       10.482   (A,B)
```

```
N(x)   / ( P/Rm )                0.044   4C       10.449   (C,D)
M(x)   / ( P )                   0.044   1C1       0.194   (A,B)
M(x)   / ( P )                   0.044   2C        0.146   (C,D)
N(x)   / ( MC/(Rm**2 * Beta) )   0.044   4A        1.005   (A,B,C,D)
M(x)   / ( MC/(Rm    * Beta) )   0.044   2A        0.062   (A,B,C,D)
N(x)   / ( ML/(Rm**2 * Beta) )   0.044   4B        0.781   (A,B,C,D)
M(x)   / ( ML/(Rm    * Beta) )   0.044   2B        0.096   (A,B,C,D)
```

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend. P	-7.8	7.8	-7.8	7.8	-10.0	10.0	-10.0	10.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb. MC	0.0	0.0	0.0	0.0	-29.8	29.8	29.8	-29.8
Circ. Memb. ML	-2.7	-2.7	2.7	2.7	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.	-29.2	20.5	10.2	-8.1	-42.1	37.5	18.8	-20.9
Long. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend. P	-10.3	10.3	-10.3	10.3	-7.8	7.8	-7.8	7.8
Long. Memb. MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend. MC	0.0	0.0	0.0	0.0	-17.9	17.9	17.9	-17.9
Long. Memb. ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend. ML	-28.0	28.0	28.0	-28.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-40.7	36.0	16.7	-18.7	-28.2	23.2	9.3	-10.9
Shear VC	1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear MT	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Tot. Shear	4.0	4.0	2.0	2.0	2.0	2.0	4.0	4.0
Str. Int.	41.9	37.0	17.2	19.0	42.4	37.8	20.3	22.3

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Circ. Pl (SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q (SUS)	-24.8	24.8	9.2	-9.2	-39.8	39.8	19.9	-19.9
Long. Pm (SUS)	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5
Long. Pl (SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q (SUS)	-38.3	38.3	17.7	-17.7	-25.7	25.7	10.1	-10.1

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)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pm (SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Pm+Pl (SUS)	122.6	124.9	128.0	130.3	124.6	126.9	125.9	128.3
Pm+Pl+Q (Total)	98.0	150.0	137.2	121.2	84.9	166.8	146.0	108.7

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	129.25	137.90	Passed
Pm+Pl (SUS)	130.29	206.85	Passed
Pm+Pl+Q (TOTAL)	166.77	413.70	Passed

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

Input, Nozzle Desc: D3 From: 70

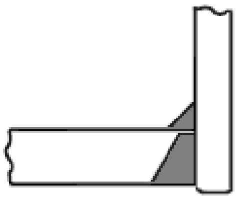
Pressure for Reinforcement Calculations	P	23.118	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		5545.53	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		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	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: D3

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

```
 Actual Inside Diameter Used in Calculation              2.000  in.
 Actual Thickness Used in Calculation                    0.654  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.12*831.0)/(138*1.0-0.6*23.12)
  = 14.0733 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (23.12*28.4)/(138*1.0-0.6*23.12)
  = 0.4810 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3431 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl   114.0000  mm.
 Parallel to Vessel Wall                        Rn+tn+t    57.0000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    34.0000  mm.
```

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

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

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.994	2.466	NA
Area in Shell	A1	0.530	3.613	NA

Area in Nozzle Wall	A2	8.921	9.015	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	10.451	13.627	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (56.8*14.0733*1.0+2*13.6*14.0733*1.0*(1-1.0))
  = 7.994 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 )
  = 57.2( 1.0 * 15.0 - 1.0 * 14.073 ) - 2 * 13.6
    ( 1.0 * 15.0 - 1.0 * 14.0733 ) * ( 1 - 1.0 )
  = 0.530 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 34.0 )( 13.6 - 0.48 )1.0
  = 8.921 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 = 3.4810 mm.
 Wall Thickness per UG16(b),                        tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure       trb1 = 17.0733 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 17.0733 mm.
 Wall Thickness, shell/head, external pressure       trb2 = 3.6235 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                       tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 17.0733, 4.5 ) ]
  = 7.8000 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.481, 7.8 )
  = 7.8000 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):
```
 Sustained  :     14.9,  Allowable :    137.9 N./mm^2  Passed
 Expansion  :      0.0,  Allowable :    329.9 N./mm^2  Passed
 Occasional :      1.9,  Allowable :    183.4 N./mm^2  Passed
```

```
 Shear       :       9.6,  Allowable :     96.5 N./mm^2  Passed
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

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

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

 Calculated Minimum Design Metal Temperature               -104 °C

 Governing MDMT of all the sub-joints of this Junction  :  -104 °C
```

Weld Size Calculations, Description: D3

```
 Intermediate Calc. for nozzle/shell Welds   Tmin     13.6000  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, (7.9936 - 0.5301 + 2 * 13.6 * 1.0 *
    (1.0 * 15.0 - 14.0733 ) )138)
  = 106.39 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 8.9209 + 0.0 + 1. - 0.0 * 1.0 ) * 138
  = 136.80 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 8.9209 + 0.0 + 1. + ( 4.08 ) ) * 138
  = 193.06 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.9209 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138
  = 193.06 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 138
```

```
  = 145. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 84.0 * ( 18.0 - 3.0 ) * 0.74 * 138
  = 202. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89 + 145 ) = 234 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89 + 0 + 202 + 0 ) = 291 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89 + 202 + 0 ) = 291 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 234 kN , must exceed W = 106 kN  or W1 = 136 kN
 Path 2-2 = 291 kN , must exceed W = 106 kN  or W2 = 193 kN
 Path 3-3 = 291 kN , must exceed W = 106 kN  or W3 = 193 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case       24.623  bars
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
 Nozzle is O.K. for the External Pressure                1.034  bars
```

The Drop for this Nozzle is : 1.0659 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 169.0659 mm.

Input Echo, WRC107/537 Item 1, Description: D3 :

```
 Diameter Basis for Vessel                      Vbasis       ID
 Cylindrical or Spherical Vessel                Cylsph       Cylindrical
 Internal Corrosion Allowance                      Cas       3.0000  mm.
 Vessel Diameter                                    Dv     1656.000  mm.
 Vessel Thickness                                   Tv       18.000  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

```
 Attachment Type                                  Type       Round

 Diameter Basis for Nozzle                      Nbasis       ID
 Corrosion Allowance for Nozzle                    Can       3.0000  mm.
 Nozzle Diameter                                    Dn       50.800  mm.
 Nozzle Thickness                                   Tn       16.600  mm.
 Nozzle Material                                         SA-350 LF2
 Nozzle UNS Number                                           K03011
 Nozzle Cold S.I. Allowable                       SNmc       137.90  N./mm^2
 Nozzle Hot  S.I. Allowable                       SNmh       137.90  N./mm^2
```

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601 ------
Nozzle Calcs.: D3 Nozl: 27 11:47am Dec 23,2021

Design Internal Pressure	Dp	23.118	bars
Include Pressure Thrust		No	

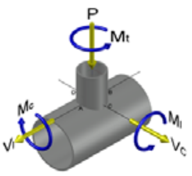
External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	2.0	kN
Longitudinal Shear	(SUS)	Vl	2.0	kN
Circumferential Shear	(SUS)	Vc	2.0	kN
Circumferential Moment	(SUS)	Mc	400.0	N-m
Longitudinal Moment	(SUS)	Ml	400.0	N-m
Torsional Moment	(SUS)	Mt	500.0	N-m

Use Interactive Control No
WRC107 Version Version March 1979

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

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



Stress Attenuation Diameter (for Insert Plates) per WRC 297:
= NozzleOD + 2 * 1.65 * sqrt(Rmean(t - ca))
= 84.0 + 2 * 1.65 * sqrt(838.5 (18.0 - 3.0))
= 454.093 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 = 55.90

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.044	4C	10.449	(A,B)
N(PHI) / (P/Rm)	0.044	3C	10.482	(C,D)
M(PHI) / (P)	0.044	2C1	0.147	(A,B)
M(PHI) / (P)	0.044	1C	0.187	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.044	3A	0.763	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.044	1A	0.103	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.044	3B	3.111	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.044	1B	0.059	(A,B,C,D)
N(x) / (P/Rm)	0.044	3C	10.482	(A,B)

```
N(x)   / ( P/Rm )                0.044   4C       10.449   (C,D)
M(x)   / ( P )                   0.044   1C1       0.194   (A,B)
M(x)   / ( P )                   0.044   2C        0.146   (C,D)
N(x)   / ( MC/(Rm**2 * Beta) )   0.044   4A        1.005   (A,B,C,D)
M(x)   / ( MC/(Rm    * Beta) )   0.044   2A        0.062   (A,B,C,D)
N(x)   / ( ML/(Rm**2 * Beta) )   0.044   4B        0.781   (A,B,C,D)
M(x)   / ( ML/(Rm    * Beta) )   0.044   2B        0.096   (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	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend. P	-7.8	7.8	-7.8	7.8	-10.0	10.0	-10.0	10.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb. MC	0.0	0.0	0.0	0.0	-29.8	29.8	29.8	-29.8
Circ. Memb. ML	-2.7	-2.7	2.7	2.7	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.	-29.2	20.5	10.2	-8.1	-42.1	37.5	18.8	-20.9
Long. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend. P	-10.3	10.3	-10.3	10.3	-7.8	7.8	-7.8	7.8
Long. Memb. MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend. MC	0.0	0.0	0.0	0.0	-17.9	17.9	17.9	-17.9
Long. Memb. ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend. ML	-28.0	28.0	28.0	-28.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-40.7	36.0	16.7	-18.7	-28.2	23.2	9.3	-10.9
Shear VC	1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear MT	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Tot. Shear	4.0	4.0	2.0	2.0	2.0	2.0	4.0	4.0
Str. Int.	41.9	37.0	17.2	19.0	42.4	37.8	20.3	22.3

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)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Circ. Pl (SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q (SUS)	-24.8	24.8	9.2	-9.2	-39.8	39.8	19.9	-19.9
Long. Pm (SUS)	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5
Long. Pl (SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q (SUS)	-38.3	38.3	17.7	-17.7	-25.7	25.7	10.1	-10.1

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)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pm (SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Pm+Pl (SUS)	122.6	124.9	128.0	130.3	124.6	126.9	125.9	128.3
Pm+Pl+Q (Total)	98.0	150.0	137.2	121.2	84.9	166.8	146.0	108.7

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	129.25	137.90	Passed
Pm+Pl (SUS)	130.29	206.85	Passed
Pm+Pl+Q (TOTAL)	166.77	413.70	Passed

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

Input, Nozzle Desc: TT From: 70

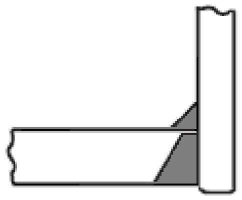
Pressure for Reinforcement Calculations	P	23.118	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		6145.53	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		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	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: TT

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

```
 Actual Inside Diameter Used in Calculation              2.000  in.
 Actual Thickness Used in Calculation                    0.654  in.
```

Nozzle input data check completed without errors.

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

```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.12*831.0)/(138*1.0-0.6*23.12)
  = 14.0733 mm.
```

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

```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (23.12*28.4)/(138*1.0-0.6*23.12)
  = 0.4810 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3431 mm.

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

```
 Parallel to Vessel Wall (Diameter Limit)            Dl    114.0000  mm.
 Parallel to Vessel Wall                        Rn+tn+t     57.0000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     34.0000  mm.
```

Weld Strength Reduction Factor [fr1]:

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

Weld Strength Reduction Factor [fr2]:

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

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 1.0, 1.0 )
  = 1.000
```

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.994	2.466	NA
Area in Shell	A1	0.530	3.613	NA

Area in Nozzle Wall	A2	8.921	9.015	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	10.451	13.627	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (56.8*14.0733*1.0+2*13.6*14.0733*1.0*(1-1.0))
  = 7.994 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 )
  = 57.2( 1.0 * 15.0 - 1.0 * 14.073 ) - 2 * 13.6
    ( 1.0 * 15.0 - 1.0 * 14.0733 ) * ( 1 - 1.0 )
  = 0.530 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 34.0 )( 13.6 - 0.48 )1.0
  = 8.921 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 = 3.4810 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 17.0733 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 17.0733 mm.
 Wall Thickness, shell/head, external pressure      trb2 = 3.6235 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 17.0733, 4.5 ) ]
  = 7.8000 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.481, 7.8 )
  = 7.8000 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

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

Sustained :	14.9,	Allowable :	137.9 N./mm^2	Passed
Expansion :	0.0,	Allowable :	329.9 N./mm^2	Passed
Occasional :	1.9,	Allowable :	183.4 N./mm^2	Passed

```
 Shear      :       9.6,  Allowable :     96.5 N./mm^2  Passed
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

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

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

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

 Calculated Minimum Design Metal Temperature                -104 °C

 Governing MDMT of all the sub-joints of this Junction  :  -104 °C
```

Weld Size Calculations, Description: TT

```
 Intermediate Calc. for nozzle/shell Welds   Tmin     13.6000  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, (7.9936 - 0.5301 + 2 * 13.6 * 1.0 *
    (1.0 * 15.0 - 14.0733 ) )138)
  = 106.39 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 8.9209 + 0.0 + 1. - 0.0 * 1.0 ) * 138
  = 136.80 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 8.9209 + 0.0 + 1. + ( 4.08 ) ) * 138
  = 193.06 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.9209 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138
  = 193.06 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 138
```

```
  = 145. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 84.0 * ( 18.0 - 3.0 ) * 0.74 * 138
  = 202. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89 + 145 ) = 234 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89 + 0 + 202 + 0 ) = 291 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89 + 202 + 0 ) = 291 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 234 kN , must exceed W = 106 kN  or W1 = 136 kN
 Path 2-2 = 291 kN , must exceed W = 106 kN  or W2 = 193 kN
 Path 3-3 = 291 kN , must exceed W = 106 kN  or W3 = 193 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case       24.623  bars
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
 Nozzle is O.K. for the External Pressure                1.034  bars
```

The Drop for this Nozzle is : 1.0659 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 169.0659 mm.

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

```
 Diameter Basis for Vessel                    Vbasis      ID
 Cylindrical or Spherical Vessel              Cylsph      Cylindrical
 Internal Corrosion Allowance                    Cas      3.0000  mm.
 Vessel Diameter                                  Dv    1656.000  mm.
 Vessel Thickness                                 Tv      18.000  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

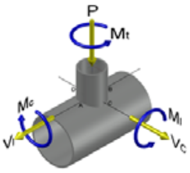
```
 Attachment Type                                Type      Round

 Diameter Basis for Nozzle                    Nbasis      ID
 Corrosion Allowance for Nozzle                  Can      3.0000  mm.
 Nozzle Diameter                                  Dn      50.800  mm.
 Nozzle Thickness                                 Tn      16.600  mm.
 Nozzle Material                                       SA-350 LF2
 Nozzle UNS Number                                        K03011
 Nozzle Cold S.I. Allowable                     SNmc      137.90  N./mm^2
 Nozzle Hot  S.I. Allowable                     SNmh      137.90  N./mm^2
```

```
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601    ------
Nozzle Calcs.: TT                         Nozl:   28  11:47am  Dec 23,2021

 Design Internal Pressure                         Dp      23.118  bars
 Include Pressure Thrust                                      No
```

External Forces and Moments in WRC 107/537 Convention:

```
 Radial Load            (SUS)                      P         2.0  kN
 Longitudinal Shear     (SUS)                      Vl        2.0  kN
 Circumferential Shear  (SUS)                      Vc        2.0  kN
 Circumferential Moment (SUS)                      Mc      400.0  N-m
 Longitudinal Moment    (SUS)                      Ml      400.0  N-m
 Torsional Moment       (SUS)                      Mt      500.0  N-m


 Use Interactive Control                                No
 WRC107 Version                                Version  March  1979

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

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



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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 84.0 + 2 * 1.65 * sqrt( 838.5 ( 18.0 - 3.0 ) )
  = 454.093 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 =   55.90
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.044	4C	10.449	(A,B)
N(PHI) / (P/Rm)	0.044	3C	10.482	(C,D)
M(PHI) / (P)	0.044	2C1	0.147	(A,B)
M(PHI) / (P)	0.044	1C	0.187	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.044	3A	0.763	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.044	1A	0.103	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.044	3B	3.111	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.044	1B	0.059	(A,B,C,D)
N(x) / (P/Rm)	0.044	3C	10.482	(A,B)

```
N(x)   / ( P/Rm )                 0.044   4C      10.449   (C,D)
M(x)   / ( P )                    0.044   1C1      0.194   (A,B)
M(x)   / ( P )                    0.044   2C       0.146   (C,D)
N(x)   / ( MC/(Rm**2 * Beta) )    0.044   4A       1.005   (A,B,C,D)
M(x)   / ( MC/(Rm    * Beta) )    0.044   2A       0.062   (A,B,C,D)
N(x)   / ( ML/(Rm**2 * Beta) )    0.044   4B       0.781   (A,B,C,D)
M(x)   / ( ML/(Rm    * Beta) )    0.044   2B       0.096   (A,B,C,D)
```

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend. P	-7.8	7.8	-7.8	7.8	-10.0	10.0	-10.0	10.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb. MC	0.0	0.0	0.0	0.0	-29.8	29.8	29.8	-29.8
Circ. Memb. ML	-2.7	-2.7	2.7	2.7	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.	-29.2	20.5	10.2	-8.1	-42.1	37.5	18.8	-20.9
Long. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend. P	-10.3	10.3	-10.3	10.3	-7.8	7.8	-7.8	7.8
Long. Memb. MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend. MC	0.0	0.0	0.0	0.0	-17.9	17.9	17.9	-17.9
Long. Memb. ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend. ML	-28.0	28.0	28.0	-28.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-40.7	36.0	16.7	-18.7	-28.2	23.2	9.3	-10.9
Shear VC	1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear MT	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Tot. Shear	4.0	4.0	2.0	2.0	2.0	2.0	4.0	4.0
Str. Int.	41.9	37.0	17.2	19.0	42.4	37.8	20.3	22.3

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)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Circ. Pl (SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q (SUS)	-24.8	24.8	9.2	-9.2	-39.8	39.8	19.9	-19.9
Long. Pm (SUS)	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5
Long. Pl (SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q (SUS)	-38.3	38.3	17.7	-17.7	-25.7	25.7	10.1	-10.1

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)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pm (SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Pm+Pl (SUS)	122.6	124.9	128.0	130.3	124.6	126.9	125.9	128.3
Pm+Pl+Q (Total)	98.0	150.0	137.2	121.2	84.9	166.8	146.0	108.7

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	129.25	137.90	Passed
Pm+Pl (SUS)	130.29	206.85	Passed
Pm+Pl+Q (TOTAL)	166.77	413.70	Passed

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

Input, Nozzle Desc: V From: 70

Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	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	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		2545.53	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

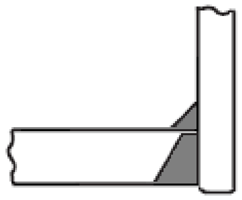
Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm^2
Allowable Stress At Ambient	Sna	137.90	N./mm^2
Diameter Basis (for tr calc only)		ID	
Layout Angle		90.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	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)

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601 ------
Nozzle Calcs.: V Nozl: 29 11:47am Dec 23,2021



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

Reinforcement CALCULATION, Description: V

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

```
 Actual Inside Diameter Used in Calculation              2.000  in.
 Actual Thickness Used in Calculation                    0.654  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.0*831.0)/(138*1.0-0.6*23.0)
  = 14.0010 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (23.0*28.4)/(138*1.0-0.6*23.0)
  = 0.4785 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3431 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl   114.0000  mm.
 Parallel to Vessel Wall                        Rn+tn+t    57.0000  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp    34.0000  mm.
```

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

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

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.953	2.466	NA
Area in Shell	A1	0.571	3.613	NA


```
 Area in Nozzle Wall         A2 |      8.923|     9.015|         NA|
 Area in Inward Nozzle       A3 |      0.000|     0.000|         NA|
 Area in Welds     A41+A42+A43 |      1.000|     1.000|         NA|
 Area in Element             A5 |      0.000|     0.000|         NA|
 TOTAL AREA AVAILABLE      Atot |     10.494|    13.627|         NA|
```

The Internal Pressure Case Governs the Analysis.

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

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (56.8*14.001*1.0+2*13.6*14.001*1.0*(1-1.0))
  = 7.953 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 )
  = 57.2( 1.0 * 15.0 - 1.0 * 14.001 ) - 2 * 13.6
    ( 1.0 * 15.0 - 1.0 * 14.001 ) * ( 1 - 1.0 )
  = 0.571 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 34.0 )( 13.6 - 0.48 )1.0
  = 8.923 cm^2
```

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

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures       ta = 3.4785 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 17.0010 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 17.0010 mm.
 Wall Thickness, shell/head, external pressure      trb2 = 3.6235 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 17.001, 4.5 ) ]
  = 7.8000 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.4785, 7.8 )
  = 7.8000 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):
```
 Sustained  :      14.9,  Allowable :     137.9 N./mm^2  Passed
 Expansion  :       0.0,  Allowable :     329.9 N./mm^2  Passed
 Occasional :       1.9,  Allowable :     183.4 N./mm^2  Passed
```

```
 Shear      :      9.6,  Allowable :     96.5 N./mm^2  Passed
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

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

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

 Calculated Minimum Design Metal Temperature                -104 °C

 Governing MDMT of all the sub-joints of this Junction  :  -104 °C
```

Weld Size Calculations, Description: V

```
 Intermediate Calc. for nozzle/shell Welds   Tmin     13.6000  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, (7.9526 - 0.5714 + 2 * 13.6 * 1.0 *
    (1.0 * 15.0 - 14.001 ) )138)
  = 105.52 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 8.9226 + 0.0 + 1. - 0.0 * 1.0 ) * 138
  = 136.82 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 8.9226 + 0.0 + 1. + ( 4.08 ) ) * 138
  = 193.08 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.9226 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138
  = 193.08 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 138
```

```
  = 145. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 84.0 * ( 18.0 - 3.0 ) * 0.74 * 138
  = 202. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89 + 145 ) = 234 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89 + 0 + 202 + 0 ) = 291 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89 + 202 + 0 ) = 291 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 234 kN , must exceed W = 105 kN  or W1 = 136 kN
 Path 2-2 = 291 kN , must exceed W = 105 kN  or W2 = 193 kN
 Path 3-3 = 291 kN , must exceed W = 105 kN  or W3 = 193 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case       24.506  bars
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
 Nozzle is O.K. for the External Pressure                1.034  bars
```

The Drop for this Nozzle is : 1.0659 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 169.0659 mm.

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

```
 Diameter Basis for Vessel                     Vbasis       ID
 Cylindrical or Spherical Vessel               Cylsph       Cylindrical
 Internal Corrosion Allowance                     Cas       3.0000   mm.
 Vessel Diameter                                   Dv     1656.000   mm.
 Vessel Thickness                                  Tv       18.000   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

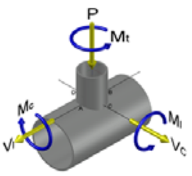
```
 Attachment Type                                 Type       Round

 Diameter Basis for Nozzle                     Nbasis       ID
 Corrosion Allowance for Nozzle                   Can       3.0000   mm.
 Nozzle Diameter                                   Dn       50.800   mm.
 Nozzle Thickness                                  Tn       16.600   mm.
 Nozzle Material                                       SA-350 LF2
 Nozzle UNS Number                                          K03011
 Nozzle Cold S.I. Allowable                      SNmc       137.90   N./mm^2
 Nozzle Hot  S.I. Allowable                      SNmh       137.90   N./mm^2
```

```
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601    ------
Nozzle Calcs.: V                        Nozl:   29  11:47am  Dec 23,2021

 Design Internal Pressure                         Dp       23.000  bars
 Include Pressure Thrust                                       No
```

External Forces and Moments in WRC 107/537 Convention:

```
 Radial Load             (SUS)                     P          2.0  kN
 Longitudinal Shear      (SUS)                    Vl          2.0  kN
 Circumferential Shear   (SUS)                    Vc          2.0  kN
 Circumferential Moment  (SUS)                    Mc        400.0  N-m
 Longitudinal Moment     (SUS)                    Ml        400.0  N-m
 Torsional Moment        (SUS)                    Mt        500.0  N-m


 Use Interactive Control                              No
 WRC107 Version                              Version  March  1979

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

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



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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 84.0 + 2 * 1.65 * sqrt( 838.5 ( 18.0 - 3.0 ) )
  = 454.093 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 =   55.90
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

```
 -------------------------------------------------------------------
 Curves read for 1979               Beta  Figure    Value   Location
 -------------------------------------------------------------------
 N(PHI) / ( P/Rm )                 0.044   4C       10.449   (A,B)
 N(PHI) / ( P/Rm )                 0.044   3C       10.482   (C,D)
 M(PHI) / ( P )                    0.044   2C1       0.147   (A,B)
 M(PHI) / ( P )                    0.044   1C        0.187   (C,D)
 N(PHI) / ( MC/(Rm**2 * Beta) )    0.044   3A        0.763   (A,B,C,D)
 M(PHI) / ( MC/(Rm    * Beta) )    0.044   1A        0.103   (A,B,C,D)
 N(PHI) / ( ML/(Rm**2 * Beta) )    0.044   3B        3.111   (A,B,C,D)
 M(PHI) / ( ML/(Rm    * Beta) )    0.044   1B        0.059   (A,B,C,D)

 N(x)   / ( P/Rm )                 0.044   3C       10.482   (A,B)
```

```
 N(x)   / ( P/Rm )                 0.044   4C       10.449   (C,D)
 M(x)   / ( P )                    0.044   1C1       0.194   (A,B)
 M(x)   / ( P )                    0.044   2C        0.146   (C,D)
 N(x)   / ( MC/(Rm**2 * Beta) )    0.044   4A        1.005   (A,B,C,D)
 M(x)   / ( MC/(Rm    * Beta) )    0.044   2A        0.062   (A,B,C,D)
 N(x)   / ( ML/(Rm**2 * Beta) )    0.044   4B        0.781   (A,B,C,D)
 M(x)   / ( ML/(Rm    * Beta) )    0.044   2B        0.096   (A,B,C,D)
```

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend. P	-7.8	7.8	-7.8	7.8	-10.0	10.0	-10.0	10.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb. MC	0.0	0.0	0.0	0.0	-29.8	29.8	29.8	-29.8
Circ. Memb. ML	-2.7	-2.7	2.7	2.7	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.	-29.2	20.5	10.2	-8.1	-42.1	37.5	18.8	-20.9
Long. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend. P	-10.3	10.3	-10.3	10.3	-7.8	7.8	-7.8	7.8
Long. Memb. MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend. MC	0.0	0.0	0.0	0.0	-17.9	17.9	17.9	-17.9
Long. Memb. ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend. ML	-28.0	28.0	28.0	-28.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-40.7	36.0	16.7	-18.7	-28.2	23.2	9.3	-10.9
Shear VC	1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear MT	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Tot. Shear	4.0	4.0	2.0	2.0	2.0	2.0	4.0	4.0
Str. Int.	41.9	37.0	17.2	19.0	42.4	37.8	20.3	22.3

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Circ. Pl (SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q (SUS)	-24.8	24.8	9.2	-9.2	-39.8	39.8	19.9	-19.9
Long. Pm (SUS)	63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.1
Long. Pl (SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q (SUS)	-38.3	38.3	17.7	-17.7	-25.7	25.7	10.1	-10.1

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)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pm (SUS)	126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Pm+Pl (SUS)	122.0	124.3	127.3	129.6	124.0	126.3	125.3	127.6
Pm+Pl+Q (Total)	97.3	149.4	136.6	120.5	84.2	166.1	145.4	108.0

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	128.59	137.90	Passed
Pm+Pl (SUS)	129.63	206.85	Passed
Pm+Pl+Q (TOTAL)	166.12	413.70	Passed

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

Input, Nozzle Desc: S4 From: 70

```
Pressure for Reinforcement Calculations        P      23.000  bars
Temperature for Internal Pressure           Temp         125  °C
Design External Pressure                    Pext        1.03  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     1656.00  mm.
Design Length of Section                       L   5217.9990  mm.
Shell Finished (Minimum) Thickness             t     18.0000  mm.
Shell Internal Corrosion Allowance             c      3.0000  mm.
Shell External Corrosion Allowance            co      0.0000  mm.

Distance from Bottom/Left Tangent                    5145.53  mm.

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

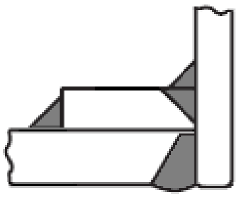
Type of Element Connected to the Shell : Nozzle

```
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                                              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    150.0000  mm.
Weld leg size between Nozzle and Pad/Shell    Wo     10.0000  mm.
Groove weld depth between Nozzle and Vessel Wgnv     18.0000  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     18.0000  mm.
Weld leg size between Pad and Shell           Wp     14.0000  mm.
Groove weld depth between Pad and Nozzle    Wgpn     18.0000  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:Evaporator E-PK1601
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601    ------
Nozzle Calcs.: S4                       Nozl:    30  11:47am  Dec 23,2021
```

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: S4

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)
  = (23.0*831.0)/(138*1.0-0.6*23.0)
  = 14.0010 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*109.5375)/(118*1.0+0.4*23.0)
  = 2.1204 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.5985 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    37.5000  mm.
```

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

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

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

Weld Strength Reduction Factor [fr3]:

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	28.730	8.910	NA
Area in Shell	A1	2.003	12.663	NA
Area in Nozzle Wall	A2	3.842	4.818	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	2.810	2.810	NA
Area in Element	A5	28.800	28.800	NA
TOTAL AREA AVAILABLE	Atot	37.456	49.092	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:            330.6005    18.0000  mm.
 Based on given Pad Diameter:             379.0750    12.5466  mm.
 Based on Shell or Nozzle Thickness:      399.7238    11.1125  mm.
```

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (202.85*14.001*1.0+2*8.1125*14.001*1.0*(1-0.86))
  = 28.730 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 * 15.0 - 1.0 * 14.001 ) - 2 * 8.113
    ( 1.0 * 15.0 - 1.0 * 14.001 ) * ( 1 - 0.855 )
  = 2.003 cm^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 37.5 ) * ( 8.11 - 2.12 ) * 0.855
  = 3.842 cm^2
```

Area Available in Welds [A41 + A42 + A43]:
```
  = (Wo² - Ar Lost)*Fr3+((Wi-can/0.707)² - Ar Lost)*fr2 + Trapfr4
  = ( 1. ) * 0.86 + (0.0 ) * 0.86 + 195.5274² * 1.0
  = 2.810 cm^2
```

Area Available in Element [A5]:
```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 379.075 - 219.075 ) * 18.0 * 1.0
  = 28.800 cm^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 5.1204 mm.
 Wall Thickness per UG16(b),                      tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 17.0010 mm.
 Wall Thickness                 tb1 = max(trb1, tr16b) = 17.0010 mm.
```

```
 Wall Thickness, shell/head, external pressure     trb2 = 3.6235 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( 17.001, 4.5 ) ]
  = 10.1600 mm.
```

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

```
  = max( ta, tb )
  = max( 5.1204, 10.16 )
  = 10.1600 mm.
```

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

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

Sustained	: 50.5,	Allowable :	117.9 N./mm^2	Passed
Expansion	: 0.0,	Allowable :	244.3 N./mm^2	Passed
Occasional	: 13.8,	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 = 2.12, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.261, 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 = 18.0, tr = 14.001, c = 3.0 mm., E* = 1.0
Thickness Ratio = tr * (E*)/(tg - c) = 0.933, Temp. Reduction = 4 °C

```
 Min Metal Temp. w/o impact per UCS-66, Curve D             -43 °C
 Min Metal Temp. at Required thickness (UCS 66.1)           -46 °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                :   -46 °C
Governing MDMT of all the sub-joints of this Junction  :   -46 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
MDMT of ANSI B16.5/47 flange per Matl. Specification       -46 °C
Flange MDMT with Temp reduction per UCS-66(i)(2)           -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: S4

```
Intermediate Calc. for nozzle/shell Welds   Tmin      8.1125  mm.
Intermediate Calc. for pad/shell Welds   TminPad     15.0000  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             7.5000 = 0.5*TminPad  9.8980 = 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, (28.7304 - 2.003 + 2 * 8.1125 * 0.855 *
    (1.0 * 15.0 - 14.001 ) )138)
  = 370.45 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 3.8425 + 28.8 + 2.8103 - 0.0 * 0.86 ) * 138
  = 488.85 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 3.8425 + 0.0 + 0.855 + ( 2.0809 ) ) * 138
  = 93.47 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 3.8425 + 0.0 + 2.8103 + 28.8 + ( 2.0809 ) ) * 138
  = 517.54 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 * 14.0 * 0.49 * 138
  = 563. 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 * 18.0 * 0.74 * 138
  = 632. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 219.075 * ( 18.0 - 3.0 ) * 0.74 * 138
  = 527. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SPEW + SNW ) = ( 563 + 222 ) = 785 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 199 + 632 + 527 + 0 ) = 1358 kN
  PATH33 = ( Spew + Tngw + Sinw )
         = ( 563 + 527 + 0 ) = 1090 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 785 kN , must exceed W = 370 kN  or W1 = 488 kN
 Path 2-2 = 1357 kN , must exceed W = 370 kN  or W2 = 93 kN
 Path 3-3 = 1089 kN , must exceed W = 370 kN  or W3 = 517 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case       24.506   bars
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
 Nozzle is O.K. for the External Pressure                1.034   bars
```

The Drop for this Nozzle is : 7.2775 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 175.2774 mm.

Input Echo, WRC107/537 Item 1, Description: S4 :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	mm.
Design Temperature	T1	125.0	°C
Vessel Material		SA-516 70	
Vessel UNS Number		K02700	

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601 ------
Nozzle Calcs.: S4 Nozl: 30 11:47am Dec 23,2021

```
 Vessel Cold S.I. Allowable                     Smc       137.90  N./mm^2
 Vessel Hot  S.I. Allowable                     Smh       137.90  N./mm^2
```

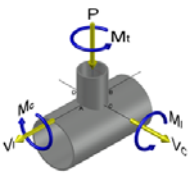
Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

```
 Attachment Type                               Type       Round

 Diameter Basis for Nozzle                   Nbasis       OD
 Corrosion Allowance for Nozzle                 Can       3.0000  mm.
 Nozzle Diameter                                 Dn      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       18.000  mm.
 Diameter  of Reinforcing Pad                  Dpad      379.075  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          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( 838.5 ( 18.0 - 3.0 ) )
   = 589.168 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 = 25.68

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.113	4C	4.590	(A,B)
N(PHI) / (P/Rm)	0.113	3C	3.985	(C,D)
M(PHI) / (P)	0.113	2C1	0.097	(A,B)
M(PHI) / (P)	0.113	1C	0.134	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.113	3A	0.723	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.113	1A	0.098	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.113	3B	2.471	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.113	1B	0.047	(A,B,C,D)
N(x) / (P/Rm)	0.113	3C	3.985	(A,B)
N(x) / (P/Rm)	0.113	4C	4.590	(C,D)
M(x) / (P)	0.113	1C1	0.136	(A,B)
M(x) / (P)	0.113	2C	0.097	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.113	4A	1.032	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.113	2A	0.054	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.113	4B	0.691	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.113	2B	0.078	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Intensity Values at							
Circ. Memb. P	-1.3	-1.3	-1.3	-1.3	-1.1	-1.1	-1.1	-1.1
Circ. Bend. P	-4.3	4.3	-4.3	4.3	-5.9	5.9	-5.9	5.9
Circ. Memb. MC	0.0	0.0	0.0	0.0	-1.8	-1.8	1.8	1.8
Circ. Memb. MC	0.0	0.0	0.0	0.0	-38.3	38.3	38.3	-38.3
Circ. Memb. ML	-6.3	-6.3	6.3	6.3	0.0	0.0	0.0	0.0
Circ. Bend. ML	-18.5	18.5	18.5	-18.5	0.0	0.0	0.0	0.0
Tot. Circ. Str.	-30.3	15.1	19.1	-9.2	-47.1	41.2	33.1	-31.7
Long. Memb. P	-1.1	-1.1	-1.1	-1.1	-1.3	-1.3	-1.3	-1.3
Long. Bend. P	-6.0	6.0	-6.0	6.0	-4.3	4.3	-4.3	4.3
Long. Memb. MC	0.0	0.0	0.0	0.0	-2.6	-2.6	2.6	2.6
Long. Bend. MC	0.0	0.0	0.0	0.0	-21.2	21.2	21.2	-21.2
Long. Memb. ML	-1.8	-1.8	1.8	1.8	0.0	0.0	0.0	0.0
Long. Bend. ML	-30.7	30.7	30.7	-30.7	0.0	0.0	0.0	0.0
Tot. Long. Str.	-39.5	33.8	25.3	-24.0	-29.4	21.5	18.3	-15.6
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	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4

Tot. Shear	4.1	4.1	2.7	2.7	2.7	2.7	4.1	4.1
Str. Int.	41.1	34.6	26.3	24.5	47.5	41.5	34.1	32.7

Dimensionless Parameters used : Gamma = 55.90

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.198	4C	7.314	(A,B)
N(PHI) / (P/Rm)	0.198	3C	4.343	(C,D)
M(PHI) / (P)	0.198	2C1	0.028	(A,B)
M(PHI) / (P)	0.198	1C !	0.066	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.198	3A	2.187	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.198	1A	0.069	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.198	3B	5.207	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.198	1B	0.020	(A,B,C,D)
N(x) / (P/Rm)	0.198	3C	4.343	(A,B)
N(x) / (P/Rm)	0.198	4C	7.314	(C,D)
M(x) / (P)	0.198	1C1	0.058	(A,B)
M(x) / (P)	0.198	2C !	0.034	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.198	4A	4.611	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.198	2A	0.032	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.198	4B	2.241	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.198	2B	0.028	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
		Stress Intensity Values at							
Circ. Memb.	P	-4.7	-4.7	-4.7	-4.7	-2.8	-2.8	-2.8	-2.8
Circ. Bend.	P	-6.0	6.0	-6.0	6.0	-14.0	14.0	-14.0	14.0
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-7.1	-7.1	7.1	7.1
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-75.4	75.4	75.4	-75.4
Circ. Memb.	ML	-17.0	-17.0	17.0	17.0	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-22.0	22.0	22.0	-22.0	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-49.6	6.4	28.4	-3.8	-99.4	79.6	65.7	-57.0
Long. Memb.	P	-2.8	-2.8	-2.8	-2.8	-4.7	-4.7	-4.7	-4.7
Long. Bend.	P	-12.4	12.4	-12.4	12.4	-7.2	7.2	-7.2	7.2
Long. Memb.	MC	0.0	0.0	0.0	0.0	-15.0	-15.0	15.0	15.0
Long. Bend.	MC	0.0	0.0	0.0	0.0	-34.8	34.8	34.8	-34.8
Long. Memb.	ML	-7.3	-7.3	7.3	7.3	0.0	0.0	0.0	0.0
Long. Bend.	ML	-30.8	30.8	30.8	-30.8	0.0	0.0	0.0	0.0
Tot. Long. Str.		-53.3	33.1	22.9	-13.8	-61.7	22.4	37.9	-17.2
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	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5

Tot. Shear	3.4	3.4	1.6	1.6	1.6	1.6	3.4	3.4
Str. Int.	55.3	33.5	28.8	14.0	99.4	79.6	66.1	57.3

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	56.8	59.1	56.8	59.1	56.8	59.1	56.8	59.1
Circ. Pl (SUS)	-7.6	-7.6	5.0	5.0	-3.0	-3.0	0.7	0.7
Circ. Q (SUS)	-22.7	22.7	14.2	-14.2	-44.2	44.2	32.4	-32.4
Long. Pm (SUS)	28.4	28.4	28.4	28.4	28.4	28.4	28.4	28.4
Long. Pl (SUS)	-2.9	-2.9	0.6	0.6	-3.9	-3.9	1.3	1.3
Long. Q (SUS)	-36.7	36.7	24.7	-24.7	-25.5	25.5	16.9	-16.9
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)	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Pm (SUS)	56.8	59.1	56.8	59.1	56.8	59.1	56.8	59.1
Pm+Pl (SUS)	49.2	51.5	61.8	64.1	53.8	56.1	57.5	59.8
Pm+Pl+Q (Total)	38.5	75.5	76.3	50.0	11.9	100.4	90.3	28.5

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	59.09	137.90	Passed
Pm+Pl (SUS)	64.06	206.85	Passed
Pm+Pl+Q (TOTAL)	100.43	413.70	Passed

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

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Circ. Pl (SUS)	-21.6	-21.6	12.3	12.3	-9.9	-9.9	4.4	4.4
Circ. Q (SUS)	-28.0	28.0	16.1	-16.1	-89.5	89.5	61.4	-61.4
Long. Pm (SUS)	63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.1
Long. Pl (SUS)	-10.1	-10.1	4.5	4.5	-19.7	-19.7	10.4	10.4
Long. Q (SUS)	-43.2	43.2	18.3	-18.3	-42.1	42.1	27.6	-27.6

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)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Pm (SUS)	126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Pm+Pl (SUS)	104.7	107.0	138.6	140.9	116.4	118.7	130.7	133.0
Pm+Pl+Q (Total)	76.9	135.2	154.7	124.9	27.0	208.2	192.1	72.0

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	128.59	137.90	Passed
Pm+Pl (SUS)	140.91	206.85	Passed
Pm+Pl+Q (TOTAL)	208.18	413.70	Passed

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

Input, Nozzle Desc: LG1 From: 70

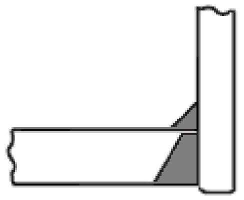
Pressure for Reinforcement Calculations	P	23.118	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		4545.53	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		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	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: LG1

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

```
 Actual Inside Diameter Used in Calculation              2.000  in.
 Actual Thickness Used in Calculation                    0.654  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.12*831.0)/(138*1.0-0.6*23.12)
  = 14.0733 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (23.12*28.4)/(138*1.0-0.6*23.12)
  = 0.4810 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3431 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl    114.0000   mm.
 Parallel to Vessel Wall                         Rn+tn+t    57.0000   mm.
 Normal to Vessel Wall (Thickness Limit), no pad    Tlnp    34.0000   mm.
```

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

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

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.994	2.466	NA
Area in Shell	A1	0.530	3.613	NA

Area in Nozzle Wall	A2	8.921	9.015	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	10.451	13.627	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (56.8*14.0733*1.0+2*13.6*14.0733*1.0*(1-1.0))
  = 7.994 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 )
  = 57.2( 1.0 * 15.0 - 1.0 * 14.073 ) - 2 * 13.6
    ( 1.0 * 15.0 - 1.0 * 14.0733 ) * ( 1 - 1.0 )
  = 0.530 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 34.0 )( 13.6 - 0.48 )1.0
  = 8.921 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 = 3.4810 mm.
 Wall Thickness per UG16(b),                        tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure       trb1 = 17.0733 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 17.0733 mm.
 Wall Thickness, shell/head, external pressure       trb2 = 3.6235 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                        tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 17.0733, 4.5 ) ]
  = 7.8000 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.481, 7.8 )
  = 7.8000 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

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

Sustained	:	14.9,	Allowable :	137.9 N./mm^2	Passed
Expansion	:	0.0,	Allowable :	329.9 N./mm^2	Passed
Occasional	:	1.9,	Allowable :	183.4 N./mm^2	Passed

```
 Shear      :      9.6,  Allowable :     96.5 N./mm^2  Passed
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

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

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

 Calculated Minimum Design Metal Temperature                -104 °C

 Governing MDMT of all the sub-joints of this Junction  :  -104 °C
```

Weld Size Calculations, Description: LG1

```
 Intermediate Calc. for nozzle/shell Welds   Tmin     13.6000  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, (7.9936 - 0.5301 + 2 * 13.6 * 1.0 *
    (1.0 * 15.0 - 14.0733 ) )138)
  = 106.39 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 8.9209 + 0.0 + 1. - 0.0 * 1.0 ) * 138
  = 136.80 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 8.9209 + 0.0 + 1. + ( 4.08 ) ) * 138
  = 193.06 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.9209 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138
  = 193.06 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 138
```

```
  = 145. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 84.0 * ( 18.0 - 3.0 ) * 0.74 * 138
  = 202. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89 + 145 ) = 234 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89 + 0 + 202 + 0 ) = 291 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89 + 202 + 0 ) = 291 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 234 kN , must exceed W = 106 kN  or W1 = 136 kN
 Path 2-2 = 291 kN , must exceed W = 106 kN  or W2 = 193 kN
 Path 3-3 = 291 kN , must exceed W = 106 kN  or W3 = 193 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case       24.623  bars
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
 Nozzle is O.K. for the External Pressure                1.034  bars
```

The Drop for this Nozzle is : 1.0659 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 169.0659 mm.

Input Echo, WRC107/537 Item 1, Description: LG1 :

```
 Diameter Basis for Vessel                    Vbasis      ID
 Cylindrical or Spherical Vessel              Cylsph      Cylindrical
 Internal Corrosion Allowance                    Cas      3.0000   mm.
 Vessel Diameter                                  Dv    1656.000   mm.
 Vessel Thickness                                 Tv      18.000   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

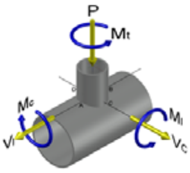
```
 Attachment Type                                Type      Round

 Diameter Basis for Nozzle                    Nbasis      ID
 Corrosion Allowance for Nozzle                  Can      3.0000   mm.
 Nozzle Diameter                                  Dn      50.800   mm.
 Nozzle Thickness                                 Tn      16.600   mm.
 Nozzle Material                                     SA-350 LF2
 Nozzle UNS Number                                        K03011
 Nozzle Cold S.I. Allowable                     SNmc      137.90   N./mm^2
 Nozzle Hot  S.I. Allowable                     SNmh      137.90   N./mm^2
```

```
 Design Internal Pressure                        Dp      23.118  bars
 Include Pressure Thrust                                     No
```

External Forces and Moments in WRC 107/537 Convention:

```
 Radial Load             (SUS)                    P         2.0  kN
 Longitudinal Shear      (SUS)                   Vl         2.0  kN
 Circumferential Shear   (SUS)                   Vc         2.0  kN
 Circumferential Moment  (SUS)                   Mc       400.0  N-m
 Longitudinal Moment     (SUS)                   Ml       400.0  N-m
 Torsional Moment        (SUS)                   Mt       500.0  N-m


 Use Interactive Control                               No
 WRC107 Version                             Version  March  1979

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

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



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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 84.0 + 2 * 1.65 * sqrt( 838.5 ( 18.0 - 3.0 ) )
  = 454.093 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 =    55.90
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

```
 -------------------------------------------------------------------
 Curves read for 1979               Beta  Figure     Value   Location
 -------------------------------------------------------------------
 N(PHI) / ( P/Rm )                 0.044   4C       10.449   (A,B)
 N(PHI) / ( P/Rm )                 0.044   3C       10.482   (C,D)
 M(PHI) / ( P )                    0.044   2C1       0.147   (A,B)
 M(PHI) / ( P )                    0.044   1C        0.187   (C,D)
 N(PHI) / ( MC/(Rm**2 * Beta) )    0.044   3A        0.763   (A,B,C,D)
 M(PHI) / ( MC/(Rm    * Beta) )    0.044   1A        0.103   (A,B,C,D)
 N(PHI) / ( ML/(Rm**2 * Beta) )    0.044   3B        3.111   (A,B,C,D)
 M(PHI) / ( ML/(Rm    * Beta) )    0.044   1B        0.059   (A,B,C,D)

 N(x)   / ( P/Rm )                 0.044   3C       10.482   (A,B)
```

N(x) / (P/Rm)	0.044	4C	10.449	(C,D)
M(x) / (P)	0.044	1C1	0.194	(A,B)
M(x) / (P)	0.044	2C	0.146	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.044	4A	1.005	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.044	2A	0.062	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.044	4B	0.781	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.044	2B	0.096	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend. P	-7.8	7.8	-7.8	7.8	-10.0	10.0	-10.0	10.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb. MC	0.0	0.0	0.0	0.0	-29.8	29.8	29.8	-29.8
Circ. Memb. ML	-2.7	-2.7	2.7	2.7	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.	-29.2	20.5	10.2	-8.1	-42.1	37.5	18.8	-20.9
Long. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend. P	-10.3	10.3	-10.3	10.3	-7.8	7.8	-7.8	7.8
Long. Memb. MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend. MC	0.0	0.0	0.0	0.0	-17.9	17.9	17.9	-17.9
Long. Memb. ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend. ML	-28.0	28.0	28.0	-28.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-40.7	36.0	16.7	-18.7	-28.2	23.2	9.3	-10.9
Shear VC	1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear MT	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Tot. Shear	4.0	4.0	2.0	2.0	2.0	2.0	4.0	4.0
Str. Int.	41.9	37.0	17.2	19.0	42.4	37.8	20.3	22.3

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Circ. Pl (SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q (SUS)	-24.8	24.8	9.2	-9.2	-39.8	39.8	19.9	-19.9
Long. Pm (SUS)	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5
Long. Pl (SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q (SUS)	-38.3	38.3	17.7	-17.7	-25.7	25.7	10.1	-10.1

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)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pm (SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Pm+Pl (SUS)	122.6	124.9	128.0	130.3	124.6	126.9	125.9	128.3
Pm+Pl+Q (Total)	98.0	150.0	137.2	121.2	84.9	166.8	146.0	108.7

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	129.25	137.90	Passed
Pm+Pl (SUS)	130.29	206.85	Passed
Pm+Pl+Q (TOTAL)	166.77	413.70	Passed

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

Input, Nozzle Desc: LG2 From: 70

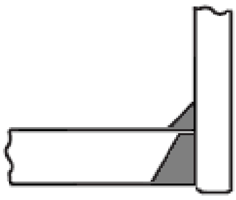
Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		4545.53	mm.
User Entered Minimum Design Metal Temperature		-45.00	°C

Type of Element Connected to the Shell : Nozzle

Material [Impact Tested]		SA-350 LF2	
Material UNS Number		K03011	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	137.90	N./mm^2
Allowable Stress At Ambient	Sna	137.90	N./mm^2
Diameter Basis (for tr calc only)		ID	
Layout Angle		90.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	16.6000	mm.
Flange Material [Normalized]		SA-350 LF2	
Flange Type		Long Weld Neck	
Corrosion Allowance	can	3.0000	mm.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	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: LG2

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

```
Actual Inside Diameter Used in Calculation            2.000  in.
Actual Thickness Used in Calculation                  0.654  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Cylindrical Shell, Tr [Int. Press]
```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (23.0*831.0)/(138*1.0-0.6*23.0)
  = 14.0010 mm.
```

Reqd thk per UG-37(a) of Nozzle Wall, Trn [Int. Press]
```
  = (P*R)/(Sn*E-0.6*P) per UG-27 (c)(1)
  = (23.0*28.4)/(138*1.0-0.6*23.0)
  = 0.4785 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.3431 mm.

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)             Dl   114.0000  mm.
Parallel to Vessel Wall                          Rn+tn+t    57.0000  mm.
Normal to Vessel Wall (Thickness Limit), no pad     Tlnp    34.0000  mm.
```

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

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

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.953	2.466	NA
Area in Shell	A1	0.571	3.613	NA

Area in Nozzle Wall	A2	8.923	9.015	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	1.000	1.000	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	10.494	13.627	NA

The Internal Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (56.8*14.001*1.0+2*13.6*14.001*1.0*(1-1.0))
  = 7.953 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 )
  = 57.2( 1.0 * 15.0 - 1.0 * 14.001 ) - 2 * 13.6
    ( 1.0 * 15.0 - 1.0 * 14.001 ) * ( 1 - 1.0 )
  = 0.571 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 34.0 )( 13.6 - 0.48 )1.0
  = 8.923 cm^2
```

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

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 3.4785 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 17.0010 mm.
 Wall Thickness                  tb1 = max(trb1, tr16b) = 17.0010 mm.
 Wall Thickness, shell/head, external pressure     trb2 = 3.6235 mm.
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm.
 Wall Thickness per table UG-45                      tb3 = 7.8000 mm.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 7.8, max( 17.001, 4.5 ) ]
  = 7.8000 mm.
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.4785, 7.8 )
  = 7.8000 mm.
```

Available Nozzle Neck Thickness = 16.6000 mm. --> OK

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

Sustained :	14.9,	Allowable :	137.9 N./mm^2	Passed
Expansion :	0.0,	Allowable :	329.9 N./mm^2	Passed
Occasional :	1.9,	Allowable :	183.4 N./mm^2	Passed

```
 Shear      :      9.6,  Allowable :     96.5 N./mm^2  Passed
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

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

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

 Calculated Minimum Design Metal Temperature                 -104 °C

 Governing MDMT of all the sub-joints of this Junction  :  -104 °C
```

Weld Size Calculations, Description: LG2

```
 Intermediate Calc. for nozzle/shell Welds   Tmin     13.6000  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, (7.9526 - 0.5714 + 2 * 13.6 * 1.0 *
    (1.0 * 15.0 - 14.001 ) )138)
  = 105.52 kN
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 8.9226 + 0.0 + 1. - 0.0 * 1.0 ) * 138
  = 136.82 kN
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 8.9226 + 0.0 + 1. + ( 4.08 ) ) * 138
  = 193.08 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 8.9226 + 0.0 + 1. + 0.0 + ( 4.08 ) ) * 138
  = 193.08 kN
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 84.0 * 10.0 * 0.49 * 138
  = 89. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 35.2) * ( 16.6 - 3.0 ) * 0.7 * 138
```

```
  = 145. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 84.0 * ( 18.0 - 3.0 ) * 0.74 * 138
  = 202. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 89 + 145 ) = 234 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 89 + 0 + 202 + 0 ) = 291 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 89 + 202 + 0 ) = 291 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 234 kN , must exceed W = 105 kN  or W1 = 136 kN
 Path 2-2 = 291 kN , must exceed W = 105 kN  or W2 = 193 kN
 Path 3-3 = 291 kN , must exceed W = 105 kN  or W3 = 193 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case       24.506  bars
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
 Nozzle is O.K. for the External Pressure                1.034  bars
```

The Drop for this Nozzle is : 1.0659 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 169.0659 mm.

Input Echo, WRC107/537 Item 1, Description: LG2 :

```
 Diameter Basis for Vessel                 Vbasis      ID
 Cylindrical or Spherical Vessel           Cylsph      Cylindrical
 Internal Corrosion Allowance                 Cas      3.0000   mm.
 Vessel Diameter                               Dv    1656.000   mm.
 Vessel Thickness                              Tv      18.000   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

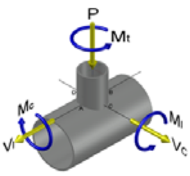
```
 Attachment Type                             Type      Round

 Diameter Basis for Nozzle                 Nbasis      ID
 Corrosion Allowance for Nozzle               Can      3.0000   mm.
 Nozzle Diameter                               Dn      50.800   mm.
 Nozzle Thickness                              Tn      16.600   mm.
 Nozzle Material                                   SA-350 LF2
 Nozzle UNS Number                                      K03011
 Nozzle Cold S.I. Allowable                  SNmc      137.90   N./mm^2
 Nozzle Hot  S.I. Allowable                  SNmh      137.90   N./mm^2
```

```
Design Internal Pressure                       Dp       23.000  bars
Include Pressure Thrust                                     No
```

External Forces and Moments in WRC 107/537 Convention:

```
Radial Load             (SUS)                  P          2.0  kN
Longitudinal Shear      (SUS)                  Vl         2.0  kN
Circumferential Shear   (SUS)                  Vc         2.0  kN
Circumferential Moment  (SUS)                  Mc       400.0  N-m
Longitudinal Moment     (SUS)                  Ml       400.0  N-m
Torsional Moment        (SUS)                  Mt       500.0  N-m


Use Interactive Control                            No
WRC107 Version                         Version  March  1979

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

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



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

```
= NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
= 84.0 + 2 * 1.65 * sqrt( 838.5 ( 18.0 - 3.0 ) )
= 454.093 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 =   55.90
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

```
-------------------------------------------------------------------
Curves read for 1979                 Beta  Figure     Value   Location
-------------------------------------------------------------------
N(PHI) / ( P/Rm )                   0.044   4C       10.449   (A,B)
N(PHI) / ( P/Rm )                   0.044   3C       10.482   (C,D)
M(PHI) / ( P )                      0.044   2C1       0.147   (A,B)
M(PHI) / ( P )                      0.044   1C        0.187   (C,D)
N(PHI) / ( MC/(Rm**2 * Beta) )      0.044   3A        0.763   (A,B,C,D)
M(PHI) / ( MC/(Rm    * Beta) )      0.044   1A        0.103   (A,B,C,D)
N(PHI) / ( ML/(Rm**2 * Beta) )      0.044   3B        3.111   (A,B,C,D)
M(PHI) / ( ML/(Rm    * Beta) )      0.044   1B        0.059   (A,B,C,D)

N(x)   / ( P/Rm )                   0.044   3C       10.482   (A,B)
```

N(x)	/ (P/Rm)	0.044	4C	10.449 (C,D)
M(x)	/ (P)	0.044	1C1	0.194 (A,B)
M(x)	/ (P)	0.044	2C	0.146 (C,D)
N(x)	/ (MC/(Rm**2 * Beta))	0.044	4A	1.005 (A,B,C,D)
M(x)	/ (MC/(Rm * Beta))	0.044	2A	0.062 (A,B,C,D)
N(x)	/ (ML/(Rm**2 * Beta))	0.044	4B	0.781 (A,B,C,D)
M(x)	/ (ML/(Rm * Beta))	0.044	2B	0.096 (A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend. P	-7.8	7.8	-7.8	7.8	-10.0	10.0	-10.0	10.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb. MC	0.0	0.0	0.0	0.0	-29.8	29.8	29.8	-29.8
Circ. Memb. ML	-2.7	-2.7	2.7	2.7	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.	-29.2	20.5	10.2	-8.1	-42.1	37.5	18.8	-20.9
Long. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend. P	-10.3	10.3	-10.3	10.3	-7.8	7.8	-7.8	7.8
Long. Memb. MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend. MC	0.0	0.0	0.0	0.0	-17.9	17.9	17.9	-17.9
Long. Memb. ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend. ML	-28.0	28.0	28.0	-28.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	-40.7	36.0	16.7	-18.7	-28.2	23.2	9.3	-10.9
Shear VC	1.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-1.0	-1.0	1.0	1.0
Shear MT	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Tot. Shear	4.0	4.0	2.0	2.0	2.0	2.0	4.0	4.0
Str. Int.	41.9	37.0	17.2	19.0	42.4	37.8	20.3	22.3

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Circ. Pl (SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q (SUS)	-24.8	24.8	9.2	-9.2	-39.8	39.8	19.9	-19.9
Long. Pm (SUS)	63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.1
Long. Pl (SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q (SUS)	-38.3	38.3	17.7	-17.7	-25.7	25.7	10.1	-10.1

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)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pm (SUS)	126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Pm+Pl (SUS)	122.0	124.3	127.3	129.6	124.0	126.3	125.3	127.6
Pm+Pl+Q (Total)	97.3	149.4	136.6	120.5	84.2	166.1	145.4	108.0

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	128.59	137.90	Passed
Pm+Pl (SUS)	129.63	206.85	Passed
Pm+Pl+Q (TOTAL)	166.12	413.70	Passed

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

Input, Nozzle Desc: LT1 From: 70

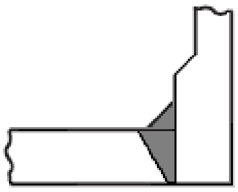
Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3345.53	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)		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	
Hub Height of Integral Nozzle	h	99.8228	mm.
Height of Beveled Transition	L'	23.8228	mm.
Hub Thickness of Integral Nozzle	(tn or x+tp)	20.0000	mm.
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	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	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)



Hub Nozzle (Set-in)

Reinforcement CALCULATION, Description: LT1

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*831.0)/(138*1.0-0.6*23.0)
  = 14.0010 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)/(138*1.0+0.4*23.0)
  = 0.4998 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2826 mm.

Intermediate Hub Nozzle Calculations:

Check to determine use of Sketch (e-1) or (e-2):
```
  = 2.5 * Corroded Hub Thickness
  = 2.5 * 17.0 Note: less than the hub height, use (e-2)
  = 42.5000 mm.
```

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl    115.0342  mm.
 Parallel to Vessel Wall                         Rn+tn+t    57.5171  mm.
 Normal to Vessel Wall (Thickness Limit), no pad    Tlnp    37.5000  mm.
```

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

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

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.145	2.216	NA
Area in Shell	A1	0.639	4.042	NA
Area in Nozzle Wall	A2	12.375	12.538	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
Area in Hub	A6	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	14.015	17.580	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)
  = (51.0342*14.001*1.0+2*17.0*14.001*1.0*(1-1.0))
  = 7.145 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 )
  = 64.0( 1.0 * 15.0 - 1.0 * 14.001 ) - 2 * 17.0
    ( 1.0 * 15.0 - 1.0 * 14.001 ) * ( 1 - 1.0 )
  = 0.639 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 37.5 )( 17.0 - 0.5 )1.0
  = 12.375 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
```

Note: There are no hub area calculations because Figure UG-40 (e-2) was used.

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures        ta = 3.4998 mm.
 Wall Thickness per UG16(b),                        tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure       trb1 = 17.0010 mm.
 Wall Thickness                 tb1 = max(trb1, tr16b) = 17.0010 mm.
 Wall Thickness, shell/head, external pressure       trb2 = 3.6235 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( 17.001, 4.5 ) ]
  = 6.4200 mm.
```

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

```
  = max( 3.4998, 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 :    137.9 N./mm^2  Passed
 Expansion  :     0.0,  Allowable :    282.7 N./mm^2  Passed
 Occasional :     5.8,  Allowable :    183.4 N./mm^2  Passed
 Shear      :    33.9,  Allowable :     96.5 N./mm^2  Passed
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle 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 for the Nozzle (Impact tested) :

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

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

 Governing MDMT of all the sub-joints of this Junction   :   -46 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
 MDMT of ANSI B16.5/47 flange per Matl. Specification        -46 °C
 Flange MDMT with Temp reduction per UCS-66(i)(2)            -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: LT1

```
 Intermediate Calc. for nozzle/shell Welds   Tmin     15.0000  mm.
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
 Nozzle Weld         6.0000 = Min per Code 7.0700 = 0.7 * Wo mm.
```

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (7.1453 - 0.6394 + 2 * 17.0 * 1.0 *
    (1.0 * 15.0 - 14.001 ) )138)
```

```
  = 94.39 kN
```

For hub type nozzles, A2 includes the area of the hub.

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

Weld Load [W1]:

```
  = (A2+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 12.3752 + 1. - 0.0 * 1.0 ) * 138
  = 184.43 kN
```

Weld Load [W2]:

```
   = ( A2 + A3 + A4 + (2(Hub Thickness) * t * fr1 )) * Sv
  = ( 12.3752 + 0.0 + 1. + ( 5.1 ) ) * 138
  = 254.75 kN
```

Weld Load [W3]:

```
  = (A2+A3+A4+(2*(Hub Thickness)* t * fr1 )) * Sv
  = ( 12.3752 + 0.0 + 1. + 0.0 ) * 138
  = 254.75 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 * 10.0 * 0.49 * 138
  = 64. kN
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 27.8398) * ( 20.0 - 3.0 ) * 0.7 * 138
  = 144. kN
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 60.325 * ( 18.0 - 3.0 ) * 0.74 * 138
  = 145. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 64 + 144 ) = 208 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 64 + 0 + 145 + 0 ) = 209 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 64 + 145 + 0 ) = 209 kN
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 207 kN , must exceed W = 94 kN  or W1 = 184 kN
 Path 2-2 = 209 kN , must exceed W = 94 kN  or W2 = 254 kN
 Path 3-3 = 209 kN , must exceed W = 94 kN  or W3 = 254 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case       24.506   bars
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
 Nozzle is O.K. for the External Pressure                1.034   bars
```

The Drop for this Nozzle is : 0.5496 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 168.5495 mm.

```
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601    ------
Nozzle Calcs.: LT1                    Nozl:   33  11:47am  Dec 23,2021
```

Input Echo, WRC107/537 Item 1, Description: LT1 :

```
 Diameter Basis for Vessel                  Vbasis      ID
 Cylindrical or Spherical Vessel            Cylsph      Cylindrical
 Internal Corrosion Allowance                  Cas      3.0000  mm.
 Vessel Diameter                                Dv    1656.000  mm.
 Vessel Thickness                               Tv      18.000  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
```

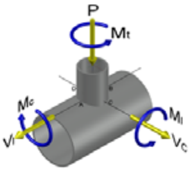
Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

```
 Attachment Type                              Type      Round

 Diameter Basis for Nozzle                  Nbasis      OD
 Corrosion Allowance for Nozzle                Can      3.0000  mm.
 Nozzle Diameter                                Dn      85.034  mm.
 Nozzle Thickness                               Tn      20.000  mm.
 Nozzle Material                                    SA-350 LF2
 Nozzle UNS Number                                      K03011
 Nozzle Cold S.I. Allowable                   SNmc      137.90  N./mm^2
 Nozzle Hot  S.I. Allowable                   SNmh      137.90  N./mm^2

 Design Internal Pressure                       Dp      23.000  bars
 Include Pressure Thrust                                    No
```

External Forces and Moments in WRC 107/537 Convention:

```
 Radial Load            (SUS)                    P         2.0  kN
 Longitudinal Shear     (SUS)                   Vl         2.0  kN
 Circumferential Shear  (SUS)                   Vc         2.0  kN
 Circumferential Moment (SUS)                   Mc       400.0  N-m
 Longitudinal Moment    (SUS)                   Ml       400.0  N-m
 Torsional Moment       (SUS)                   Mt       500.0  N-m


 Use Interactive Control                            No
 WRC107 Version                            Version  March  1979

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

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



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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 85.034 + 2 * 1.65 * sqrt( 838.5 ( 18.0 - 3.0 ) )
  = 455.127 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 = 55.90

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.044	4C	10.441	(A,B)
N(PHI) / (P/Rm)	0.044	3C	10.458	(C,D)
M(PHI) / (P)	0.044	2C1	0.146	(A,B)
M(PHI) / (P)	0.044	1C	0.186	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.044	3A	0.776	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.044	1A	0.103	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.044	3B	3.153	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.044	1B	0.058	(A,B,C,D)
N(x) / (P/Rm)	0.044	3C	10.458	(A,B)
N(x) / (P/Rm)	0.044	4C	10.441	(C,D)
M(x) / (P)	0.044	1C1	0.192	(A,B)
M(x) / (P)	0.044	2C	0.145	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.044	4A	1.024	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.044	2A	0.062	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.044	4B	0.794	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.044	2B	0.096	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress	Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend.	P	-7.8	7.8	-7.8	7.8	-9.9	9.9	-9.9	9.9
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-29.5	29.5	29.5	-29.5
Circ. Memb.	ML	-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-16.7	16.7	16.7	-16.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-28.9	20.1	10.0	-7.9	-41.7	37.0	18.5	-20.5

Long. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend. P	-10.3	10.3	-10.3	10.3	-7.7	7.7	-7.7	7.7
Long. Memb. MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend. MC	0.0	0.0	0.0	0.0	-17.7	17.7	17.7	-17.7
Long. Memb. ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend. ML	-27.6	27.6	27.6	-27.6	0.0	0.0	0.0	0.0
Tot. Long. Str.	-40.2	35.5	16.3	-18.3	-27.9	22.9	9.2	-10.7
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	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Tot. Shear	3.9	3.9	1.9	1.9	1.9	1.9	3.9	3.9
Str. Int.	41.4	36.4	16.9	18.6	42.0	37.3	20.0	21.9

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at							
	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Circ. Pl (SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q (SUS)	-24.5	24.5	9.0	-9.0	-39.4	39.4	19.5	-19.5
Long. Pm (SUS)	63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.1
Long. Pl (SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q (SUS)	-37.8	37.8	17.3	-17.3	-25.4	25.4	9.9	-9.9
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)	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Pm (SUS)	126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Pm+Pl (SUS)	121.9	124.2	127.3	129.6	124.0	126.3	125.3	127.6
Pm+Pl+Q (Total)	97.6	149.0	136.4	120.7	84.7	165.7	145.0	108.3

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	128.59	137.90	Passed
Pm+Pl (SUS)	129.64	206.85	Passed
Pm+Pl+Q (TOTAL)	165.68	413.70	Passed

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

Input, Nozzle Desc: LT3 From: 70

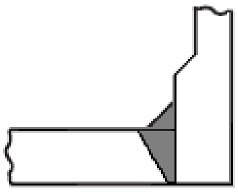
Pressure for Reinforcement Calculations	P	23.000	bars
Temperature for Internal Pressure	Temp	125	°C
Design External Pressure	Pext	1.03	bars
Temperature for External Pressure	Tempex	125	°C
Shell Material [Impact Tested]		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	N./mm^2
Shell Allowable Stress At Ambient	Sva	137.90	N./mm^2
Inside Diameter of Cylindrical Shell	D	1656.00	mm.
Design Length of Section	L	5217.9990	mm.
Shell Finished (Minimum) Thickness	t	18.0000	mm.
Shell Internal Corrosion Allowance	c	3.0000	mm.
Shell External Corrosion Allowance	co	0.0000	mm.
Distance from Bottom/Left Tangent		3845.53	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)		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	
Hub Height of Integral Nozzle	h	99.8228	mm.
Height of Beveled Transition	L'	23.8228	mm.
Hub Thickness of Integral Nozzle (tn or x+tp)		20.0000	mm.
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	150.0000	mm.
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm.
Groove weld depth between Nozzle and Vessel	Wgnv	18.0000	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)



Hub Nozzle (Set-in)

Reinforcement CALCULATION, Description: LT3

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*831.0)/(138*1.0-0.6*23.0)
  = 14.0010 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)/(138*1.0+0.4*23.0)
  = 0.4998 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2826 mm.

Intermediate Hub Nozzle Calculations:

Check to determine use of Sketch (e-1) or (e-2):
```
  = 2.5 * Corroded Hub Thickness
  = 2.5 * 17.0 Note: less than the hub height, use (e-2)
  = 42.5000 mm.
```

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl   115.0342  mm.
 Parallel to Vessel Wall                         Rn+tn+t    57.5171  mm.
 Normal to Vessel Wall (Thickness Limit), no pad    Tlnp    37.5000  mm.
```

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

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

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.145	2.216	NA
Area in Shell	A1	0.639	4.042	NA
Area in Nozzle Wall	A2	12.375	12.538	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
Area in Hub	A6	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	14.015	17.580	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)
  = (51.0342*14.001*1.0+2*17.0*14.001*1.0*(1-1.0))
  = 7.145 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 )
  = 64.0( 1.0 * 15.0 - 1.0 * 14.001 ) - 2 * 17.0
    ( 1.0 * 15.0 - 1.0 * 14.001 ) * ( 1 - 1.0 )
  = 0.639 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 37.5 )( 17.0 - 0.5 )1.0
  = 12.375 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
```

Note: There are no hub area calculations because Figure UG-40 (e-2) was used.

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 3.4998 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure      trb1 = 17.0010 mm.
 Wall Thickness                 tb1 = max(trb1, tr16b) = 17.0010 mm.
 Wall Thickness, shell/head, external pressure      trb2 = 3.6235 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( 17.001, 4.5 ) ]
  = 6.4200 mm.
```

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

```
  = max( 3.4998, 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 :    137.9 N./mm^2  Passed
 Expansion   :     0.0,  Allowable :    282.7 N./mm^2  Passed
 Occasional  :     5.8,  Allowable :    183.4 N./mm^2  Passed
 Shear       :    33.9,  Allowable :     96.5 N./mm^2  Passed
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle 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 for the Nozzle (Impact tested) :

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

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

 Governing MDMT of all the sub-joints of this Junction  :   -46 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

<u>Weld Size Calculations, Description: LT3</u>

```
 Intermediate Calc. for nozzle/shell Welds   Tmin     15.0000  mm.
```

Results Per UW-16.1:

```
                          Required Thickness    Actual Thickness
 Nozzle Weld            6.0000 = Min per Code 7.0700 = 0.7 * Wo mm.
```

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

Weld Load [W]:
```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (7.1453 - 0.6394 + 2 * 17.0 * 1.0 *
    (1.0 * 15.0 - 14.001 ) )138)
```

```
  = 94.39 kN
```

For hub type nozzles, A2 includes the area of the hub.

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

Weld Load [W1]:
```
  = (A2+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 12.3752 + 1. - 0.0 * 1.0 ) * 138
  = 184.43 kN
```

Weld Load [W2]:
```
   = ( A2 + A3 + A4 + (2(Hub Thickness) * t * fr1 )) * Sv
  = ( 12.3752 + 0.0 + 1. + ( 5.1 ) ) * 138
  = 254.75 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+(2*(Hub Thickness)* t * fr1 )) * Sv
  = ( 12.3752 + 0.0 + 1. + 0.0 ) * 138
  = 254.75 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 * 10.0 * 0.49 * 138
  = 64. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 27.8398) * ( 20.0 - 3.0 ) * 0.7 * 138
  = 144. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 60.325 * ( 18.0 - 3.0 ) * 0.74 * 138
  = 145. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 64 + 144 ) = 208 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 64 + 0 + 145 + 0 ) = 209 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 64 + 145 + 0 ) = 209 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 207 kN , must exceed W = 94 kN  or W1 = 184 kN
 Path 2-2 = 209 kN , must exceed W = 94 kN  or W2 = 254 kN
 Path 3-3 = 209 kN , must exceed W = 94 kN  or W3 = 254 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case       24.506   bars
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
 Nozzle is O.K. for the External Pressure                 1.034   bars
```

The Drop for this Nozzle is : 0.5496 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 168.5495 mm.

Input Echo, WRC107/537 Item 1, Description: LT3 :

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm.
Vessel Diameter	Dv	1656.000	mm.
Vessel Thickness	Tv	18.000	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

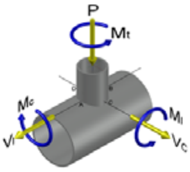
Attachment Type	Type	Round	
Diameter Basis for Nozzle	Nbasis	OD	
Corrosion Allowance for Nozzle	Can	3.0000	mm.
Nozzle Diameter	Dn	85.034	mm.
Nozzle Thickness	Tn	20.000	mm.
Nozzle Material		SA-350 LF2	
Nozzle UNS Number		K03011	
Nozzle Cold S.I. Allowable	SNmc	137.90	N./mm^2
Nozzle Hot S.I. Allowable	SNmh	137.90	N./mm^2
Design Internal Pressure	Dp	23.000	bars
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	2.0	kN
Longitudinal Shear	(SUS)	Vl	2.0	kN
Circumferential Shear	(SUS)	Vc	2.0	kN
Circumferential Moment	(SUS)	Mc	400.0	N-m
Longitudinal Moment	(SUS)	Ml	400.0	N-m
Torsional Moment	(SUS)	Mt	500.0	N-m

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

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



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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 85.034 + 2 * 1.65 * sqrt( 838.5 ( 18.0 - 3.0 ) )
  = 455.127 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 = 55.90

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.044	4C	10.441	(A,B)
N(PHI) / (P/Rm)	0.044	3C	10.458	(C,D)
M(PHI) / (P)	0.044	2C1	0.146	(A,B)
M(PHI) / (P)	0.044	1C	0.186	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.044	3A	0.776	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.044	1A	0.103	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.044	3B	3.153	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.044	1B	0.058	(A,B,C,D)
N(x) / (P/Rm)	0.044	3C	10.458	(A,B)
N(x) / (P/Rm)	0.044	4C	10.441	(C,D)
M(x) / (P)	0.044	1C1	0.192	(A,B)
M(x) / (P)	0.044	2C	0.145	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.044	4A	1.024	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.044	2A	0.062	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.044	4B	0.794	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.044	2B	0.096	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

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

Type of Stress	Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb.	P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend.	P	-7.8	7.8	-7.8	7.8	-9.9	9.9	-9.9	9.9
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-29.5	29.5	29.5	-29.5
Circ. Memb.	ML	-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-16.7	16.7	16.7	-16.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-28.9	20.1	10.0	-7.9	-41.7	37.0	18.5	-20.5

Long. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend. P	-10.3	10.3	-10.3	10.3	-7.7	7.7	-7.7	7.7
Long. Memb. MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend. MC	0.0	0.0	0.0	0.0	-17.7	17.7	17.7	-17.7
Long. Memb. ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend. ML	-27.6	27.6	27.6	-27.6	0.0	0.0	0.0	0.0
Tot. Long. Str.	-40.2	35.5	16.3	-18.3	-27.9	22.9	9.2	-10.7
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	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Tot. Shear	3.9	3.9	1.9	1.9	1.9	1.9	3.9	3.9
Str. Int.	41.4	36.4	16.9	18.6	42.0	37.3	20.0	21.9

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Circ. Pl (SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q (SUS)	-24.5	24.5	9.0	-9.0	-39.4	39.4	19.5	-19.5
Long. Pm (SUS)	63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.1
Long. Pl (SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q (SUS)	-37.8	37.8	17.3	-17.3	-25.4	25.4	9.9	-9.9
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)	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Pm (SUS)	126.3	128.6	126.3	128.6	126.3	128.6	126.3	128.6
Pm+Pl (SUS)	121.9	124.2	127.3	129.6	124.0	126.3	125.3	127.6
Pm+Pl+Q (Total)	97.6	149.0	136.4	120.7	84.7	165.7	145.0	108.3

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	128.59	137.90	Passed
Pm+Pl (SUS)	129.64	206.85	Passed
Pm+Pl+Q (TOTAL)	165.68	413.70	Passed

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

Input, Nozzle Desc: LT2 From: 70

```
Pressure for Reinforcement Calculations         P       23.118  bars
Temperature for Internal Pressure            Temp          125  °C
Design External Pressure                     Pext         1.03  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      1656.00  mm.
Design Length of Section                        L    5217.9990  mm.
Shell Finished (Minimum) Thickness              t      18.0000  mm.
Shell Internal Corrosion Allowance              c       3.0000  mm.
Shell External Corrosion Allowance             co       0.0000  mm.

Distance from Bottom/Left Tangent                      3345.53  mm.

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

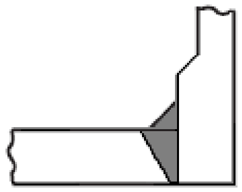
Type of Element Connected to the Shell : Nozzle

```
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)                         OD
Layout Angle                                            270.00  deg
Diameter                                                2.0000  in.

Size and Thickness Basis                                 Minimum
Nominal Thickness                              tn        160

Flange Material                                    SA-350 LF2
Flange Type                                   Weld Neck Flange

Hub Height of Integral Nozzle                   h      99.8228  mm.
Height of Beveled Transition                   L'      23.8228  mm.
Hub Thickness of Integral Nozzle  ( tn or x+tp )       20.0000  mm.

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     150.0000  mm.
Weld leg size between Nozzle and Pad/Shell     Wo      10.0000  mm.
Groove weld depth between Nozzle and Vessel Wgnv       18.0000  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)

```
DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601    ------
Nozzle Calcs.: LT2                      Nozl:    35   11:47am   Dec 23,2021
```



Hub Nozzle (Set-in)

Reinforcement CALCULATION, Description: LT2

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)
  = (23.12*831.0)/(138*1.0-0.6*23.12)
  = 14.0733 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*30.1625)/(138*1.0+0.4*23.12)
  = 0.5023 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2826 mm.

Intermediate Hub Nozzle Calculations:

Check to determine use of Sketch (e-1) or (e-2):
```
  = 2.5 * Corroded Hub Thickness
  = 2.5 * 17.0 Note: less than the hub height, use (e-2)
  = 42.5000 mm.
```

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl    115.0342  mm.
 Parallel to Vessel Wall                        Rn+tn+t     57.5171  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     37.5000  mm.
```

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

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

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.182	2.216	NA
Area in Shell	A1	0.593	4.042	NA
Area in Nozzle Wall	A2	12.373	12.538	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
Area in Hub	A6	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	13.966	17.580	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)
  = (51.0342*14.0733*1.0+2*17.0*14.0733*1.0*(1-1.0))
  = 7.182 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 )
  = 64.0( 1.0 * 15.0 - 1.0 * 14.073 ) - 2 * 17.0
    ( 1.0 * 15.0 - 1.0 * 14.0733 ) * ( 1 - 1.0 )
  = 0.593 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 37.5 )( 17.0 - 0.5 )1.0
  = 12.373 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
```

Note: There are no hub area calculations because Figure UG-40 (e-2) was used.

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 3.5023 mm.
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure     trb1 = 17.0733 mm.
 Wall Thickness                tb1 = max(trb1, tr16b) = 17.0733 mm.
 Wall Thickness, shell/head, external pressure     trb2 = 3.6235 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( 17.0733, 4.5 ) ]
  = 6.4200 mm.
```

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

```
  = max( 3.5023, 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  :    62.1,  Allowable :    137.9 N./mm^2  Passed
 Expansion  :     0.0,  Allowable :    282.7 N./mm^2  Passed
 Occasional :     5.8,  Allowable :    183.4 N./mm^2  Passed
 Shear      :    33.9,  Allowable :     96.5 N./mm^2  Passed
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle 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 for the Nozzle (Impact tested) :

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

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

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

 Governing MDMT of all the sub-joints of this Junction   :   -46 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

<u>Weld Size Calculations, Description: LT2</u>

```
 Intermediate Calc. for nozzle/shell Welds   Tmin     15.0000  mm.
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
 Nozzle Weld          6.0000 = Min per Code 7.0700 = 0.7 * Wo mm.
```

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (7.1822 - 0.5931 + 2 * 17.0 * 1.0 *
    (1.0 * 15.0 - 14.0733 ) )138)
```

```
  = 95.20 kN
```

For hub type nozzles, A2 includes the area of the hub.

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

Weld Load [W1]:
```
  = (A2+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 12.3733 + 1. - 0.0 * 1.0 ) * 138
  = 184.40 kN
```

Weld Load [W2]:
```
   = ( A2 + A3 + A4 + (2(Hub Thickness) * t * fr1 )) * Sv
  = ( 12.3733 + 0.0 + 1. + ( 5.1 ) ) * 138
  = 254.72 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+(2*(Hub Thickness)* t * fr1 )) * Sv
  = ( 12.3733 + 0.0 + 1. + 0.0 ) * 138
  = 254.72 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 * 10.0 * 0.49 * 138
  = 64. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 27.8398) * ( 20.0 - 3.0 ) * 0.7 * 138
  = 144. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 60.325 * ( 18.0 - 3.0 ) * 0.74 * 138
  = 145. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 64 + 144 ) = 208 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 64 + 0 + 145 + 0 ) = 209 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 64 + 145 + 0 ) = 209 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 207 kN , must exceed W = 95 kN  or W1 = 184 kN
 Path 2-2 = 209 kN , must exceed W = 95 kN  or W2 = 254 kN
 Path 3-3 = 209 kN , must exceed W = 95 kN  or W3 = 254 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case       24.623  bars
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
 Nozzle is O.K. for the External Pressure                1.034  bars
```

The Drop for this Nozzle is : 0.5496 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 168.5495 mm.

Input Echo, WRC107/537 Item 1, Description: LT2 :

```
 Diameter Basis for Vessel                    Vbasis      ID
 Cylindrical or Spherical Vessel              Cylsph      Cylindrical
 Internal Corrosion Allowance                    Cas      3.0000  mm.
 Vessel Diameter                                  Dv    1656.000  mm.
 Vessel Thickness                                 Tv      18.000  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

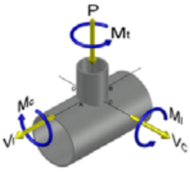
```
 Attachment Type                                Type      Round

 Diameter Basis for Nozzle                    Nbasis      OD
 Corrosion Allowance for Nozzle                  Can      3.0000  mm.
 Nozzle Diameter                                  Dn      85.034  mm.
 Nozzle Thickness                                 Tn      20.000  mm.
 Nozzle Material                                     SA-350 LF2
 Nozzle UNS Number                                       K03011
 Nozzle Cold S.I. Allowable                     SNmc      137.90  N./mm^2
 Nozzle Hot  S.I. Allowable                     SNmh      137.90  N./mm^2

 Design Internal Pressure                         Dp      23.118  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".

DEHDASHT PETROCHEMICAL INDUSTRY COMPANY
DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
Tag no:Evaporator E-PK1601
PV Elite 2019 SP1 Licensee: SPLM Licensed User
FileName : Calculation Book for Evaporator E-PK1601 ------
Nozzle Calcs.: LT2 Nozl: 35 11:47am Dec 23,2021



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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 85.034 + 2 * 1.65 * sqrt( 838.5 ( 18.0 - 3.0 ) )
  = 455.127 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 = 55.90

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.044	4C	10.441	(A,B)
N(PHI) / (P/Rm)	0.044	3C	10.458	(C,D)
M(PHI) / (P)	0.044	2C1	0.146	(A,B)
M(PHI) / (P)	0.044	1C	0.186	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.044	3A	0.776	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.044	1A	0.103	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.044	3B	3.153	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.044	1B	0.058	(A,B,C,D)
N(x) / (P/Rm)	0.044	3C	10.458	(A,B)
N(x) / (P/Rm)	0.044	4C	10.441	(C,D)
M(x) / (P)	0.044	1C1	0.192	(A,B)
M(x) / (P)	0.044	2C	0.145	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.044	4A	1.024	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.044	2A	0.062	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.044	4B	0.794	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.044	2B	0.096	(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	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend.	P	-7.8	7.8	-7.8	7.8	-9.9	9.9	-9.9	9.9
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-29.5	29.5	29.5	-29.5
Circ. Memb.	ML	-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-16.7	16.7	16.7	-16.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-28.9	20.1	10.0	-7.9	-41.7	37.0	18.5	-20.5

Long. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend. P	-10.3	10.3	-10.3	10.3	-7.7	7.7	-7.7	7.7
Long. Memb. MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend. MC	0.0	0.0	0.0	0.0	-17.7	17.7	17.7	-17.7
Long. Memb. ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend. ML	-27.6	27.6	27.6	-27.6	0.0	0.0	0.0	0.0
Tot. Long. Str.	-40.2	35.5	16.3	-18.3	-27.9	22.9	9.2	-10.7
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	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Tot. Shear	3.9	3.9	1.9	1.9	1.9	1.9	3.9	3.9
Str. Int.	41.4	36.4	16.9	18.6	42.0	37.3	20.0	21.9

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Circ. Pl (SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q (SUS)	-24.5	24.5	9.0	-9.0	-39.4	39.4	19.5	-19.5
Long. Pm (SUS)	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5
Long. Pl (SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q (SUS)	-37.8	37.8	17.3	-17.3	-25.4	25.4	9.9	-9.9
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)	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Pm (SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Pm+Pl (SUS)	122.6	124.9	128.0	130.3	124.6	126.9	125.9	128.3
Pm+Pl+Q (Total)	98.3	149.7	137.0	121.4	85.3	166.3	145.7	109.0

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	129.25	137.90	Passed
Pm+Pl (SUS)	130.29	206.85	Passed
Pm+Pl+Q (TOTAL)	166.34	413.70	Passed

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

Input, Nozzle Desc: LT4 From: 70

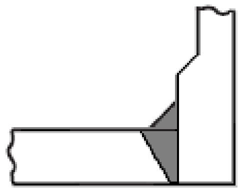
```
Pressure for Reinforcement Calculations        P      23.118  bars
Temperature for Internal Pressure           Temp         125  °C
Design External Pressure                    Pext        1.03  bars
Temperature for External Pressure         Tempex         125  °C

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     1656.00  mm.
Design Length of Section                       L   5217.9990  mm.
Shell Finished (Minimum) Thickness             t     18.0000  mm.
Shell Internal Corrosion Allowance             c      3.0000  mm.
Shell External Corrosion Allowance            co      0.0000  mm.

Distance from Bottom/Left Tangent                    3845.53  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)                       OD
Layout Angle                                          270.00  deg
Diameter                                              2.0000  in.

Size and Thickness Basis                               Minimum
Nominal Thickness                             tn       160

Flange Material                                  SA-350 LF2
Flange Type                                 Weld Neck Flange

Hub Height of Integral Nozzle                  h     99.8228  mm.
Height of Beveled Transition                  L'     23.8228  mm.
Hub Thickness of Integral Nozzle  ( tn or x+tp )     20.0000  mm.

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    150.0000  mm.
Weld leg size between Nozzle and Pad/Shell    Wo     10.0000  mm.
Groove weld depth between Nozzle and Vessel Wgnv     18.0000  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)



Hub Nozzle (Set-in)

Reinforcement CALCULATION, Description: LT4

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)
  = (23.12*831.0)/(138*1.0-0.6*23.12)
  = 14.0733 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*30.1625)/(138*1.0+0.4*23.12)
  = 0.5023 mm.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.2826 mm.

Intermediate Hub Nozzle Calculations:

Check to determine use of Sketch (e-1) or (e-2):
```
  = 2.5 * Corroded Hub Thickness
  = 2.5 * 17.0 Note: less than the hub height, use (e-2)
  = 42.5000 mm.
```

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl    115.0342  mm.
 Parallel to Vessel Wall                        Rn+tn+t     57.5171  mm.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     37.5000  mm.
```

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

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

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

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

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	7.182	2.216	NA
Area in Shell	A1	0.593	4.042	NA
Area in Nozzle Wall	A2	12.373	12.538	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
Area in Hub	A6	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	13.966	17.580	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)
  = (51.0342*14.0733*1.0+2*17.0*14.0733*1.0*(1-1.0))
  = 7.182 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 )
  = 64.0( 1.0 * 15.0 - 1.0 * 14.073 ) - 2 * 17.0
    ( 1.0 * 15.0 - 1.0 * 14.0733 ) * ( 1 - 1.0 )
  = 0.593 cm^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 37.5 )( 17.0 - 0.5 )1.0
  = 12.373 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
```

Note: There are no hub area calculations because Figure UG-40 (e-2) was used.

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures        ta = 3.5023 mm.
 Wall Thickness per UG16(b),                         tr16b = 4.5000 mm.
 Wall Thickness, shell/head, internal pressure        trb1 = 17.0733 mm.
 Wall Thickness                 tb1 = max(trb1, tr16b) = 17.0733 mm.
 Wall Thickness, shell/head, external pressure        trb2 = 3.6235 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( 17.0733, 4.5 ) ]
  = 6.4200 mm.
```

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

```
  = max( 3.5023, 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  :    62.1,  Allowable :    137.9 N./mm^2  Passed
 Expansion  :     0.0,  Allowable :    282.7 N./mm^2  Passed
 Occasional :     5.8,  Allowable :    183.4 N./mm^2  Passed
 Shear      :    33.9,  Allowable :     96.5 N./mm^2  Passed
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle 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 for the Nozzle (Impact tested) :

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

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

 Governing MDMT of all the sub-joints of this Junction  :   -46 °C
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

<u>Weld Size Calculations, Description: LT4</u>

```
 Intermediate Calc. for nozzle/shell Welds   Tmin     15.0000  mm.
```

Results Per UW-16.1:

```
                           Required Thickness    Actual Thickness
 Nozzle Weld             6.0000 = Min per Code 7.0700 = 0.7 * Wo mm.
```

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

Weld Load [W]:

```
  = max( 0, (A-A1+2*tn*fr1*(E1*t-tr))Sv)
  = max( 0, (7.1822 - 0.5931 + 2 * 17.0 * 1.0 *
    (1.0 * 15.0 - 14.0733 ) )138)
```



```
  = 95.20 kN
```

For hub type nozzles, A2 includes the area of the hub.

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

Weld Load [W1]:
```
  = (A2+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 12.3733 + 1. - 0.0 * 1.0 ) * 138
  = 184.40 kN
```

Weld Load [W2]:
```
   = ( A2 + A3 + A4 + (2(Hub Thickness) * t * fr1 )) * Sv
  = ( 12.3733 + 0.0 + 1. + ( 5.1 ) ) * 138
  = 254.72 kN
```

Weld Load [W3]:
```
  = (A2+A3+A4+(2*(Hub Thickness)* t * fr1 )) * Sv
  = ( 12.3733 + 0.0 + 1. + 0.0 ) * 138
  = 254.72 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 * 10.0 * 0.49 * 138
  = 64. kN
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 27.8398) * ( 20.0 - 3.0 ) * 0.7 * 138
  = 144. kN
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * (Wgnvi-Cas) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 60.325 * ( 18.0 - 3.0 ) * 0.74 * 138
  = 145. kN
```

Strength of Failure Paths:

```
  PATH11 = ( SONW + SNW ) = ( 64 + 144 ) = 208 kN
  PATH22 = ( Sonw + Tpgw + Tngw + Sinw )
         = ( 64 + 0 + 145 + 0 ) = 209 kN
  PATH33 = ( Sonw + Tngw + Sinw )
         = ( 64 + 145 + 0 ) = 209 kN
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 207 kN , must exceed W = 95 kN  or W1 = 184 kN
 Path 2-2 = 209 kN , must exceed W = 95 kN  or W2 = 254 kN
 Path 3-3 = 209 kN , must exceed W = 95 kN  or W3 = 254 kN
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Max. Allow. Pressure in Operating case       24.623  bars
```

Note: The MAWP of this junction was limited by the parent Shell/Head.

```
 Nozzle is O.K. for the External Pressure                1.034  bars
```

The Drop for this Nozzle is : 0.5496 mm.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 168.5495 mm.

Input Echo, WRC107/537 Item 1, Description: LT4 :

```
Diameter Basis for Vessel                   Vbasis      ID
Cylindrical or Spherical Vessel             Cylsph      Cylindrical
Internal Corrosion Allowance                   Cas      3.0000  mm.
Vessel Diameter                                 Dv    1656.000  mm.
Vessel Thickness                                Tv      18.000  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
```

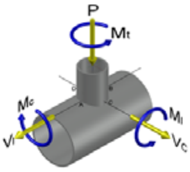
Note:
Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-516 70

```
Attachment Type                               Type      Round

Diameter Basis for Nozzle                   Nbasis      OD
Corrosion Allowance for Nozzle                 Can      3.0000  mm.
Nozzle Diameter                                 Dn      85.034  mm.
Nozzle Thickness                                Tn      20.000  mm.
Nozzle Material                                     SA-350 LF2
Nozzle UNS Number                                       K03011
Nozzle Cold S.I. Allowable                    SNmc      137.90  N./mm^2
Nozzle Hot  S.I. Allowable                    SNmh      137.90  N./mm^2

Design Internal Pressure                        Dp      23.118  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))
= 85.034 + 2 * 1.65 * sqrt(838.5 (18.0 - 3.0))
= 455.127 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 = 55.90

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.044	4C	10.441	(A,B)
N(PHI) / (P/Rm)	0.044	3C	10.458	(C,D)
M(PHI) / (P)	0.044	2C1	0.146	(A,B)
M(PHI) / (P)	0.044	1C	0.186	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.044	3A	0.776	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.044	1A	0.103	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.044	3B	3.153	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.044	1B	0.058	(A,B,C,D)
N(x) / (P/Rm)	0.044	3C	10.458	(A,B)
N(x) / (P/Rm)	0.044	4C	10.441	(C,D)
M(x) / (P)	0.044	1C1	0.192	(A,B)
M(x) / (P)	0.044	2C	0.145	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.044	4A	1.024	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.044	2A	0.062	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.044	4B	0.794	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.044	2B	0.096	(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	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Circ. Bend.	P	-7.8	7.8	-7.8	7.8	-9.9	9.9	-9.9	9.9
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Circ. Memb.	MC	0.0	0.0	0.0	0.0	-29.5	29.5	29.5	-29.5
Circ. Memb.	ML	-2.7	-2.7	2.7	2.7	0.0	0.0	0.0	0.0
Circ. Bend.	ML	-16.7	16.7	16.7	-16.7	0.0	0.0	0.0	0.0
Tot. Circ. Str.		-28.9	20.1	10.0	-7.9	-41.7	37.0	18.5	-20.5

Long. Memb. P	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
Long. Bend. P	-10.3	10.3	-10.3	10.3	-7.7	7.7	-7.7	7.7
Long. Memb. MC	0.0	0.0	0.0	0.0	-0.9	-0.9	0.9	0.9
Long. Bend. MC	0.0	0.0	0.0	0.0	-17.7	17.7	17.7	-17.7
Long. Memb. ML	-0.7	-0.7	0.7	0.7	0.0	0.0	0.0	0.0
Long. Bend. ML	-27.6	27.6	27.6	-27.6	0.0	0.0	0.0	0.0
Tot. Long. Str.	-40.2	35.5	16.3	-18.3	-27.9	22.9	9.2	-10.7
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	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Tot. Shear	3.9	3.9	1.9	1.9	1.9	1.9	3.9	3.9
Str. Int.	41.4	36.4	16.9	18.6	42.0	37.3	20.0	21.9

WRC 107/537 Stress Summations:

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

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Circ. Pl (SUS)	-4.4	-4.4	1.0	1.0	-2.3	-2.3	-1.0	-1.0
Circ. Q (SUS)	-24.5	24.5	9.0	-9.0	-39.4	39.4	19.5	-19.5
Long. Pm (SUS)	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5
Long. Pl (SUS)	-2.3	-2.3	-1.0	-1.0	-2.5	-2.5	-0.8	-0.8
Long. Q (SUS)	-37.8	37.8	17.3	-17.3	-25.4	25.4	9.9	-9.9
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)	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Pm (SUS)	126.9	129.2	126.9	129.2	126.9	129.2	126.9	129.2
Pm+Pl (SUS)	122.6	124.9	128.0	130.3	124.6	126.9	125.9	128.3
Pm+Pl+Q (Total)	98.3	149.7	137.0	121.4	85.3	166.3	145.7	109.0

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

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	129.25	137.90	Passed
Pm+Pl (SUS)	130.29	206.85	Passed
Pm+Pl+Q (TOTAL)	166.34	413.70	Passed

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

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
D4	2.000 in	Actual	LWN	3.307	16.600	...	...	171.24	300
D2	2.000 in	Actual	LWN	3.307	16.600	...	...	169.07	300
D1	2.000 in	Actual	LWN	3.307	16.600	...	...	169.07	300
D3	2.000 in	Actual	LWN	3.307	16.600	...	...	169.07	300
TT	2.000 in	Actual	LWN	3.307	16.600	...	...	169.07	300
V	2.000 in	Actual	LWN	3.307	16.600	...	...	169.07	300
LG1	2.000 in	Actual	LWN	3.307	16.600	...	...	169.07	300
LG2	2.000 in	Actual	LWN	3.307	16.600	...	...	169.07	300
LT1	2.000 in	160	WNF	2.375	8.738	...	...	168.55	300
LT3	2.000 in	160	WNF	2.375	8.738	...	...	168.55	300
LT2	2.000 in	160	WNF	2.375	8.738	...	...	168.55	300
LT4	2.000 in	160	WNF	2.375	8.738	...	...	168.55	300
S2	8.000 in	80	WNF	8.625	12.700	379.08	18.00	175.28	300
S1	8.000 in	80	WNF	8.625	12.700	379.08	18.00	175.28	300
S3	8.000 in	80	WNF	8.625	12.700	379.08	18.00	175.28	300
S4	8.000 in	80	WNF	8.625	12.700	379.08	18.00	175.28	300
T2	20.000 in	Actual	WNF	20.000	20.000	748.00	20.00	221.42	300
T1	20.000 in	Actual	WNF	20.000	20.000	748.00	20.00	221.42	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
D4	SA-350 LF2	20.000	10.000	...	...	...
D2	SA-350 LF2	18.000	10.000	...	...	...
D1	SA-350 LF2	18.000	10.000	...	...	...
D3	SA-350 LF2	18.000	10.000	...	...	...
TT	SA-350 LF2	18.000	10.000	...	...	...
V	SA-350 LF2	18.000	10.000	...	...	...
LG1	SA-350 LF2	18.000	10.000	...	...	...
LG2	SA-350 LF2	18.000	10.000	...	...	...
LT1	SA-350 LF2	18.000	10.000	...	...	...
LT3	SA-350 LF2	18.000	10.000	...	...	...
LT2	SA-350 LF2	18.000	10.000	...	...	...
LT4	SA-350 LF2	18.000	10.000	...	...	...
S2	SA-333 6	18.000	10.000	14.000	18.000	...
S1	SA-333 6	18.000	10.000	14.000	18.000	...
S3	SA-333 6	18.000	10.000	14.000	18.000	...
S4	SA-333 6	18.000	10.000	14.000	18.000	...
T2	SA-516 70	15.000	18.000	12.000	15.000	...
T1	SA-516 70	15.000	18.000	12.000	15.000	...

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
D4	1865.525	270.0	150.00	0.00	CON
D2	2895.525	270.0	150.00	0.00	SHELL 002
D1	4695.525	270.0	150.00	0.00	SHELL 002
D3	5495.525	270.0	150.00	0.00	SHELL 002
TT	6095.525	270.0	150.00	0.00	SHELL 002
V	2495.525	90.0	150.00	0.00	SHELL 002
LG1	4495.525	270.0	150.00	0.00	SHELL 002
LG2	4495.525	90.0	150.00	0.00	SHELL 002
LT1	3295.525	90.0	150.00	0.00	SHELL 002
LT3	3795.525	90.0	150.00	0.00	SHELL 002
LT2	3295.525	270.0	150.00	0.00	SHELL 002
LT4	3795.525	270.0	150.00	0.00	SHELL 002
S2	2495.525	270.0	150.00	0.00	SHELL 002
S1	5095.525	270.0	150.00	0.00	SHELL 002
S3	2895.525	90.0	150.00	0.00	SHELL 002
S4	5095.525	90.0	150.00	0.00	SHELL 002
T2	400.000	90.0	150.00	0.00	SHELL 001
T1	400.000	270.0	150.00	0.00	SHELL 001

Input Echo, Tubesheet Number 1, Description: TUBE SHEET

Shell Data:

Main Shell Description: SHELL 002

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	20.0000	mm.
Shell Internal Corrosion Allowance	cas	3.0000	mm.
Shell External Corrosion Allowance	caext	0.0000	mm.
Inside Diameter of Shell	Ds	1200.000	mm.
Shell Temperature for Internal Pressure	Ts	125.00	°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: SHELL 001

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	1200.000	mm.
Channel Design Temperature	TEMPC	125.00	°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	1740	
Tube Wall Thickness	et	2.1100	mm.
Tube Outside Diameter	D	19.0500	mm.
Total Straight Tube Length	Lt	4200.00	mm.
Straight Tube Length (bet. inner tubsht faces)	L	4060.00	mm.
Design Temperature of the Tubes		125.00	°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	216.71	N./mm^2
Tube Pitch (Center to Center Spacing)	P	24.0000	mm.
Tube Layout Pattern		Square	

Fillet Weld Leg	af	1.5000	mm.
Groove Weld Leg	ag	1.5000	mm.
Tube-Tubesheet Joint Weld Type		Full Strength	
Method for Tube-Tubesheet Jt. Allow.		UW-20	
Tube-Tubesheet Joint Classification		f	

Radius to Outermost Tube Hole Center	ro	581.890	mm.
Largest Center-to-Center Tube Distance	Ul	57.8000	mm.
Length of Expanded Portion of Tube	ltx	0.0000	mm.
Tube-side pass partition groove depth	hg	5.0000	mm.

Tubesheet Data:

Tubesheet TYPE: U-tube, Gasketed both Sides, Conf. d

Tubesheet Design Metal Temperature	T	125.00	°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	140.0000	mm.
Tubesheet Corr. Allowance (Shell side)	Cats	3.0000	mm.
Tubesheet Corr. Allowance (Channel side)	Catc	3.0000	mm.
Tubesheet Outside Diameter	A	1360.000	mm.

Additional Data for Stepped Tubesheets:

Is the Tubesheet Stepped?		YES	
Is the Tubesheet Flat on Tubeside?		NO	
Step 1 Diameter on the Tubeside	dt1	406.00	mm.
Step 1 Depth on the Tubeside	ht1	7.00	mm.
Step 2 Diameter on the Tubeside	dt2	337.00	mm.
Step 2 Depth on the Tubeside	ht2	6.00	mm.
Is the Tubesheet Flat on Shellside?		NO	
Step 1 Diameter on the Shellside	ds1	406.00	mm.
Step 1 Depth on the Shellside	hs1	7.00	mm.
Step 2 Diameter on the Shellside	ds2	337.00	mm.
Step 2 Depth on the Shellside	hs2	6.00	mm.
Calculated Tubesheet Diameter as per UHX-10(b)		1360.00	mm.

Note: Tubesheet diameter is now: 1360.000 mm. per UHX-10(b).

Dimension G for the Channel Side	Gc	1250.063	mm.
Area of the Untubed Lanes	AL	255.9	cm^2

Junction Stress Reduction option		Increase Tubesheet thickness	
Perform Differential Pressure Design		NO	
Run Multiple Load Cases		YES	
Channel Side Min. Design Pressure	Ptd,min	1.0342	bars

Additional Data for Gasketed Tubesheets:

Tubesheet Gasket on which Side		Both	
Flange Outside Diameter	A	1360.000	mm.
Flange Inside Diameter	B	1200.000	mm.
Flange Face Outside Diameter	Fod	1269.000	mm.
Flange Face Inside Diameter	Fid	1200.000	mm.

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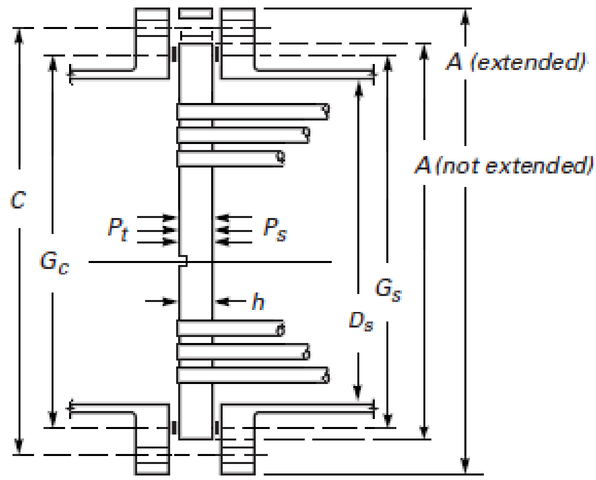
Gasket Outside Diameter	Go	1266.000	mm.
Gasket Inside Diameter	Gi	1226.000	mm.
Small end Hub thk.	g0	18.0000	mm.
Large end Hub thk.	g1	23.0000	mm.
Gasket Factor,	m	3.00	
Gasket Design Seating Stress	y	68.95	N./mm^2
Flange Facing Sketch	Code Sketch 1a		

Tubesheet Gasketed With Shell and Channel



Configuration d:

Column for Gasket Seating Code
Column II

Gasket Thickness	tg	3.0000	mm.
Full face Gasket Flange Option	Program Selects		

Bolting Information:

Diameter of Bolt Circle	C	1310.000	mm.
Nominal Bolt Diameter	dB	22.2250	mm.
Type of Thread Series	TEMA Thread Series		
Number of Bolts	n	72	
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.
Alternate Flange Operating Bolt Load, Wm1		3271.23	kN
Alternate Flange Seating Bolt Load, Wm2		2157.58	kN
Alternate Flange Design Bolt Load, W		3312.96	kN
Tubesheet Integral with		None	
Tubesheet Extended as Flange		Yes	
Thickness of Extended Portion of Tubesheet	Tf	118.0000	mm.
Is Bolt Load Transferred to the Tubesheet		Yes	

ASME TubeSheet Results per Part UHX, 2017

Elasticity/Expansion Material Properties :

Shell - TM-1 Carbon Steels with C<= 0.3%

```
 Elastic Mod. at Design Temperature      125.0 °C      0.19660E+09 KPa.
 Elastic Mod. at Ambient Temperature      21.1 °C      0.20270E+09 KPa.
```

Channel - TM-1 Carbon Steels with C<= 0.3%

```
 -----------------------------------------------------------------
 Elastic Mod. at Design Temperature      125.0 °C      0.19660E+09 KPa.
 Elastic Mod. at Ambient Temperature      21.1 °C      0.20270E+09 KPa.
```

Tubes - TM-1 Carbon Steels with C<= 0.3%

```
 -----------------------------------------------------------------
 Elastic Mod. at Tubsht. Design Temp.    125.0 °C      0.19660E+09 KPa.
 Elastic Mod. at Ambient Temperature      21.1 °C      0.20270E+09 KPa.
```

TubeSheet - TM-1 Carbon Steels with C> 0.3%

```
 -----------------------------------------------------------------
 Elastic Mod. at Design Temperature      125.0 °C      0.19522E+09 KPa.
 Elastic Mod. at Ambient Temperature      21.1 °C      0.20132E+09 KPa.
```

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)
  = (23.0*(19.05/2-0.0)/(117.9*1.0+0.4*23.0)
  = 0.1844 + 0.0000 = 0.1844 mm.
```

Tube Required Thickness under External Pressure (Shellside pressure) :

```
 External Pressure Chart     CS-2             at       125.00  °C
 Elastic Modulus for Material                   199943392.00  KPa.
```

Results for Max. Allowable External Pressure (Emawp):

TCA	ODCA	SLEN	D/T	L/D	Factor A	B
2.1100	19.05	4641.89	9.03	50.0000	0.0134948	122.73

EMAWP = (2.167/(D/T)-0.0833)*B = 192.3322 bars

Results for Reqd Thickness for Ext. Pressure (Tca):

TCA	ODCA	SLEN	D/T	L/D	Factor A	B
0.4839	19.05	4641.89	39.37	50.0000	0.0007098	70.97

EMAWP = (4*B)/(3*(D/T)) = (4 *70.9657)/(3 *39.3662) = 24.0347 bars

Summary of Tube Required Thickness Results:

```
 Total Required Thickness including Corrosion all.          0.4839  mm.
 Allowable Internal Pressure at Corroded thickness          286.56  bars
 Required Internal Design Pressure                           23.00  bars
 Allowable External Pressure at Corroded thickness          192.33  bars
 Required External Design Pressure                           24.03  bars
 Required Thickness due to Shell Side pressure              0.4839  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              1250.068  mm.
```

Bolting Information for TEMA Imperial 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	188.817	194.632	

```
 Flange Design Bolt Load, Seating Condition    W  :     3312.96  kN
 Flange Design Bolt Load, Operating Condition  Wm1:     3254.46  kN
```

Results for ASME U-tube Tubesheet Calculations for Configuration d,
Per Edition 2017, Original Thickness :

Minimum Required Thickness for Shear [HreqS]:
```
  = 1/(4 * Mu) * (Do/(0.8 * S)) * [Ps - Pt] + Cats + Catc
  = 1/(4 * 0.206 ) * (1182.83/(0.8 * 137.9 )) * [23.0 - 23.0 ] + 0.0
  = 0.0000 mm.
```

UHX-12.5.1 Step 1:

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
```
  = 2 * ro + dt
  = 2 * 581.89 + 19.05 = 1182.83 mm.
```

Determine the Basic Ligament Efficiency for Shear [mu]:
```
  = (p - dt) / p
  = (24.0 - 19.05 )/24.0 = 0.206
```

UHX-12.5.2 Step 2:

Compute the Ratio [Rhos]:
```
  = Gs / Do (Configurations d, e, f)
  = 1250.0685/1182.83 = 1.0568
```

Compute the Ratio [Rhoc]:
```
  = Gc / Do (Configurations d)
  = 1250.0626/1182.83 = 1.0568
```

Moment on Tubesheet due to Pressures (Ps, Pt) [Mts]:
```
  = Do²/16 * [(Rhos-1)*(Rhos²+1)* Ps - (Rhoc-1) * (Rhoc²+1) * Pt ]
  = 1182.83²/16 * [ (1.057 - 1) * (1.057² + 1) * 23.0 -
    (1.057 - 1) * (1.057² + 1) * 23.0 ]
  = 22.5152 bars*mm.²
```

UHX-12.5.3 Step 3, Determination of Effective Elastic Properties :

Compute the Ratio [rho]:
```
  = ltx/h = 0.0/140.0 = 0.0 ( must be 0 <= rho <= 1 )
```

Compute the Effective Tube Hole Diameter [d*]:
```
  = max( dt - 2tt*( Et/E )( St/S )( rho ), dt - 2tt)
  = max( 19.05 -2*2.11 *(.19660E+09/.19522E+09)*
       ( 117/137 )*(0.0 ), 19.05 -2*2.11 )
  = 19.0500 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( 255.94 *100.0, 4*1182.83 *24.0 )
```

```
    (3.141* 1182.83²) )
  = 24.2845 mm.
```

Compute the Effective Ligament Efficiency for Bending [mu*]:

```
  = (p* - d*)/p* = (24.2845 - 19.05 )/24.2845 = 0.21555
```

E*/E, nu* for Square pattern from Fig. UHX-11.4.

```
   h/p =   5.833333 ;  mu* =   0.215548
  E*/E =   0.251278 ;  nu* =   0.335866 ;  E* = 49054772. KPa.
```

Note: As h/p (5.833) is > 2, data values for h/p = 2 were used.

Skip Step 4 for Configuration d :

UHX-12.5.5 Step 5:

Diameter ratio [K]:

```
  = A/Do = 1360.0/1182.83 = 1.1498
```

Determine Coefficient [F]:

```
  = (1 - nu*)/E* * ( E * ln(K) )
  = (1 - 0.34 )/49054772 * ( 0.19522E+09 * ln(1.15 ) )
  = 0.3689
```

UHX-12.5.6 Step 6:

Moment Acting on Unperforated Tubesheet Rim [M*]

```
  = Mts + W* * (Gc - Gs)/(2 * pi * Do)
  = 22.5 + 3271.2 * (1250.063 - 1250.063 )/(2 * pi * 1182.83 )
  = 22.5152 bars*mm.²
```

Note: W is the maximum of the bolt loads between the shell and channel sides.*

UHX-12.5.7 Step 7:

Maximum Bending Moment acting on Periphery of Tubesheet [Mp]:

```
  = ((M*) - Do²/32 * F * (Ps - Pt) ) / (1 + F)
  = ((22.52 ) - 1182.83²/32 * 0.369 * (23.0 - 23.0 ) )/(1 + 0.37 )
  = 16.4477 bars*mm.²
```

Maximum Bending Moment acting on Center of Tubesheet [Mo]:

```
  = Mp + Do²/64 * (3 + rnu*)(Ps - Pt)
  = 16.45 + 1182.83²/64 * (3 + 0.336 )(23.0 - 23.0 )
  = 16.4477 bars*mm.²
```

Maximum Bending Moment acting on Tubesheet [M]:

```
  = Max( abs(Mp), abs(Mo) )
  = Max( abs(16.448 ), abs(16.448 ) )
  = 16.4477 bars*mm.²
```

UHX-12.5.8 Step 8:

Tubesheet Bending Stress at Original Thickness:

```
  = 6 * M / ( (mu*) * ( h - hg')² )
  = 6 * 16.448/( ( 0.2155 ) * ( 140.0 - 5.0 )² )
  = 0.0025 N./mm^2
```

The Allowable Tubesheet Bending Stress [SigmaAll]:

```
  = 2 * S = 2 * 137.9 = 275.8 N./mm^2
```

Tubesheet Bending Stress at Final Thickness [Sigma]:

```
  = 6 * M / ( (mu*) * ( h - hg')²
  = 6 * 16.473/( ( 0.2155 ) * ( 0.508 - 5.0 )²
  = 2.2726 N./mm^2
```

Required Tubesheet Thickness, for Bending Stress [HreqB]:
```
  = H + CATS + CATC = 0.508 + 0.0 + 0.0 = 0.508 mm.
```

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:
```
  = Max( HreqB, HreqS ) = Max( 0.508, 0.0 ) = 0.508 mm.
```

UHX-12.5.9 Step 9:

```
  abs(Ps - Pt) = abs(23.0 - 23.0 ) = 0.0 bars
```

Shear Stress check [Tau_limit]:
```
  = 3.2 * S * MU * h / Do
  = 3.2 * 137.9 * 0.206 * 140.0/1182.83 = 107.72 bars
```

Average Shear Stress at the Outer Edge of Perforated Region [Tau]:
```
  = 1/(4* Mu) * (Do/h) * [Ps - Pt]
  = 1/(4*0.206)*(1182.83/140.0)*[23.0-23.0]N./mm^2
  = 0.00 N./mm^2
```

Note: Analysis Completed for Tubesheet Configuration d.

Tube Weld Size Results per UW-20:

Tube Strength [Ft]:
```
  = 3.1415 * t * ( do - t ) * Sa
  = 3.1415 * 2.11 * ( 19.05 - 2.11 ) * 117.9 = 13.239 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 = 13.2385 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)
  = 2.5620  mm.
```

```
 Minimum Required Fillet Weld Leg             afr      1.2810  mm.
 Minimum Required Groove Weld Leg             agr      1.2810  mm.
```

```
 Tube-Tubesheet Jt allowable, 13.24 is >= tube strength 13.24 kN
```
Note: This tube-tubesheet joint is a Full Strength joint

Stress/Force summary for loadcase D3 un-corr. (Psd,max + Ptd,max):

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Stress Description	Actual		Allowable	Pass/Fail
Tubesheet bend. stress	0.0	<=	275.8 N./mm^2	Ok
Tubesheet shear stress	0.0	<=	110.3 N./mm^2	Ok

Thickness results for loadcase D3 un-corr. (Psd,max + Ptd,max):

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	0.508	140.000	Ok
Tube-Tubesheet Fillet Weld Leg :	1.281	1.500	Ok
Tube-Tubesheet Groove Weld Leg :	1.281	1.500	Ok

U-Tube Tubesheet results per ASME UHX-12 2017

Results for 8 Load Cases:

	--Reqd. Thk. + CA		---- Tubesheet Stresses				Case	Pass/
Case#	Tbsht	Extnsn	Bend	Allwd	Shear	Allwd	Type	Fail
D1uc	131.418	33.080	242	276	24	110	Ps+Pt D1	Ok
D2uc	134.225	...	253	276	25	110	Ps+Pt D2	Ok
D3uc	0.508	...	...	276	...	110	Ps+Pt D3	Ok
D4uc	31.855	...	11	276	1	110	Ps+Pt D4	Ok
D1c	134.407	33.080	253	276	25	110	Ps+Pt-c D1	Ok
D2c	137.218	...	264	276	26	110	Ps+Pt-c D2	Ok
D3c	6.508	...	...	276	...	110	Ps+Pt-c D3	Ok
D4c	34.828	...	11	276	1	110	Ps+Pt-c D4	Ok
Max:	137.2176	33.080	mm.	0.958		0.233	(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

[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)

Summary of Thickness Comparisons for 8 Load Cases:

Thickness (mm.)	Required	Actual	P/F
Tubesheet Thickness :	137.218	140.000	Ok
Tubesheet Thickness Flanged Extension :	33.080	118.000	Ok
Tube Thickness :	0.484	2.110	Ok
Tube-Tubesheet Fillet Weld Leg :	1.281	1.500	Ok
Tube-Tubesheet Groove Weld Leg :	1.281	1.500	Ok

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Note: This is a full strength Tube to Tubesheet Joint.

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	25.080	1.000	25.080	1.000
Tubesheet Shear Stress	103.101	1.000	103.101	1.000
Tube Pressure Stress	286.561	1.000	192.331	1.000
Tubesheet Extension Stress	23.707	...	No Calc	No Calc
Minimum MAWP	23.707		25.080	

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	26.233	1.000	26.233	1.000
Tubesheet Shear Stress	107.717	1.000	107.717	1.000
Tube Pressure Stress	286.561	1.000	192.331	1.000
Tubesheet Extension Stress	23.707	...	No Calc	No Calc
Minimum MAPnc	23.707		26.233	

(*) 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.

Determine the governing MDMT considering the governing condition:

Governing thickness on the shell side per figure UCS-66.3 (c):
= tubesheet thickness/4
= 140.0/4
= 35.000 mm.

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

Impact Test Temperature provided per Specification -46 °C

where the MDMT reduction ratio per UCS 66 (b)(1)(b) is:
= max(pt/Tubeside MAPnc, ps/Shellside MAPnc), must be <= 1
= max(23.0/23.71, 23.0/26.23)
= 0.970

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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
body flange 0	[11]	!	-46	-46		0.617	18.000	1.00	No
SHELL 002	[8]	!	-45	-66		0.613	20.000	1.00	No
Tubesheet: SS	[13]	!	-46	-46		0.970	35.000	1.00	No
Warmest MDMT:			-45	-46					
BODY FLANGE 0	[11]	!	-46	-46		0.854	15.000	1.00	No
HEAD 001	[10]	!	-45	-54		0.840	15.000	1.00	No
HEAD 001	[7]	!	-45	-63		0.682	18.000	1.00	No
SHELL 001	[8]	!	-45	-53		0.853	15.000	1.00	No
CON	[8]	!	-45	-48		0.947	20.000	1.00	No
SHELL 002	[8]	!	-45	-48		0.940	18.000	1.00	No
HEAD 002	[10]	!	-45	-45		0.994	17.000	1.00	No
HEAD 002	[7]	!	-45	-54		0.829	20.000	1.00	No
T2	[1]	D	-47	-48	-29	0.847	15.000	1.00	No
Nozzle Flg	[4]	D	-29	-104					
T1	[1]	D	-47	-48	-29	0.851	15.000	1.00	No
Nozzle Flg	[4]	D	-29	-104					
D4	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg	[5]	!	-46	-46					
S2	[1]	D	-43	-46	-29	0.938	18.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
S1	[1]	D	-43	-46	-29	0.938	18.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
S3	[1]	D	-43	-46	-29	0.933	18.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
D2	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg	[5]	!	-46	-46					
D1	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg	[5]	!	-46	-46					
D3	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg	[5]	!	-46	-46					
TT	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg	[5]	!	-46	-46					
V	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg	[5]	!	-46	-46					
S4	[1]	D	-43	-46	-29	0.933	18.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
LG1	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg	[5]	!	-46	-46					
LG2	[1]	!	-46	-104		0.035	16.600	1.00	No
Nozzle Flg	[5]	!	-46	-46					
LT1	[1]	!	-46	-46		0.933	18.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
LT3	[1]	!	-46	-46		0.933	18.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
LT2	[1]	!	-46	-46		0.938	18.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
LT4	[1]	!	-46	-46		0.938	18.000	1.00	No
Nozzle Flg	[4]	!	-46	-104					
Tubesheet: CS	[14]	!	-46	-46		0.970	35.000	1.00	No
Warmest MDMT:			-29	-45					

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Exchanger Side	Computed MDMT °C	Required MDMT °C	Pass/Fail
Shell	-46.0	-45.0	Pass
Channel/Tube	-45.0	-45.0	Pass

Notes:
[!] - This was an impact tested material.
[1] - Governing Nozzle Weld.
[4] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-c).
[5] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-b).
[6] - MDMT Calculations at the Shell/Head Joint.
[7] - MDMT Calculations for the Straight Flange.
[8] - Cylinder/Cone/Flange Junction MDMT.
[9] - Calculations in the Spherical Portion of the Head.
[10] - Calculations in the Knuckle Portion of the Head.
[11] - Calculated (Body Flange) Flange MDMT.
[12] - Calculated Flat Head MDMT per UCS-66.3
[13] - Tubesheet MDMT, shell side, if applicable
[14] - Tubesheet MDMT, tube side, if applicable
[15] - Nozzle Material
[16] - Shell or Head Material
[17] - Impact Testing required
[18] - Impact Testing not required, see UCS-66(b)(3)
[20] - Cylinder/Cone Junction MDMT based on Longitudinal Stress considerations
[21] - Bolting Material

UG-84(b)(2) was not considered.
UCS-66(g) was not considered.
UCS-66(i) was not considered.

Notes:
Impact test temps were not entered in and not considered in the analysis.
UCS-66(i) applies to impact tested materials not by specification and
UCS-66(g) applies to materials impact tested per UG-84.1 General Note (c).
The Basic MDMT includes the (30F) PWHT credit if applicable.

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DEHDASHT HIGH DENSITY POLYETHYLENE PROJECT
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FileName : Calculation Book for Evaporator E-PK1601 ------
Vessel Design Summary: Step: 38 11:47am Dec 23,2021

ASME Code, Section VIII Division 1, 2017

```
Diameter Spec : 1200.000 x 1656.000 mm. ID
Vessel Design Length, Tangent to Tangent          6395.52  mm.

Specified Datum Line Distance                       50.00  mm.

Shell  Side  Design Temperature                       125  °C
Channel Side Design Temperature                       125  °C

Shell  Side  Design Pressure                       23.000  bars
Channel Side Design Pressure                       23.000  bars

Shell  Side  Hydrostatic Test Pressure             29.900  bars
Channel Side Hydrostatic Test Pressure             29.900  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	No	Yes
Head	SA-516 70	...	...	K02700	No	Yes
Cone	SA-516 70	...	...	K02700	No	Yes
Flange	SA-350 LF2	1	...	K03011	No	Yes
Nozzle	SA-516 70	...	...	K02700	Yes	No
Nozzle	SA-350 LF2	1	...	K03011	No	Yes
Nozzle	SA-333 6	...	...	K03006	No	Yes
Re-Pad	SA-516 70	...	...	K02700	Yes	No
Nozzle Flg	SA-350 LF2	1	...	K03011	No	No
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 001	23.118	1.03	27.450	3.0000	No	No
SHELL 001	23.118	1.03	26.999	3.0000	N/A	No
BODY FLANGE 001	23.118	1.03	23.589	3.0000	N/A	No
body flange 02	23.118	1.03	23.589	3.0000	N/A	No
SHELL 002	23.118	1.03	38.110	3.0000	N/A	No
CON	23.118	1.03	24.330	3.0000	N/A	No
SHELL 002	23.118	1.03	24.506	3.0000	N/A	No
HEAD 002	23.118	1.03	23.185	3.0000	No	No

Liquid Level: 1200.00 mm. Dens.: 0.001 kg./cm^3 Sp. Gr.: 1.000

Element Types and Properties:

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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	18.0	15.0	13.1	6.2	1.00	1.00
Cylinder	800.0	800.0	15.0	15.0	13.2	6.5	1.00	1.00
Body Flg	955.0	155.0	60.0	110.0	107.8	79.3	1.00	1.00
Body Flg	1265.5	155.0	60.0	110.0	99.5	65.5	1.00	1.00
Cylinder	1465.5	200.0	20.0	20.0	13.2	10.2	1.00	1.00
Conical	2295.5	830.0	20.0	20.0	19.1	11.7	1.00	1.00
Cylinder	6295.5	4000.0	18.0	18.0	17.1	11.7	1.00	1.00
Ellipse	6345.5	50.0	20.0	17.0	16.9	7.4	1.00	1.00

Saddle Parameters:

Saddle Width	172.000	mm.
Saddle Bearing Angle	120.000	deg.
Centerline Dimension	972.000	mm.
Wear Pad Width	332.000	mm.
Wear Pad Thickness	12.000	mm.
Wear Pad Bearing Angle	140.000	deg.
Distance from Saddle to Tangent	352.000	mm.

Baseplate Length	1450.000	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	326.000	mm.
Number of Bolts in Baseplate	4	

Baseplate Sketch

```
|------------------ 1450.000 mm. -------------------|
----------------------------------------------------- ---
|                                                   |
|                                                   | 220.000 mm.
|                                                   |
----------------------------------------------------- ---
```

Baseplate Plan View

```
----------------------------------------------------- ---
|                                                   | 16.000 mm.
----------------------------------------------------- ---
```

Baseplate Side View

Maximum Tensile Bolt Load 1. kN

Summary of Maximum Saddle Loads, Operating Case :

Maximum Vertical Saddle Load	266.39	kN
Maximum Transverse Saddle Shear Load	34.78	kN
Maximum Longitudinal Saddle Shear Load	69.57	kN

Summary of Maximum Saddle Loads, Operating Case, Un-Factored :

Maximum Vertical Saddle Load	306.10	kN
Maximum Transverse Saddle Shear Load	92.66	kN
Maximum Longitudinal Saddle Shear Load	99.38	kN

Summary of Maximum Saddle Loads, Hydrotest Case :

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Maximum Vertical Saddle Load	191.92	kN
Maximum Transverse Saddle Shear Load	1.72	kN
Maximum Longitudinal Saddle Shear Load	1.55	kN

Local Stress Analysis Results:

Description	Analysis Type	Max Stress Ratio	Pass Fail
T2	WRC-107/537	0.871	Passed
T1	WRC-107/537	0.873	Passed
S2	WRC-107/537	0.937	Passed
S1	WRC-107/537	0.937	Passed
S3	WRC-107/537	0.932	Passed
D2	WRC-107/537	0.937	Passed
D1	WRC-107/537	0.937	Passed
D3	WRC-107/537	0.937	Passed
TT	WRC-107/537	0.937	Passed
V	WRC-107/537	0.932	Passed
S4	WRC-107/537	0.932	Passed
LG1	WRC-107/537	0.937	Passed
LG2	WRC-107/537	0.932	Passed
LT1	WRC-107/537	0.932	Passed
LT3	WRC-107/537	0.932	Passed
LT2	WRC-107/537	0.937	Passed
LT4	WRC-107/537	0.937	Passed

Weights:

Fabricated	- Bare W/O Removable Internals	18480.4	kg.
Shop Test	- Fabricated + Water (Full)	32350.8	kg.
Shipping	- Fab. + Rem. Intls.+ Shipping App.	18480.4	kg.
Erected	- Fab. + Rem. Intls.+ Insul. (etc)	18480.4	kg.
Empty	- Fab. + Intls. + Details + Wghts.	18480.4	kg.
Operating	- Empty + Operating Liquid (No CA)	30041.8	kg.
Field Test	- Empty Weight + Water (Full)	31455.0	kg.