MECHANICAL CALCULATION REPORT

PROJECT NAME: World Energy Renew Amine US7L

ITEM NO. ： 18-X-262

PROJECT NUMBER: EN207121

PURCHASE ORDER NO.: 4505600577

SERVICE ： LEAN / RICH AMINE EXCHANGER

VENDOR DOC. NO: WXCE6723-CAL-1

DRAWING NO. : WXCE6723-DWG-G001

DRAWING REV. NO.: 04

04	17/01/2023	FOR REVIEW	Huang Jialing	Zhao Shengfang	Kevin Yang
03	31/10/2022	FOR REVIEW	Huang Jialing	Zhao Shengfang	Kevin Yang
02	22/08/2022	FOR REVIEW	Huang Jialing	Zhao Shengfang	Kevin Yang
01	30/05/2022	FOR REVIEW	Huang Jialing	Zhao Shengfang	Kevin Yang
00	05/03/2022	FOR REVIEW	Huang Jialing	Zhao Shengfang	Kevin Yang
REV.	**DATE**	**REASON FOR ISSUE**	**PREPARED**	**REVIEWED**	**APPROVED**

WUXI CHEMICAL EQUIPMENT CO., LTD.

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SHIPPING CALCULATION WILL BE PROVIDE IN WXCE6723-CAL-2

DESIGN CALCULATION

In Accordance with ASME Section VIII Division 1

```
ASME Code Version     : 2021

Analysis Performed by : WCE

Job File              : F:\+0\1.17AP\18-X-262\程序\04\1.18-X-262-04.pvdb

Date of Analysis      : Jan 17,2023   8:44am
```

PV Elite 24, January 2022

Units used in this Analysis (AP-in):

Name	System Unit	Constant	User Unit
Length	Feet	12.0000	in
Force	Pounds	1.0000	lbf
Mass	Pounds	1.0000	lbm
Area	sq. inches	1.0000	in^2
Moment	ft. lbs.	1.0000	ft-lb
Stress	lbs./sq.in.	1.0000	psi
Temperature	Degrees F	1.0000	F
Pressure	psig	1.0000	psig
Elast. Modulus	lbs./sq.in.	1.0000	psi
Pipe Density	lbs./cu.in.	1.0000	lbm/in^3
Ins. Density	lbs./cu.ft.	1.0000	lbm/ft^3
Fluid Density	lbs./cu.ft.	1.0000	lbm/ft^3
Wind Speed	miles/hr	1.0000	mile/hr
Tray Weight	lbs./sq.ft.	1.0000	lb/ft^2
Inertia	in.**4	1.0000	in**4
G Load	G's	1.0000	g's
Wind Load	lbs./sq.ft.	1.0000	psf
Elevation	Feet	12.0000	in
Volume	in.**3	0.0006	ft3
Diameter	inches	1.0000	in
Thickness	inches	1.0000	in

PV Elite Vessel Analysis Program: Input Data

Exchanger Design Pressures and Temperatures

Shell Side Design Pressure	150	psig
Channel Side Design Pressure	195	psig
Shell Side Design Temperature	330.0	F
Channel Side Design Temperature	300.0	F
Radiography, Shell Side	RT-1	
Radiography, Channel Side	RT-1	
Service Type, Shell Side	Sour	
Service Type, Channel Side	Sour	
MDMT (CET), Shell Side	32.0	F
MDMT (CET), Tube Side	32.0	F
User defined MAWP, Shell Side	280.14	psig
User defined MAWP, Channel Side	280.14	psig
User defined MAPnc, Shell Side	0	psig
User defined MAPnc, Channel Side	0	psig
User defined Test Pres., Shell Side	0	psig
User defined Test Pres., Channel Side	0	psig

Projection of Nozzle from Vessel Top	0	in
Projection of Nozzle from Vessel Bottom	0	in
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	

Shop Pressure Test:

Type of Pressure Test	UG-99(c)
Pressure Test Position	Horizontal

```
 Test Performed in Corroded Condition                     No
```

Field Pressure Test:

```
 Type of Pressure Test                             UG-99(b)
 Pressure Test Position                          Horizontal
 Test Performed in Corroded Condition                   Yes

 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/SEI 7-16
 Wind Load Reduction Scale Factor                       0.600
 Basic Wind Speed                   [V]                   101  mile/hr
 Surface Roughness Category                   C: Open Terrain
 Importance Factor                                        1.0
 Type of Surface                            Moderately Smooth
 Base Elevation                                           988  in
 Percent Wind for Hydrotest                              50.0
 Using User defined Wind Press. Vs Elev.                    N
 Height of Hill or Escarpment     H or Hh                   0  in
 Distance Upwind of Crest              Lh                   0  in
 Distance from Crest to the Vessel      x                   0  in
 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
 Site Elevation above Sea Level                             0  in

 Seismic Design Code                            ASCE/SEI 7-16
 Seismic Load Reduction Scale Factor                    0.700
 Importance Factor                                      1.500
 Table Value Fa                                         1.000
 Table Value Fv                                         1.721
 Max. Mapped Res. Acceleration     [Ss]                 1.616
 Max. Eff. Ground Acceleration      [S]                 0.579
 Force Modification Factor R                            2.500
 Site Class                                                 D
 Component Elevation Ratio          z/h                 1.000
 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 )                       1.077
 User Value of Sd1 (used if > 0 )                       0.996
 Moment Reduction Factor Tau                            1.000

 M.A.W.P + Static Head to Nozzle                            Y
```

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

 Perform Blast Load Analysis                          No
 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             No
  Consider Longitudinal Stress in MDMT Calculations       Yes
```

Complete Listing of Vessel Elements and Details:

```
 Element From Node                                        10
 Element To Node                                          20
 Element Type                                         Flange
 Description                                           COVER
 Distance "FROM" to "TO"                              4.4488  in
 Flange Outside Diameter                              54.724  in
 Element Thickness                                    4.4488  in
 Internal Corrosion Allowance                              0  in
 Nominal Thickness                                     4.921  in
 External Corrosion Allowance                              0  in
 Design Internal Pressure                                195  psig
 Design Temperature Internal Pressure                    300  F
 Design External Pressure                                 15  psig
 Design Temperature External Pressure                    300  F
 Effective Diameter Multiplier                          1.37
 Material Name                                      SA-266 2
     Allowable Stress, Ambient                         20000  psi
     Allowable Stress, Operating                       20000  psi
     Allowable Stress, Hydrotest                       26004  psi
     Material Density                                   0.28  lbm/in^3
     P Number Thickness                                 1.22  in
     Yield Stress, Operating                           31806  psi
     UCS-66 Chart Curve Designation                        C
     External Pressure Chart Name                       CS-2
     UNS Number                                       K03506
     Product Form                                   Forgings
 Perform Flange Stress Calculation (Y/N)                   Y
 Weld is pre-Heated                                       No

     Element From Node                                    10
     Detail Type                                      Liquid
     Detail ID                                    Liquid: 10
     Dist. from "FROM" Node / Offset dist                  0  in
     Height/Length of Liquid                              44  in
     Liquid Density                                   65.433  lbm/ft^3

     Element From Node                                    10
     Detail Type                                  Insulation
     Detail ID                                       Ins: 10
```

```
    Dist. from "FROM" Node / Offset dist              0  in
    Height/Length of Insulation                  4.5276  in
    Thickness of Insulation                         1.5  in
    Density                                      9.3633  lbm/ft^3

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

Element From Node                                    20
Element To Node                                      30
Element Type                                     Flange
Description                                CHANNEL FLG1
Distance "FROM" to "TO"                           7.087  in
Flange Inside Diameter                           44.504  in
Element Thickness                                 5.315  in
Internal Corrosion Allowance                          0  in
Nominal Thickness                                 5.787  in
External Corrosion Allowance                          0  in
Design Internal Pressure                            195  psig
Design Temperature Internal Pressure                300  F
Design External Pressure                             15  psig
Design Temperature External Pressure                300  F
Effective Diameter Multiplier                      1.37
Material Name                                  SA-266 2
Perform Flange Stress Calculation (Y/N)               Y
Weld is pre-Heated                                   No

    Element From Node                                20
    Detail Type                                  Liquid
    Detail ID                                Liquid: 20
    Dist. from "FROM" Node / Offset dist              0  in
    Height/Length of Liquid                          44  in
    Liquid Density                               65.433  lbm/ft^3

    Element From Node                                20
    Detail Type                              Insulation
    Detail ID                                   Ins: 20
    Dist. from "FROM" Node / Offset dist              0  in
    Height/Length of Insulation                  7.0315  in
    Thickness of Insulation                         1.5  in
    Density                                      9.3633  lbm/ft^3

    Element From Node                                20
    Detail Type                                  Lining
    Detail ID                                   OVERLAY
    Dist. from "FROM" Node / Offset dist              0  in
    Height/Length of Lining                       7.087  in
    Thickness of Lining                           0.252  in
    Density                                      495.01  lbm/ft^3

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

Element From Node                                    30
Element To Node                                      40
Element Type          Cylinder                  ! Atype
Description                                     CHANNEL
Distance "FROM" to "TO"                          33.465  in
Inside Diameter                                  44.252  in
Element Thickness                                  0.63  in
Internal Corrosion Allowance                          0  in
Nominal Thickness                                  0.63  in
External Corrosion Allowance                          0  in
Design Internal Pressure                            195  psig
Design Temperature Internal Pressure                300  F
Design External Pressure                             15  psig
```

```
 Design Temperature External Pressure                300  F
 Effective Diameter Multiplier                       1.37
 Material Name                               SA-516 70 [Normalized]
     Allowable Stress, Ambient                     20000  psi
     Allowable Stress, Operating                   20000  psi
     Allowable Stress, Hydrotest                   26000  psi
     Material Density                               0.28  lbm/in^3
     P Number Thickness                             1.25  in
     Yield Stress, Operating                       33600  psi
     UCS-66 Chart Curve Designation                    D
     External Pressure Chart Name                   CS-2
     UNS Number                                   K02700
     Product Form                                  Plate
 Efficiency, Longitudinal Seam                       1.0
 Efficiency, Circumferential Seam                    1.0
 Weld is pre-Heated                                   No

     Element From Node                                30
     Detail Type                                  Liquid
     Detail ID                                Liquid: 30
     Dist. from "FROM" Node / Offset dist              0  in
     Height/Length of Liquid                          44  in
     Liquid Density                               65.433  lbm/ft^3

     Element From Node                                30
     Detail Type                              Insulation
     Detail ID                                       INS
     Dist. from "FROM" Node / Offset dist              0  in
     Height/Length of Insulation                  33.465  in
     Thickness of Insulation                         1.5  in
     Density                                      9.3633  lbm/ft^3

     Element From Node                                30
     Detail Type                                  Lining
     Detail ID                                      CLAD
     Dist. from "FROM" Node / Offset dist              0  in
     Height/Length of Lining                      33.465  in
     Thickness of Lining                           0.125  in
     Density                                      495.01  lbm/ft^3

     Element From Node                                30
     Detail Type                                  Nozzle
     Detail ID                                        T2
     Dist. from "FROM" Node / Offset dist         16.732  in
     Nozzle Diameter                                  10  in.
     Nozzle Schedule                                  80
     Nozzle Class                                    300
     Layout Angle                                23.2973
     Blind Flange (Y/N)                                N
     Weight of Nozzle ( Used if > 0 )                  0  lbf
     Grade of Attached Flange                     GR 1.1
     Nozzle Matl                                SA-106 B

     Element From Node                                30
     Detail Type                                  Nozzle
     Detail ID                                        T1
     Dist. from "FROM" Node / Offset dist         16.732  in
     Nozzle Diameter                                  10  in.
     Nozzle Schedule                                  80
     Nozzle Class                                    300
     Layout Angle                                156.703
     Blind Flange (Y/N)                                N
     Weight of Nozzle ( Used if > 0 )                  0  lbf
     Grade of Attached Flange                     GR 1.1
```

```
    Nozzle Matl                                 SA-106 B

    Element From Node                                 30
    Detail Type                                   Nozzle
    Detail ID                                         V1
    Dist. from "FROM" Node / Offset dist          16.732  in
    Nozzle Diameter                                    2  in.
    Nozzle Schedule                                 None
    Nozzle Class                                     300
    Layout Angle                              -25.629299
    Blind Flange (Y/N)                                 Y
    Weight of Nozzle ( Used if > 0 )                   0  lbf
    Grade of Attached Flange                      GR 1.1
    Nozzle Matl                                   SA-105 [Normalized]

    Element From Node                                 30
    Detail Type                                   Nozzle
    Detail ID                                         D1
    Dist. from "FROM" Node / Offset dist          16.732  in
    Nozzle Diameter                                    2  in.
    Nozzle Schedule                                 None
    Nozzle Class                                     300
    Layout Angle                               205.62801
    Blind Flange (Y/N)                                 Y
    Weight of Nozzle ( Used if > 0 )                   0  lbf
    Grade of Attached Flange                      GR 1.1
    Nozzle Matl                                   SA-105 [Normalized]

    Element From Node                                 30
    Detail Type                                   Nozzle
    Detail ID                                       Aux1
    Dist. from "FROM" Node / Offset dist           5.787  in
    Nozzle Diameter                                    2  in.
    Nozzle Schedule                                 None
    Nozzle Class                                     300
    Layout Angle                                    90.0
    Blind Flange (Y/N)                                 Y
    Weight of Nozzle ( Used if > 0 )                   0  lbf
    Grade of Attached Flange                      GR 1.1
    Nozzle Matl                                   SA-105 [Normalized]

    Element From Node                                 30
    Detail Type                                   Nozzle
    Detail ID                                       Aux2
    Dist. from "FROM" Node / Offset dist          5.7874  in
    Nozzle Diameter                                    2  in.
    Nozzle Schedule                                 None
    Nozzle Class                                     300
    Layout Angle                                    90.0
    Blind Flange (Y/N)                                 Y
    Weight of Nozzle ( Used if > 0 )                   0  lbf
    Grade of Attached Flange                      GR 1.1
    Nozzle Matl                                   SA-105 [Normalized]

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

Element From Node                                     40
Element To Node                                       50
Element Type                                      Flange
Description                                 CHANNEL FLG2
Distance "FROM" to "TO"                            7.087  in
Flange Inside Diameter                            44.504  in
Element Thickness                                  5.315  in
Internal Corrosion Allowance                           0  in
```

```
 Nominal Thickness                                  5.787  in
 External Corrosion Allowance                           0  in
 Design Internal Pressure                             195  psig
 Design Temperature Internal Pressure                 300  F
 Design External Pressure                              15  psig
 Design Temperature External Pressure                 300  F
 Effective Diameter Multiplier                       1.37
 Material Name                                   SA-266 2
     Allowable Stress, Ambient                      20000  psi
     Allowable Stress, Operating                    20000  psi
     Allowable Stress, Hydrotest                    32400  psi
     Material Density                                0.28  lbm/in^3
     P Number Thickness                              1.22  in
     Yield Stress, Operating                        31806  psi
     UCS-66 Chart Curve Designation                     C
     External Pressure Chart Name                    CS-2
     UNS Number                                    K03506
     Product Form                                Forgings
 Perform Flange Stress Calculation (Y/N)                Y
 Weld is pre-Heated                                    No

     Element From Node                                 40
     Detail Type                                   Liquid
     Detail ID                                 Liquid: 40
     Dist. from "FROM" Node / Offset dist               0  in
     Height/Length of Liquid                           44  in
     Liquid Density                                65.433  lbm/ft^3

     Element From Node                                 40
     Detail Type                               Insulation
     Detail ID                                    Ins: 40
     Dist. from "FROM" Node / Offset dist               0  in
     Height/Length of Insulation                   7.0315  in
     Thickness of Insulation                          1.5  in
     Density                                       9.3633  lbm/ft^3

     Element From Node                                 40
     Detail Type                                   Lining
     Detail ID                                    OVERLAY
     Dist. from "FROM" Node / Offset dist               0  in
     Height/Length of Lining                        7.087  in
     Thickness of Lining                            0.252  in
     Density                                       495.01  lbm/ft^3

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

 Element From Node                                     50
 Element To Node                                       60
 Element Type                                      Flange
 Description                                    SHELL FLG
 Distance "FROM" to "TO"                            7.087  in
 Flange Inside Diameter                            44.504  in
 Element Thickness                                  5.315  in
 Internal Corrosion Allowance                           0  in
 Nominal Thickness                                  5.787  in
 External Corrosion Allowance                           0  in
 Design Internal Pressure                             150  psig
 Design Temperature Internal Pressure                 330  F
 Design External Pressure                              15  psig
 Design Temperature External Pressure                 300  F
 Effective Diameter Multiplier                       1.37
 Material Name                                   SA-266 2
 Perform Flange Stress Calculation (Y/N)                Y
 Weld is pre-Heated                                    No
```

```
    Element From Node                                  50
    Detail Type                                    Liquid
    Detail ID                                  Liquid: 50
    Dist. from "FROM" Node / Offset dist                0  in
    Height/Length of Liquid                            44  in
    Liquid Density                                 61.358  lbm/ft^3

    Element From Node                                  50
    Detail Type                                Insulation
    Detail ID                                     Ins: 50
    Dist. from "FROM" Node / Offset dist                0  in
    Height/Length of Insulation                    7.0315  in
    Thickness of Insulation                           1.5  in
    Density                                        9.3633  lbm/ft^3

    Element From Node                                  50
    Detail Type                                    Lining
    Detail ID                                     overlay
    Dist. from "FROM" Node / Offset dist                0  in
    Height/Length of Lining                         7.087  in
    Thickness of Lining                             0.252  in
    Density                                        495.01  lbm/ft^3

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

Element From Node                                      60
Element To Node                                        70
Element Type           Cylinder                   ! Atype
Description                                         SHELL
Distance "FROM" to "TO"                            208.66  in
Inside Diameter                                    44.252  in
Element Thickness                                    0.63  in
Internal Corrosion Allowance                            0  in
Nominal Thickness                                    0.63  in
External Corrosion Allowance                            0  in
Design Internal Pressure                              150  psig
Design Temperature Internal Pressure                  330  F
Design External Pressure                               15  psig
Design Temperature External Pressure                  300  F
Effective Diameter Multiplier                        1.37
Material Name                                  SA-516 70 [Normalized]
    Allowable Stress, Ambient                       20000  psi
    Allowable Stress, Operating                     20000  psi
    Allowable Stress, Hydrotest                     26000  psi
    Material Density                                 0.28  lbm/in^3
    P Number Thickness                               1.25  in
    Yield Stress, Operating                         33270  psi
    UCS-66 Chart Curve Designation                      D
    External Pressure Chart Name                     CS-2
    UNS Number                                     K02700
    Product Form                                    Plate
Efficiency, Longitudinal Seam                         1.0
Efficiency, Circumferential Seam                      1.0
Weld is pre-Heated                                     No

    Element From Node                                  60
    Detail Type                                    Saddle
    Detail ID                              Sliding Saddle
    Dist. from "FROM" Node / Offset dist           12.992  in
    Width of Saddle                                7.4252  in
    Height of Saddle at Bottom                         40  in
    Saddle Contact Angle                            120.0
    Height of Composite Ring Stiffener                  0  in
```

```
Width of Wear Plate                              9  in
Thickness of Wear Plate                       0.63  in
Contact Angle, Wear Plate (degrees)          132.0
Friction coefficient                    0.40000001
Moment Factor                                  3.0
Dimension E at base (optional)                   0  in
Circumferential Eff. over Saddle               1.0
Circumferential Eff. at Midspan                1.0
Tangent to Tangent dist. (optional)              0  in

Element From Node                               60
Detail Type                                 Saddle
Detail ID                             Fixed Saddle
Dist. from "FROM" Node / Offset dist        151.99  in
Width of Saddle                             7.4252  in
Height of Saddle at Bottom                      40  in
Saddle Contact Angle                         120.0
Height of Composite Ring Stiffener               0  in
Width of Wear Plate                              9  in
Thickness of Wear Plate                       0.63  in
Contact Angle, Wear Plate (degrees)          132.0
Friction coefficient                           0.0
Moment Factor                                  3.0
Dimension E at base (optional)                   0  in
Circumferential Eff. over Saddle               1.0
Circumferential Eff. at Midspan                1.0
Tangent to Tangent dist. (optional)              0  in

Element From Node                               60
Detail Type                                 Liquid
Detail ID                               Liquid: 50
Dist. from "FROM" Node / Offset dist             0  in
Height/Length of Liquid                         44  in
Liquid Density                              61.358  lbm/ft^3

Element From Node                               60
Detail Type                             Insulation
Detail ID                                  Ins: 60
Dist. from "FROM" Node / Offset dist             0  in
Height/Length of Insulation                 208.66  in
Thickness of Insulation                        1.5  in
Density                                     9.3633  lbm/ft^3

Element From Node                               60
Detail Type                                 Lining
Detail ID                                     clad
Dist. from "FROM" Node / Offset dist             0  in
Height/Length of Lining                     208.66  in
Thickness of Lining                          0.125  in
Density                                     495.01  lbm/ft^3

Element From Node                               60
Detail Type                                 Nozzle
Detail ID                                       S1
Dist. from "FROM" Node / Offset dist        12.797  in
Nozzle Diameter                                 12  in.
Nozzle Schedule                               None
Nozzle Class                                   300
Layout Angle                                   0.0
Blind Flange (Y/N)                               N
Weight of Nozzle ( Used if > 0 )                 0  lbf
Grade of Attached Flange                    GR 1.1
Nozzle Matl                             SA-516 70 [Normalized]
```

```
    Element From Node                               60
    Detail Type                                 Nozzle
    Detail ID                                       S2
    Dist. from "FROM" Node / Offset dist        177.21  in
    Nozzle Diameter                                 10  in.
    Nozzle Schedule                                 80
    Nozzle Class                                   300
    Layout Angle                                 180.0
    Blind Flange (Y/N)                               N
    Weight of Nozzle ( Used if > 0 )                 0  lbf
    Grade of Attached Flange                    GR 1.1
    Nozzle Matl                               SA-106 B

    Element From Node                               60
    Detail Type                                 Nozzle
    Detail ID                                     Aux3
    Dist. from "FROM" Node / Offset dist         4.898  in
    Nozzle Diameter                                  2  in.
    Nozzle Schedule                               None
    Nozzle Class                                   300
    Layout Angle                                  90.0
    Blind Flange (Y/N)                               Y
    Weight of Nozzle ( Used if > 0 )                 0  lbf
    Grade of Attached Flange                    GR 1.1
    Nozzle Matl                                 SA-105 [Normalized]

    Element From Node                               60
    Detail Type                                 Nozzle
    Detail ID                                     Aux4
    Dist. from "FROM" Node / Offset dist         4.898  in
    Nozzle Diameter                                  2  in.
    Nozzle Schedule                               None
    Nozzle Class                                   300
    Layout Angle                                  90.0
    Blind Flange (Y/N)                               Y
    Weight of Nozzle ( Used if > 0 )                 0  lbf
    Grade of Attached Flange                    GR 1.1
    Nozzle Matl                                 SA-105 [Normalized]

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

Element From Node                                   70
Element To Node                                     80
Element Type                                Elliptical
Description                                       HEAD
Distance "FROM" to "TO"                              2  in
Inside Diameter                                 44.252  in
Element Thickness                                0.472  in
Internal Corrosion Allowance                         0  in
Nominal Thickness                                0.551  in
External Corrosion Allowance                         0  in
Design Internal Pressure                           150  psig
Design Temperature Internal Pressure               330  F
Design External Pressure                            15  psig
Design Temperature External Pressure               300  F
Effective Diameter Multiplier                     1.37
Material Name                                SA-516 70 [Normalized]
Efficiency, Longitudinal Seam                      1.0
Efficiency, Circumferential Seam                   1.0
Elliptical Head Factor                             2.0
Weld is pre-Heated                                  No

    Element From Node                               70
    Detail Type                                 Liquid
```

```
Detail ID                                  Liquid: 70
Dist. from "FROM" Node / Offset dist                0  in
Height/Length of Liquid                            44  in
Liquid Density                                 61.358  lbm/ft^3

Element From Node                                  70
Detail Type                                Insulation
Detail ID                                     Ins: 70
Dist. from "FROM" Node / Offset dist                0  in
Height/Length of Insulation                    13.062  in
Thickness of Insulation                           1.5  in
Density                                        9.3633  lbm/ft^3

Element From Node                                  70
Detail Type                                    Lining
Detail ID                                        clad
Dist. from "FROM" Node / Offset dist                0  in
Height/Length of Lining                        13.062  in
Thickness of Lining                             0.157  in
Density                                        495.01  lbm/ft^3
```

XY Coordinate Calculations:

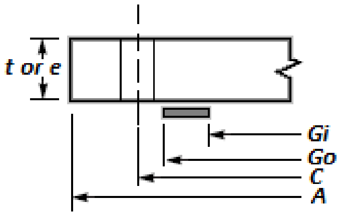
From	To	X (Horiz.) in	Y (Vert.) in	DX (Horiz.) in	DY (Vert.) in
	COVER	4.85582	...	4.44882	...
	CHANNEL FLG1	12.2248	...	7.087	...
	CHANNEL	45.6894	...	33.4646	...
	CHANNEL FLG2	52.7764	...	7.087	...
	SHELL FLG	65.0264	...	7.087	...
	SHELL	273.688	...	208.661	...
	HEAD	275.688	...	2	...

PV Elite includes an 1/8 inch (3.175mm) raised face and gasket thicknesses for girth flanges and tubesheet thicknesses where applicable in the Tangent to Tangent length calculation. The calculated dimensions are based on the given element lengths. Due to variability in manufacturing (weld gaps etc.), the Tangent to Tangent length may not be exact.

Flange Input Data Values **Description:** COVER :

COVER

```
 Flange Type                                TEMA Channel Cover

 Design Pressure                            P          196.67  psig
 Design Temperature                                       300  F
 Internal Corrosion Allowance              ci          0.0000  in
 External Corrosion Allowance              ce          0.0000  in
Use Corrosion Allowance in Thickness Calcs.                No
 Flange Outside Diameter                    A          54.724  in
 Flange Thickness                           t          4.4488  in

 Flange Material                                     SA-266 2
 Flange Material UNS number                            K03506
 Flange Allowable Stress At Temperature   Sfo        20000.00  psi
 Flange Allowable Stress At Ambient       Sfa        20000.00  psi

 Bolt Material                                      SA-193 B7M
 Bolt Allowable Stress At Temperature      Sb        20000.00  psi
 Bolt Allowable Stress At Ambient          Sa        20000.00  psi

 Diameter of the Load Reaction, Long  Span  D           0.000  in
 Diameter of the Load Reaction, Short Span  d           0.000  in
 Perimeter along the Center of the Bolts    L         160.171  in
 Youngs Modulus for Blind Flange Matl.     Sy     28300000.00  psi
 Allowed Channel Cover Deflection     dfAllow          0.0550  in

 Diameter of Bolt Circle                    C          50.984  in
 Nominal Bolt Diameter                      a          1.5000  in
 Type of Threads                            TEMA Thread Series
 Number of Bolts                                           44

 Flange Face Outside Diameter             Fod          46.850  in
 Flange Face Inside Diameter              Fid          44.000  in
 Flange Facing Sketch                        1, Code Sketch 1a

 Gasket Outside Diameter                   Go          46.850  in
 Gasket Inside Diameter                    Gi          45.276  in
 Gasket Factor                              m          4.2500
 Gasket Design Seating Stress               y        10100.00  psi

 Column for Gasket Seating                   2, Code Column II
 Gasket Thickness                          tg          0.1570  in

 Length of Partition Gasket                lp         67.9130  in
 Width  of Partition Gasket                tp          0.3940  in
 Partition Gasket Factor                mPart          4.2500
 Partition Gasket Design Seating Stress yPart        10100.00  psi
```



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```
Gasket Contact Width,       N = (Go - Gi) / 2            0.787  in
Basic Gasket Width,        bo = N / 2                    0.394  in
Effective Gasket Width,     b = sqrt(bo)/2               0.314  in
Gasket Reaction Diameter,   G = Go - 2 * b              46.223  in
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:

```
  = 0.785 * G² * Peq
  = 0.7854 * 46.223² * 196.67
  = 330012.250 lbf
```

Contact Load on Gasket Surfaces [Hp]:

```
  = 2 * b * pi * G * m * P + 2 * lp * bPart * mPart * P
  = 2 * 0.3136 * pi * 46.223 * 4.25 * 196.67
    + 2 * 67.913 * 0.197 * 4.25 * 196.67
  = 98502.297 lbf
```

Operating Bolt Load [Wm1]:

```
  = max( H + Hp + H'p, 0 )
  = max( 330012 + 98502 + 0, 0 )
  = 428514.562 lbf
```

Gasket Seating Bolt Load [Wm2]:

```
  = y * b * pi * G  + yPart * bPart * lp
  = 10100*0.3136*pi*46.223+10100*0.197*67.913
  = 595140.125 lbf
```

Required Bolt Area [Am]:

```
  = max( Wm1/Sb, Wm2/Sa )
  = max( 428515/20000, 595140/20000 )
  = 29.757 in^2
```

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

```
  = 2a + 6t/(m + 0.5)
  = 2 * 1.5 + 6 * 4.4488/(4.25 + 0.5)
  = 8.620 in
```

Actual Circumferential Bolt Spacing [Bs]:

```
  = C * sin( pi / n )
  = 50.984 * sin( pi/44 )
  = 3.637 in
```

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

```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 3.6372/( 2 * 1.5 + 4.4488 )), 1 )
  = 1.0000
```

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

	Minimum	Actual	Maximum
Bolt Area:	29.757	61.820	
Radial Distance between Bolts and Edge:	1.500	1.870	
Circ. Spacing between the Bolts:	3.250	3.637	8.620

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

```
  = Ab * Sa/( y * pi(Go + Gi) )
  = 61.82 * 20000/(10100 * pi(46.85 + 45.276 ) )
  = 0.423 in
```

Flange Design Bolt Load, Gasket Seating [W]:
 = Sa(Am + Ab) / 2
 = 20000(29.757 + 61.82)/2
 = 915770.06 lbf

Gasket Load for the Operating Condition [HG]:
 = Wm1
 = 428514.56 lbf

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
 = (C - G) / 2
 = (50.984 - 46.223)/2
 = 2.3806 in

Tangential Flange Stress, Flat Head (UG-34), Operating [STo]:
 = 1.9 * Wm1 * hG * Bsc/(t^2 * G) + C * Z * Peq * G^2/t^2
 = 1.9*428515*2.3806*1/(4.4488^2*46.223)+0.3*1*196.67*$46.223^2/4.4488^2$
 = 8487.67 psi

Tangential Flange Stress, Flat Head (UG-34), Seating [STa]:
 = 1.9 * W * hG * Bsc/ (t^2 * G)
 = 1.9*915770*2.3806*1/(4.4488^2*46.223)
 = 4527.74 psi

Bolt Stress, Operating [BSo]:
 = Wm1 / Ab
 = 428515/61.82
 = 6931.65 psi

Bolt Stress, Seating [BSa]:
 = (Wm2 / Ab)
 = (595140/61.82)
 = 9626.98 psi

Flange Stress Analysis Results: psi

	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Tangential Flange	8487.67	20000.00	4527.74	20000.00
Bolting	6931.65	20000.00	9626.98	20000.00

TEMA Channel Cover Deflection Calculations:
 Actual deflection at center per TEMA formula 0.0430 in
 Allowed deflection at center of Cover 0.0550 in

 Reqd. Blind Flange Thickness at Center 2.898 in
 Reqd. Blind Flange Thickness at Gasket 2.117 in
 Min. Required Flange Thickness per TEMA 4.097 in
 Estimated M.A.W.P. (Operating) 347.61 psig
 Estimated Finished Weight of Flange at given Thk. 2929.9 lbm
 Estimated Unfinished Weight of Forging at given Thk 2929.9 lbm

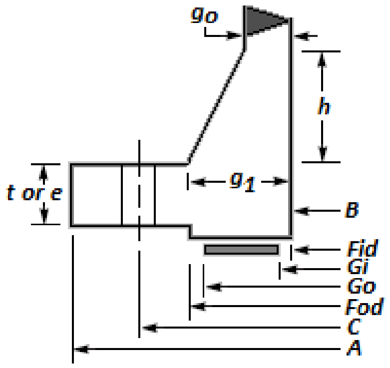
Minimum Design Metal Temperature Results:
Thickness Ratio = 0.8059, Temperature Reduction per Fig. UCS 66.1 = 0 F

 Min Metal Temp. w/o impact per UCS-66, Curve C 0 F

Flange Input Data Values **Description:** CHANNEL FLG1 **:**

CHANNEL FLG1

```
 Flange Type                              Integral Weld Neck

 Design Pressure                           P          196.67  psig
 Design Temperature                                      300  F
 Internal Corrosion Allowance             ci          0.0000  in
 External Corrosion Allowance             ce          0.0000  in
 Use Corrosion Allowance in Thickness Calcs.              No
 Flange Inside Diameter                    B          44.504  in
 Flange Outside Diameter                   A          54.724  in
 Flange Thickness                          t          5.3150  in
 Thickness of Hub at Small End            go          0.5040  in
 Thickness of Hub at Large End            g1          0.8190  in
 Length of Hub                             h          1.7720  in

 Flange Material                                    SA-266 2
 Flange Material UNS number                           K03506
 Flange Allowable Stress At Temperature  Sfo        20000.00  psi
 Flange Allowable Stress At Ambient      Sfa        20000.00  psi

 Bolt Material                                    SA-193 B7M
 Bolt Allowable Stress At Temperature     Sb        20000.00  psi
 Bolt Allowable Stress At Ambient         Sa        20000.00  psi

 Diameter of Bolt Circle                   C          50.984  in
 Nominal Bolt Diameter                     a          1.5000  in
 Type of Threads                          TEMA Thread Series
 Number of Bolts                                          44

 Flange Face Outside Diameter            Fod          46.969  in
 Flange Face Inside Diameter             Fid          44.504  in
 Flange Facing Sketch                      1, Code Sketch 1a

 Gasket Outside Diameter                  Go          46.850  in
 Gasket Inside Diameter                   Gi          45.276  in
 Gasket Factor                             m          4.2500
 Gasket Design Seating Stress              y        10100.00  psi

 Column for Gasket Seating                 2, Code Column II
 Gasket Thickness                         tg          0.1570  in

 Length of Partition Gasket               lp         67.9130  in
 Width  of Partition Gasket               tp          0.3940  in
 Partition Gasket Factor               mPart          4.2500
 Partition Gasket Design Seating Stress yPart       10100.00  psi
```



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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)
  = (196.67*(44.504/2+0))/(20000*1-0.6*196.67)+Ca
  = 0.2201 in
```

Hub Small End Hub MAWP:

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (20000 * 1 * 0.504 )/(22.252 + 0.6 * 0.504 )
  = 446.920 psig
```

```
 Corroded Flange ID,      Bcor = B+2*Fcor               44.504  in
 Corroded Large Hub,     g1Cor = g1-ci                   0.819  in
 Corroded Small Hub,     g0Cor = go-ci                   0.504  in
 Code R Dimension,           R = (C-B)/2 - g1            2.421  in

 Gasket Contact Width,       N = (Go - Gi) / 2           0.787  in
 Basic Gasket Width,        bo = N / 2                   0.393  in
 Effective Gasket Width,     b = sqrt(bo)/2              0.314  in
 Gasket Reaction Diameter,   G = Go - 2 * b             46.223  in
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:

```
  = 0.785 * G² * Peq
  = 0.7854 * 46.223² * 196.67
  = 330012.250 lbf
```

Contact Load on Gasket Surfaces [Hp]:

```
  = 2 * b * pi * G * m * P + 2 * lp * bPart * mPart * P
  = 2 * 0.3136 * pi * 46.223 * 4.25 * 196.67
    + 2 * 67.913 * 0.197 * 4.25 * 196.67
  = 98501.922 lbf
```

Hydrostatic End Load at Flange ID [Hd]:

```
  = pi * Bcor² * P  / 4
  = pi * 44.504² *196.67/4
  = 305925.375 lbf
```

Pressure Force on Flange Face [Ht]:

```
  = H - Hd
  = 330012 - 305925
  = 24086.875 lbf
```

Operating Bolt Load [Wm1]:

```
  = max( H + Hp + H'p, 0 )
  = max( 330012 + 98502 + 0, 0 )
  = 428514.188 lbf
```

Gasket Seating Bolt Load [Wm2]:

```
  = y * b * pi * G  + yPart * bPart * lp
  = 10100*0.3136*pi*46.223+10100*0.197*67.913
  = 595137.875 lbf
```

Required Bolt Area [Am]:

```
  = max( Wm1/Sb, Wm2/Sa )
  = max( 428514/20000, 595138/20000 )
  = 29.757 in^2
```

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

```
  = 2a + 6t/(m + 0.5)
  = 2 * 1.5 + 6 * 5.315/(4.25 + 0.5)
  = 9.714 in
```

Actual Circumferential Bolt Spacing [Bs]:

```
  = C * sin( pi / n )
  = 50.984 * sin( pi/44 )
  = 3.637 in
```

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

```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 3.6372/( 2 * 1.5 + 5.315 )), 1 )
  = 1.0000
```

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

	Minimum	Actual	Maximum
Bolt Area:	29.757	61.820	
Radial Distance between Hub and Bolts:	2.000	2.421	
Radial Distance between Bolts and Edge:	1.500	1.870	
Circ. Spacing between the Bolts:	3.250	3.637	9.714

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

```
  = Ab * Sa/( y * pi(Go + Gi) )
  = 61.82 * 20000/(10100 * pi(46.85 + 45.276 ) )
  = 0.423 in
```

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

```
 = 1.250 in[Note: Exceeds actual gasket width, 0.787  ]
```

Flange Design Bolt Load, Gasket Seating [W]:

```
  = Sa( Am + Ab ) / 2
  = 20000( 29.757 + 61.82 )/2
  = 915768.88 lbf
```

Gasket Load for the Operating Condition [HG]:

```
  = Wm1 - H
  = 428514 - 330012
  = 98501.94 lbf
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
  = (C - G ) / 2
  = ( 50.984 - 46.223 )/2
  = 2.3806 in
```

Distance to Face Pressure Reaction [ht]:
```
  = ( R + g1 + hg ) / 2
  = ( 2.421 + 0.819 + 2.3806 )/2
  = 2.8103 in
```

Distance to End Pressure Reaction [hd]:
```
  = R + ( g1 / 2 )
  = 2.421 +( 0.819/2.0 )
  = 2.8305 in
```

Summary of Moments for Internal Pressure: (ft-lb)

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	305925.	2.8305	1.0000	72160.
Face Pressure,	Mt	24087.	2.8103	1.0000	5641.
Gasket Load,	Mg	98502.	2.3806	1.0000	19541.
Gasket Seating,	Matm	915769.	2.3806	1.0000	181673.

```
 Total Moment for Operation,      Mop                             97342. ft-lb
 Total Moment for Gasket seating, Matm                           181673. ft-lb

 Effective Hub Length, ho = sqrt(Bcor*goCor)           4.736 in
 Hub Ratio,          h/h0 = HL / H0                    0.374
 Thickness Ratio,   g1/g0 = (g1Cor/goCor)              1.625
```

Flange Factors for Integral Flange:
```
 Factor F                                              0.863
 Factor V                                              0.320
 Factor f                                              1.117
 Factors from Figure 2-7.1                    K =      1.230
                    T =      1.827            U =     10.451
                    Y =      9.511            Z =      4.906
                    e =     0.1821 1/in       d =     39.294 in^3
 Stress Factors                           Alpha =      1.968
                 Beta =      2.291        Gamma =      1.077
                Delta =      3.821       Lambda =      4.898
```

Longitudinal Hub Stress, Operating [SHo]:
```
  = ( f * Mop / Bcor ) / ( L * g1² )
  = (1.117*1168106/44.504)/(4.8983*0.819²)
  = 8923.49 psi
```

Longitudinal Hub Stress, Seating [SHa]:
```
  = ( f * Matm / Bcor ) / ( L * g1² )
  = (1.117*2180077/44.504)/(4.8983*0.819²)
  = 16654.21 psi
```

Radial Flange Stress, Operating [SRo]:
```
  = ( beta * Mop / Bcor ) / ( L * t² )
  = (2.2908*1168106/44.504)/(4.8983*5.315²)
  = 434.53 psi
```

Radial Flange Stress, Seating [SRa]:
```
  = ( beta * Matm/Bcor ) / ( L * t² )
  = (2.2908*2180077/44.504)/(4.8983*5.315²)
  = 810.97 psi
```

Tangential Flange Stress, Operating [STo]:
```
  = ( Y * Mo / (t² * Bcor) ) - Z * SRo
  = (9.5109*1168106/(5.315²*44.504))-4.906*434.53
  = 6705.05 psi
```

Tangential Flange Stress, Seating [STa]:

```
  = ( y * Matm / (t² * Bcor) ) - Z * SRa
  = (9.5109*2180077/(5.315²*44.504))-4.906*810.97
  = 12513.87 psi
```

Average Flange Stress, Operating [SAo]:

```
  = ( SHo + max( SRo, STo ) ) / 2
  = (8923.5+max(434.53,6705.1))/2
  = 7814.27 psi
```

Average Flange Stress, Seating [SAa]:

```
  = ( SHa + max( SRa, STa ) ) / 2
  = (16654+max(810.97,12514))/2
  = 14584.04 psi
```

Bolt Stress, Operating [BSo]:

```
  = Wm1 / Ab
  = 428514/61.82
  = 6931.64 psi
```

Bolt Stress, Seating [BSa]:

```
  = ( Wm2 / Ab )
  = (595138/61.82)
  = 9626.95 psi
```

Flange Stress Analysis Results: psi

	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Longitudinal Hub	8923.49	30000.00	16654.21	30000.00
Radial Flange	434.53	20000.00	810.97	20000.00
Tangential Flange	6705.05	20000.00	12513.87	20000.00
Maximum Average	7814.27	20000.00	14584.04	20000.00
Bolting	6931.64	20000.00	9626.95	20000.00

```
Minimum Required Flange Thickness [Rigidity]           4.569 in
Estimated M.A.W.P. ( Operating )                      503.35 psig
Estimated Finished Weight of Flange at given Thk.     1231.9 lbm
Estimated Unfinished Weight of Forging at given Thk   1580.5 lbm
```

Flange Stress results per WRC-538 at computed Sfmax (psi):

		Operating Actual	Operating Allowed	stress ratio	Gasket Seating Actual	Gasket Seating Allowed	stress ratio
Longitudinal Hub	Sh	66399.30	72000.00	0.922	66399.30	72000.00	0.922
Tangential Flange	St	49282.89	54000.00	0.913	49282.89	54000.00	0.913
Tangential Flange	Sto	23056.27	36000.00	0.640	23056.27	36000.00	0.640
Combined	Sh/f + St	108000.00	108000.00	1.000	108000.00	108000.00	1.000
Combined	Sr + St	52476.71	108000.00	0.486	52476.71	108000.00	0.486
Combined	Sh + Sto	89455.57	108000.00	0.828	89455.57	108000.00	0.828
Radial Flange	Sr	3193.83	72000.00	0.044	3193.83	72000.00	0.044
Maximum Stress Ratio				1.000			1.000

Coefficients for f and f2

	f	f2	f3
a	-0.71375912	-0.01447638	-0.06456312
b	-0.12846279	-0.27814745	-0.08232239
c	1.08037907	0.01035395	0.13691677
d	0.99766848	1.37984158	-0.77879888
e	1.21823466	-0.34346764	0.14909019
f	0.01024612	0.02536192	0.00660062
g	0.4262313	-0.0014508	0.0616252
h	1.4204976	2.25543162	0.74639834
i	-0.70278181	-0.60889597	-0.079595
j	-0.02483937	-0.15735462	0.09851673
k	-1.59460436	1.22516062	-0.1121436

$$f_n = \frac{\left[a + c\left(\frac{g1}{g0}\right) + e\left(\frac{h}{h0}\right) + g\left(\frac{g1}{g0}\right)^2 + i\left(\frac{h}{h0}\right)^2 + k\left(\frac{g1}{g0}\right)\left(\frac{h}{h0}\right)\right]}{\left[1 + b\left(\frac{g1}{g0}\right) + d\left(\frac{h}{h0}\right) + f\left(\frac{g1}{g0}\right)^2 + h\left(\frac{h}{h0}\right)^2 + j\left(\frac{g1}{g0}\right)\left(\frac{h}{h0}\right)\right]}$$

Hub Stress Correction Factor [f]:
```
  = max( 1, F1_(num) / F1_(den) )
  = max( 1, 1.5553/1.3753 )
  = 1.1308
```

Hub Stress Correction Factor [f2]:
```
  = max( 0.25, fn2 ) if h/ho < 0.35, else max ( 0.25, fn3 )
  = max( 0.25, 0.5297/1.3513 ) if h/ho < 0.35, else max( 0.25, 0.2971/0.7567 )
  = 0.3927
```

In this case, the hub ratio h/ho, 0.3742 was >= 0.35.

PV Elite iterates on the assembly bolt load stress, Sfmax, until it exceeds the limits provided by WRC 538.

Bolting and Gasket Calculations per ASME PCC-1 Appendix O:

Input Data:

Maximum permissible bolt stress	Sbmax	56000.0 psi
Minimum permissible bolt stress	Sbmin	32000.0 psi
Max. permissible bolt stress prior to flange damage	Sfmax	58339.3 psi
Target assembly gasket stress	SgT	49500.0 psi
Maximum permissible gasket stress	Sgmax	55000.0 psi
Minimum gasket operating stress	Sgmin-O	14000.0 psi
Minimum gasket seating stress	Sgmin-S	20000.0 psi
Nut Factor	K	0.200
Fraction of Gasket Load remaining after relaxation	Phig	0.700

```
 Root Area of a Single Bolt                                  Abs      1.4050 in^2
 Max. permissible single flange rotation for gasket    Thetagmax       1.000 deg
```

Calculated Results:

```
 Flange Material Ambient Yield Stress                        Sya     36000.0 psi
 Flange Material Operating Yield Stress                      Syo     31805.7 psi
 Single flange rotation at Sfmax                       Thetafmax       0.827 deg
```

Gasket Contact Area [Ag]:

```
  = pi/4( GO.D.^2 - GI.D.^2 ) + ( PartFactor * lp * bPart )
  = pi/4( 46.85^2 - 45.276^2 ) +( 0.5 * 67.913 * 0.197 )
  = 120.6 in^2
```

Target Bolt Stress [Sbsel]:

```
  = SGT * Ag / ( nb * Ab )          (O-1)
  = 49500 * 120.58/( 44 * 1.405 )
  = 96547.4 psi
```

Upper Bolt Stress Limit [Sbsel]:

```
  = min( Sbsel, Sbmax )             (O-4)
  = min( 56000, 56000 )
  = 56000.0 psi
```

Lower Bolt Stress Limit [Sbsel]:

```
  = max( Sbsel, Sbmin )             (O-5)
  = max( 56000, 32000 )
  = 56000.0 psi
```

Upper Bolt Stress Limit including the Flange [Sbsel]:

```
  = min( Sbsel, Sfmax )             (O-6)
  = min( 56000, 58339 )
  = 56000.0 psi
```

Gasket Assembly Stress [GAS]:

```
  = Sgmin-S( Ag / ( nb * Abs ) )    (O-7)
  = 20000( 120.58/( 44 * 1.405 ) )
  = 39009.0 psi
```

Since Sbsel >= GAS, check passes.

Gasket Operating Stress [GOS]:

```
  = (Sgmin-O * Ag + pi/4 * Pmax * GI.D.^2)/(PhiG * Abs * nb)  (O-8)
  = (14000*120.58+pi/4*196.67*45.276^2)/(0.7*1.405*44)
  = 46325.969 psi
```

Since Sbsel >= GOS, check passes.

Gasket Maximum Stress [GMS]:

```
  = Sgmax( Ag / ( nb * Abs ) )      (O-9)
  = 55000( 120.58/( 44 * 1.405 ) )
  = 107274.9 psi
```

Since Sbsel <= GMS, check passes.

Flange Rotation Limit [FRL]:

```
  = Sfmax( thetagmax / thetafmax )  (O-10)
  = 58339( 1/0.8268 )
  = 70560.3 psi
```

Since Sbsel <= FRL, check passes.

Assembly Bolt Torque [Tb]:

```
  = Sbsel * K * Abs * Phib/12       (O-2)
```

```
  = 56000 * 0.2 * 1.405 * 1.5/12
  = 1967.0 ft-lb

 Bolt Allowable Stress for: SA-193 B8 Cl. 2  SbB8  15000 psi
 Bolt Allowable Stress for: SA-193 B7M         Sb  20000 psi
```

Note: Since Sb >= SbB8, bolt allowable stress comparison check Passes.

Flange Rigidity Based on Required Thickness [ASME]:

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

$= 52.14 * Ma / Bsc * Cnv\_fac * V / (Lambda * Eamb * go^2 * ho * Ki)$
$= 52.14*181673/1*12*0.32/(3.4296*29400000*0.504^2*4.736*0.3)$
$= 0.999$ (should be <= 1)

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

$= 52.14 * Mo / Bsc * Cnv\_fac * V / (Lambda * Eop * goc^2 * ho * Ki)$
$= 52.14*97342/1*12*0.32/(3.4296*28300000*0.504^2*4.736*0.3)$
$= 0.556$ (should be <= 1)

Flange Rigidity Based on Given Thickness [ASME]:

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

$= 52.14 * Ma / Bsc * Cnv\_fac * V / (Lambda * Eamb * go^2 * ho * Ki)$
$= 52.14*181673/1*12*0.32/(4.8983*29400000*0.504^2*4.736*0.3)$
$= 0.699$ (should be <= 1)

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

$= 52.14 * Mo / Bsc * Cnv\_fac * V / (Lambda * Eop * goc^2 * ho * Ki)$
$= 52.14*97342/1*12*0.32/(4.8983*28300000*0.504^2*4.736*0.3)$
$= 0.389$ (should be <= 1)

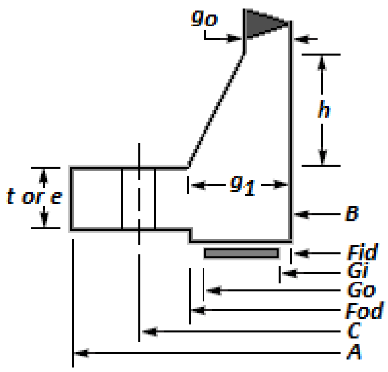
Minimum Design Metal Temperature Results:
Thickness Ratio = 0.5566, Temperature Reduction per Fig. UCS 66.1 = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve C            -36 F
```

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

CHANNEL FLG2

```
 Flange Type                               Integral Weld Neck

 Design Pressure                          P          196.67  psig
 Design Temperature                                     300  F
 Internal Corrosion Allowance            ci          0.0000  in
 External Corrosion Allowance            ce          0.0000  in
 Use Corrosion Allowance in Thickness Calcs.             No
 Flange Inside Diameter                   B          44.504  in
 Flange Outside Diameter                  A          54.724  in
 Flange Thickness                         t          5.3150  in
 Thickness of Hub at Small End           go          0.5040  in
 Thickness of Hub at Large End           g1          0.8190  in
 Length of Hub                            h          1.7720  in

 Flange Material                                   SA-266 2
 Flange Material UNS number                          K03506
 Flange Allowable Stress At Temperature Sfo        20000.00  psi
 Flange Allowable Stress At Ambient     Sfa        20000.00  psi

 Bolt Material                                   SA-193 B7M
 Bolt Allowable Stress At Temperature    Sb        20000.00  psi
 Bolt Allowable Stress At Ambient        Sa        20000.00  psi

 Diameter of Bolt Circle                  C          50.984  in
 Nominal Bolt Diameter                    a          1.5000  in
 Type of Threads                          TEMA Thread Series
 Number of Bolts                                         44

 Flange Face Outside Diameter           Fod          46.969  in
 Flange Face Inside Diameter            Fid          44.504  in
 Flange Facing Sketch                      1, Code Sketch 1a

 Gasket Outside Diameter                 Go          46.850  in
 Gasket Inside Diameter                  Gi          45.276  in
 Gasket Factor                            m          4.2500
 Gasket Design Seating Stress             y        10100.00  psi

 Column for Gasket Seating                 2, Code Column II
 Gasket Thickness                        tg          0.1570  in

 Length of Partition Gasket              lp         67.9130  in
 Width  of Partition Gasket              tp          0.3940  in
 Partition Gasket Factor              mPart          4.2500
 Partition Gasket Design Seating Stress yPart      10100.00  psi
```



ASME Code, Section VIII Division 1, 2021

Hub Small End Required Thickness due to Internal Pressure:
```
  = (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
  = (196.67*(44.504/2+0))/(20000*1-0.6*196.67)+Ca
  = 0.2201 in
```

Hub Small End Hub MAWP:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (20000 * 1 * 0.504 )/(22.252 + 0.6 * 0.504 )
  = 446.920 psig
```

```
 Corroded Flange ID,      Bcor = B+2*Fcor              44.504  in
 Corroded Large Hub,     g1Cor = g1-ci                  0.819  in
 Corroded Small Hub,     g0Cor = go-ci                  0.504  in
 Code R Dimension,           R = (C-B)/2 - g1           2.421  in

 Gasket Contact Width,       N = (Go - Gi) / 2          0.787  in
 Basic Gasket Width,        bo = N / 2                  0.393  in
 Effective Gasket Width,     b = sqrt(bo)/2             0.314  in
 Gasket Reaction Diameter,   G = Go - 2 * b            46.223  in
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.7854 * 46.223² * 196.67
  = 330012.250 lbf
```

Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * pi * G * m * P + 2 * lp * bPart * mPart * P
  = 2 * 0.3136 * pi * 46.223 * 4.25 * 196.67
    + 2 * 67.913 * 0.197 * 4.25 * 196.67
  = 98501.922 lbf
```

Hydrostatic End Load at Flange ID [Hd]:
```
  = pi * Bcor² * P  / 4
  = pi * 44.504² *196.67/4
  = 305925.375 lbf
```

Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 330012 - 305925
  = 24086.875 lbf
```

Operating Bolt Load [Wm1]:

```
  = max( H + Hp + H'p, 0 )
  = max( 330012 + 98502 + 0, 0 )
  = 428514.188 lbf
```

Gasket Seating Bolt Load [Wm2]:

```
  = y * b * pi * G  + yPart * bPart * lp
  = 10100*0.3136*pi*46.223+10100*0.197*67.913
  = 595137.875 lbf
```

Required Bolt Area [Am]:

```
  = max( Wm1/Sb, Wm2/Sa )
  = max( 428514/20000, 595138/20000 )
  = 29.757 in^2
```

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

```
  = 2a + 6t/(m + 0.5)
  = 2 * 1.5 + 6 * 5.315/(4.25 + 0.5)
  = 9.714 in
```

Actual Circumferential Bolt Spacing [Bs]:

```
  = C * sin( pi / n )
  = 50.984 * sin( pi/44 )
  = 3.637 in
```

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

```
  = max( sqrt( Bs/( 2a + t )), 1 )
  = max( sqrt( 3.6372/( 2 * 1.5 + 5.315 )), 1 )
  = 1.0000
```

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

	Minimum	Actual	Maximum
Bolt Area:	29.757	61.820	
Radial Distance between Hub and Bolts:	2.000	2.421	
Radial Distance between Bolts and Edge:	1.500	1.870	
Circ. Spacing between the Bolts:	3.250	3.637	9.714

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

```
  = Ab * Sa/( y * pi(Go + Gi) )
  = 61.82 * 20000/(10100 * pi(46.85 + 45.276 ) )
  = 0.423 in
```

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

```
 = 1.250 in[Note: Exceeds actual gasket width, 0.787  ]
```

Flange Design Bolt Load, Gasket Seating [W]:

```
  = Sa( Am + Ab ) / 2
  = 20000( 29.757 + 61.82 )/2
  = 915768.88 lbf
```

Gasket Load for the Operating Condition [HG]:

```
  = Wm1 - H
  = 428514 - 330012
  = 98501.94 lbf
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
  = (C - G ) / 2
  = ( 50.984 - 46.223 )/2
  = 2.3806 in
```

Distance to Face Pressure Reaction [ht]:
```
  = ( R + g1 + hg ) / 2
  = ( 2.4211 + 0.819 + 2.3806 )/2
  = 2.8104 in
```

Distance to End Pressure Reaction [hd]:
```
  = R + ( g1 / 2 )
  = 2.4211 +( 0.819/2.0 )
  = 2.8306 in
```

Summary of Moments for Internal Pressure: (ft-lb)

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	305925.	2.8306	1.0000	72161.
Face Pressure,	Mt	24087.	2.8104	1.0000	5641.
Gasket Load,	Mg	98502.	2.3806	1.0000	19542.
Gasket Seating,	Matm	915769.	2.3806	1.0000	181677.

```
 Total Moment for Operation,      Mop                             97344. ft-lb
 Total Moment for Gasket seating, Matm                           181677. ft-lb

 Effective Hub Length, ho = sqrt(Bcor*goCor)           4.736 in
 Hub Ratio,          h/h0 = HL / H0                    0.374
 Thickness Ratio,   g1/g0 = (g1Cor/goCor)              1.625
```

Flange Factors for Integral Flange:
```
 Factor F                                              0.863
 Factor V                                              0.320
 Factor f                                              1.117
 Factors from Figure 2-7.1                    K =      1.230
                    T =      1.827            U =     10.451
                    Y =      9.511            Z =      4.906
                    e =     0.1821 1/in       d =     39.294 in^3
 Stress Factors                           Alpha =      1.968
                 Beta =      2.291        Gamma =      1.077
                Delta =      3.821       Lambda =      4.898
```

Longitudinal Hub Stress, Operating [SHo]:
```
  = ( f * Mop / Bcor ) / ( L * g1² )
  = (1.117*1168128/44.504)/(4.8983*0.819²)
  = 8923.65 psi
```

Longitudinal Hub Stress, Seating [SHa]:
```
  = ( f * Matm / Bcor ) / ( L * g1² )
  = (1.117*2180124/44.504)/(4.8983*0.819²)
  = 16654.57 psi
```

Radial Flange Stress, Operating [SRo]:
```
  = ( beta * Mop / Bcor ) / ( L * t² )
  = (2.2908*1168128/44.504)/(4.8983*5.315²)
  = 434.54 psi
```

Radial Flange Stress, Seating [SRa]:
```
  = ( beta * Matm/Bcor ) / ( L * t² )
  = (2.2908*2180124/44.504)/(4.8983*5.315²)
  = 810.99 psi
```

Tangential Flange Stress, Operating [STo]:
```
  = ( Y * Mo / (t² * Bcor) ) - Z * SRo
  = (9.5109*1168128/(5.315²*44.504))-4.906*434.54
  = 6705.18 psi
```

Tangential Flange Stress, Seating [STa]:

```
  = ( y * Matm / (t² * Bcor) ) - Z * SRa
  = (9.5109*2180124/(5.315²*44.504))-4.906*810.99
  = 12514.14 psi
```

Average Flange Stress, Operating [SAo]:

```
  = ( SHo + max( SRo, STo ) ) / 2
  = (8923.7+max(434.54,6705.2))/2
  = 7814.42 psi
```

Average Flange Stress, Seating [SAa]:

```
  = ( SHa + max( SRa, STa ) ) / 2
  = (16655+max(810.99,12514))/2
  = 14584.35 psi
```

Bolt Stress, Operating [BSo]:

```
  = Wm1 / Ab
  = 428514/61.82
  = 6931.64 psi
```

Bolt Stress, Seating [BSa]:

```
  = ( Wm2 / Ab )
  = (595138/61.82)
  = 9626.95 psi
```

Flange Stress Analysis Results: psi

	Operating		Gasket Seating	
	Actual	Allowed	Actual	Allowed
Longitudinal Hub	8923.65	30000.00	16654.57	30000.00
Radial Flange	434.54	20000.00	810.99	20000.00
Tangential Flange	6705.18	20000.00	12514.14	20000.00
Maximum Average	7814.42	20000.00	14584.35	20000.00
Bolting	6931.64	20000.00	9626.95	20000.00

```
Minimum Required Flange Thickness [Rigidity]          4.569 in
Estimated M.A.W.P. ( Operating )                     503.34 psig
Estimated Finished Weight of Flange at given Thk.    1231.9 lbm
Estimated Unfinished Weight of Forging at given Thk  1580.5 lbm
```

Flange Stress results per WRC-538 at computed Sfmax (psi):

		Operating		stress	Gasket Seating		stress
		Actual	Allowed	ratio	Actual	Allowed	ratio
Longitudinal Hub	Sh	66399.30	72000.00	0.922	66399.30	72000.00	0.922
Tangential Flange	St	49282.88	54000.00	0.913	49282.88	54000.00	0.913
Tangential Flange	Sto	23056.27	36000.00	0.640	23056.27	36000.00	0.640
Combined	Sh/f + St	107999.98	108000.00	1.000	107999.98	108000.00	1.000
Combined	Sr + St	52476.70	108000.00	0.486	52476.70	108000.00	0.486
Combined	Sh + Sto	89455.57	108000.00	0.828	89455.57	108000.00	0.828
Radial Flange	Sr	3193.83	72000.00	0.044	3193.83	72000.00	0.044
Maximum Stress Ratio				1.000			1.000

Coefficients for f and f2

	f	f2	f3
a	-0.71375912	-0.01447638	-0.06456312
b	-0.12846279	-0.27814745	-0.08232239
c	1.08037907	0.01035395	0.13691677
d	0.99766848	1.37984158	-0.77879888
e	1.21823466	-0.34346764	0.14909019
f	0.01024612	0.02536192	0.00660062
g	0.4262313	-0.0014508	0.0616252
h	1.4204976	2.25543162	0.74639834
i	-0.70278181	-0.60889597	-0.079595
j	-0.02483937	-0.15735462	0.09851673
k	-1.59460436	1.22516062	-0.1121436

$$f_n = \frac{\left[a + c\left(\frac{g1}{g0}\right) + e\left(\frac{h}{h0}\right) + g\left(\frac{g1}{g0}\right)^2 + i\left(\frac{h}{h0}\right)^2 + k\left(\frac{g1}{g0}\right)\left(\frac{h}{h0}\right)\right]}{\left[1 + b\left(\frac{g1}{g0}\right) + d\left(\frac{h}{h0}\right) + f\left(\frac{g1}{g0}\right)^2 + h\left(\frac{h}{h0}\right)^2 + j\left(\frac{g1}{g0}\right)\left(\frac{h}{h0}\right)\right]}$$

Hub Stress Correction Factor [f]:
```
  = max( 1, F1_(num) / F1_(den) )
  = max( 1, 1.5553/1.3753 )
  = 1.1308
```

Hub Stress Correction Factor [f2]:
```
  = max( 0.25, fn2 ) if h/ho < 0.35, else max ( 0.25, fn3 )
  = max( 0.25, 0.5297/1.3513 ) if h/ho < 0.35, else max( 0.25, 0.2971/0.7567 )
  = 0.3927
```

In this case, the hub ratio h/ho, 0.3742 was >= 0.35.

PV Elite iterates on the assembly bolt load stress, Sfmax, until it exceeds the limits provided by WRC 538.

Bolting and Gasket Calculations per ASME PCC-1 Appendix O:

Input Data:

```
 Maximum permissible bolt stress                           Sbmax     56000.0 psi
 Minimum permissible bolt stress                           Sbmin     32000.0 psi
 Max. permissible bolt stress prior to flange damage       Sfmax     58338.1 psi
 Target assembly gasket stress                               SgT     49500.0 psi
 Maximum permissible gasket stress                         Sgmax     55000.0 psi
 Minimum gasket operating stress                         Sgmin-O     14000.0 psi
 Minimum gasket seating stress                           Sgmin-S     20000.0 psi
 Nut Factor                                                    K       0.200
 Fraction of Gasket Load remaining after relaxation         Phig       0.700
```

```
 Root Area of a Single Bolt                                  Abs      1.4050 in^2
 Max. permissible single flange rotation for gasket    Thetagmax       1.000 deg
```

Calculated Results:

```
 Flange Material Ambient Yield Stress                        Sya     36000.0 psi
 Flange Material Operating Yield Stress                      Syo     31805.7 psi
 Single flange rotation at Sfmax                       Thetafmax       0.827 deg
```

Gasket Contact Area [Ag]:

```
  = pi/4( GO.D.^2 - GI.D.^2 ) + ( PartFactor * lp * bPart )
  = pi/4( 46.85^2 - 45.276^2 ) +( 0.5 * 67.913 * 0.197 )
  = 120.6 in^2
```

Target Bolt Stress [Sbsel]:

```
  = SGT * Ag / ( nb * Ab )          (O-1)
  = 49500 * 120.58/( 44 * 1.405 )
  = 96547.4 psi
```

Upper Bolt Stress Limit [Sbsel]:

```
  = min( Sbsel, Sbmax )             (O-4)
  = min( 56000, 56000 )
  = 56000.0 psi
```

Lower Bolt Stress Limit [Sbsel]:

```
  = max( Sbsel, Sbmin )             (O-5)
  = max( 56000, 32000 )
  = 56000.0 psi
```

Upper Bolt Stress Limit including the Flange [Sbsel]:

```
  = min( Sbsel, Sfmax )             (O-6)
  = min( 56000, 58338 )
  = 56000.0 psi
```

Gasket Assembly Stress [GAS]:

```
  = Sgmin-S( Ag / ( nb * Abs ) )     (O-7)
  = 20000( 120.58/( 44 * 1.405 ) )
  = 39009.0 psi
```

Since Sbsel >= GAS, check passes.

Gasket Operating Stress [GOS]:

```
  = (Sgmin-O * Ag + pi/4 * Pmax * GI.D.^2)/(PhiG * Abs * nb)  (O-8)
  = (14000*120.58+pi/4*196.67*45.276^2)/(0.7*1.405*44)
  = 46325.969 psi
```

Since Sbsel >= GOS, check passes.

Gasket Maximum Stress [GMS]:

```
  = Sgmax( Ag / ( nb * Abs ) )       (O-9)
  = 55000( 120.58/( 44 * 1.405 ) )
  = 107274.9 psi
```

Since Sbsel <= GMS, check passes.

Flange Rotation Limit [FRL]:

```
  = Sfmax( thetagmax / thetafmax )   (O-10)
  = 58338( 1/0.8268 )
  = 70558.8 psi
```

Since Sbsel <= FRL, check passes.

Assembly Bolt Torque [Tb]:

```
  = Sbsel * K * Abs * Phib/12        (O-2)
```

```
  = 56000 * 0.2 * 1.405 * 1.5/12
  = 1967.0 ft-lb

 Bolt Allowable Stress for: SA-193 B8 Cl. 2  SbB8  15000 psi
 Bolt Allowable Stress for: SA-193 B7M         Sb  20000 psi
```

Note: Since Sb >= SbB8, bolt allowable stress comparison check Passes.

Flange Rigidity Based on Required Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
$= 52.14 * Ma / Bsc * Cnv\_fac * V / (Lambda * Eamb * go^2 * ho * Ki)$
$= 52.14*181677/1*12*0.32/(3.4296*29400000*0.504^2*4.736*0.3)$
= 0.999   (should be <= 1)

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:
$= 52.14 * Mo / Bsc * Cnv\_fac * V / (Lambda * Eop * goc^2 * ho * Ki)$
$= 52.14*97344/1*12*0.32/(3.4296*28300002*0.504^2*4.736*0.3)$
= 0.556   (should be <= 1)

Flange Rigidity Based on Given Thickness [ASME]:

Flange Rigidity Index, Seating (rotation check) per APP. 2 [Js]:
$= 52.14 * Ma / Bsc * Cnv\_fac * V / (Lambda * Eamb * go^2 * ho * Ki)$
$= 52.14*181677/1*12*0.32/(4.8983*29400000*0.504^2*4.736*0.3)$
= 0.699   (should be <= 1)

Flange Rigidity Index Operating (rotation check) per APP. 2 [J]:
$= 52.14 * Mo / Bsc * Cnv\_fac * V / (Lambda * Eop * goc^2 * ho * Ki)$
$= 52.14*97344/1*12*0.32/(4.8983*28300002*0.504^2*4.736*0.3)$
= 0.389   (should be <= 1)

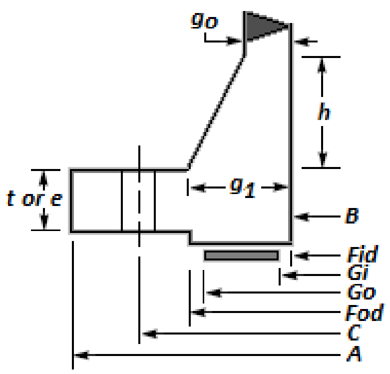
Minimum Design Metal Temperature Results:
Thickness Ratio = 0.5566, Temperature Reduction per Fig. UCS 66.1 = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve C            -36 F
```

Flange Input Data Values **Description:** SHELL FLG :

SHELL FLG

Flange Type		Integral Weld Neck	
Design Pressure	P	151.56	psig
Design Temperature		330	F
Internal Corrosion Allowance	ci	0.0000	in
External Corrosion Allowance	ce	0.0000	in
Use Corrosion Allowance in Thickness Calcs.		No	
Flange Inside Diameter	B	44.504	in
Flange Outside Diameter	A	54.724	in
Flange Thickness	t	5.3150	in
Thickness of Hub at Small End	go	0.5040	in
Thickness of Hub at Large End	g1	0.8190	in
Length of Hub	h	1.7720	in
Flange Material		SA-266 2	
Flange Material UNS number		K03506	
Flange Allowable Stress At Temperature	Sfo	20000.00	psi
Flange Allowable Stress At Ambient	Sfa	20000.00	psi
Bolt Material		SA-193 B7M	
Bolt Allowable Stress At Temperature	Sb	20000.00	psi
Bolt Allowable Stress At Ambient	Sa	20000.00	psi
Diameter of Bolt Circle	C	50.984	in
Nominal Bolt Diameter	a	1.5000	in
Type of Threads		TEMA Thread Series	
Number of Bolts		44	
Flange Face Outside Diameter	Fod	46.969	in
Flange Face Inside Diameter	Fid	44.504	in
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	46.850	in
Gasket Inside Diameter	Gi	45.276	in
Gasket Factor	m	4.2500	
Gasket Design Seating Stress	y	10100.00	psi
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	0.1570	in



ASME Code, Section VIII Division 1, 2021

Hub Small End Required Thickness due to Internal Pressure:
```
  = (P*(D/2+Ca))/(S*E-0.6*P) per UG-27 (c)(1)
  = (151.56*(44.504/2+0))/(20000*1-0.6*151.56)+Ca
  = 0.1694 in
```

Hub Small End Hub MAWP:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (20000 * 1 * 0.504 )/(22.252 + 0.6 * 0.504 )
  = 446.920 psig
```

```
 Corroded Flange ID,      Bcor = B+2*Fcor                 44.504  in
 Corroded Large Hub,     g1Cor = g1-ci                     0.819  in
 Corroded Small Hub,     g0Cor = go-ci                     0.504  in
 Code R Dimension,           R = (C-B)/2 - g1              2.421  in

 Gasket Contact Width,       N = (Go - Gi) / 2             0.787  in
 Basic Gasket Width,        bo = N / 2                     0.393  in
 Effective Gasket Width,     b = sqrt(bo)/2                0.314  in
 Gasket Reaction Diameter,   G = Go - 2 * b               46.223  in
```

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
```
  = 0.785 * G² * Peq
  = 0.7854 * 46.223² * 151.56
  = 254326.656 lbf
```

Contact Load on Gasket Surfaces [Hp]:
```
  = 2 * b * pi * G * m * P
  = 2 * 0.3136 * pi * 46.223 * 4.25 * 151.56
  = 58675.590 lbf
```

Hydrostatic End Load at Flange ID [Hd]:
```
  = pi * Bcor² * P  / 4
  = pi * 44.504² *151.56/4
  = 235763.906 lbf
```

Pressure Force on Flange Face [Ht]:
```
  = H - Hd
  = 254327 - 235764
  = 18562.750 lbf
```

Operating Bolt Load [Wm1]:
```
  = max( H + Hp + H'p, 0 )
  = max( 254327 + 58676 + 0, 0 )
  = 313002.250 lbf
  = 428514.188 lbf, Mating Flange Load Governs
```

Gasket Seating Bolt Load [Wm2]:
```
  = y * b * pi * G  + yPart * bPart * lp
  = 10100*0.3136*pi*46.223+0*0*0
  = 460011.406 lbf
  = 595137.875 lbf, Mating Flange Load Governs
```

Required Bolt Area [Am]:
```
  = max( Wm1/Sb, Wm2/Sa )
  = max( 428514/20000, 595138/20000 )
  = 29.757 in^2
```

ASME Maximum Circumferential Spacing between Bolts per App. 2 eq. (3) [Bsmax]:
```
  = 2a + 6t/(m + 0.5)
  = 2 * 1.5 + 6 * 5.315/(4.25 + 0.5)
  = 9.714 in
```

Actual Circumferential Bolt Spacing [Bs]:
 = C * sin(pi / n)
 = 50.984 * sin(pi/44)
 = 3.637 in

ASME Moment Multiplier for Bolt Spacing per App. 2 eq. (7) [Bsc]:
 = max(sqrt(Bs/(2a + t)), 1)
 = max(sqrt(3.6372/(2 * 1.5 + 5.315)), 1)
 = 1.0000

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

	Minimum	Actual	Maximum
Bolt Area:	29.757	61.820	
Radial Distance between Hub and Bolts:	2.000	2.421	
Radial Distance between Bolts and Edge:	1.500	1.870	
Circ. Spacing between the Bolts:	3.250	3.637	9.714

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:
 = Ab * Sa/(y * pi(Go + Gi))
 = 61.82 * 20000/(10100 * pi(46.85 + 45.276))
 = 0.423 in

Note: Recommended Min. Width for Sheet and Composite Gaskets per table 2-4 :
 = 1.250 in[Note: Exceeds actual gasket width, 0.787]

Flange Design Bolt Load, Gasket Seating [W]:
 = Sa(Am + Ab) / 2
 = 20000(29.757 + 61.82)/2
 = 915768.88 lbf

Gasket Load for the Operating Condition [HG]:
 = Wm1 - H
 = 428514 - 254327
 = 174187.53 lbf

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
 = (C - G) / 2
 = (50.984 - 46.223)/2
 = 2.3806 in

Distance to Face Pressure Reaction [ht]:
 = (R + g1 + hg) / 2
 = (2.4211 + 0.819 + 2.3806)/2
 = 2.8104 in

Distance to End Pressure Reaction [hd]:
 = R + (g1 / 2)
 = 2.4211 +(0.819/2.0)
 = 2.8306 in

Summary of Moments for Internal Pressure: (ft-lb)

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	235764.	2.8306	1.0000	55612.
Face Pressure,	Mt	18563.	2.8104	1.0000	4347.
Gasket Load,	Mg	174188.	2.3806	1.0000	34557.
Gasket Seating,	Matm	915769.	2.3806	1.0000	181677.

```
 Total Moment for Operation,      Mop                             94516. ft-lb
 Total Moment for Gasket seating, Matm                           181677. ft-lb

 Effective Hub Length, ho = sqrt(Bcor*goCor)           4.736 in
 Hub Ratio,          h/h0 = HL / H0                    0.374
 Thickness Ratio,   g1/g0 = (g1Cor/goCor)              1.625
```

Flange Factors for Integral Flange:

```
 Factor F                                              0.863
 Factor V                                              0.320
 Factor f                                              1.117
 Factors from Figure 2-7.1                   K =       1.230
                    T =      1.827           U =      10.451
                    Y =      9.511           Z =       4.906
                    e =     0.1821 1/in      d =      39.294 in^3
 Stress Factors                          Alpha =       1.968
                 Beta =      2.291       Gamma =       1.077
                Delta =      3.821      Lambda =       4.898
```

Longitudinal Hub Stress, Operating [SHo]:

```
  = ( f * Mop / Bcor ) / ( L * g1² )
  = (1.117*1134189/44.504)/(4.8983*0.819²)
  = 8664.38 psi
```

Longitudinal Hub Stress, Seating [SHa]:

```
  = ( f * Matm / Bcor ) / ( L * g1² )
  = (1.117*2180124/44.504)/(4.8983*0.819²)
  = 16654.56 psi
```

Radial Flange Stress, Operating [SRo]:

```
  = ( beta * Mop / Bcor ) / ( L * t² )
  = (2.2908*1134189/44.504)/(4.8983*5.315²)
  = 421.91 psi
```

Radial Flange Stress, Seating [SRa]:

```
  = ( beta * Matm/Bcor ) / ( L * t² )
  = (2.2908*2180124/44.504)/(4.8983*5.315²)
  = 810.99 psi
```

Tangential Flange Stress, Operating [STo]:

```
  = ( Y * Mo / (t² * Bcor) ) - Z * SRo
  = (9.5109*1134189/(5.315²*44.504))-4.906*421.91
  = 6510.36 psi
```

Tangential Flange Stress, Seating [STa]:

```
  = ( y * Matm / (t² * Bcor) ) - Z * SRa
  = (9.5109*2180124/(5.315²*44.504))-4.906*810.99
  = 12514.14 psi
```

Average Flange Stress, Operating [SAo]:

```
  = ( SHo + max( SRo, STo ) ) / 2
  = (8664.4+max(421.91,6510.4))/2
  = 7587.37 psi
```

Average Flange Stress, Seating [SAa]:

```
  = ( SHa + max( SRa, STa ) ) / 2
  = (16655+max(810.99,12514))/2
  = 14584.35 psi
```

Bolt Stress, Operating [BSo]:

```
  = Wm1 / Ab
  = 428514/61.82
  = 6931.64 psi
```

Bolt Stress, Seating [BSa]:
= (Wm2 / Ab)
= (595138/61.82)
= 9626.95 psi

Flange Stress Analysis Results: psi

	Operating Actual	Operating Allowed	Gasket Seating Actual	Gasket Seating Allowed
Longitudinal Hub	8664.38	30000.00	16654.56	30000.00
Radial Flange	421.91	20000.00	810.99	20000.00
Tangential Flange	6510.36	20000.00	12514.14	20000.00
Maximum Average	7587.37	20000.00	14584.35	20000.00
Bolting	6931.64	20000.00	9626.95	20000.00

Minimum Required Flange Thickness [Rigidity]	4.569 in
Estimated M.A.W.P. (Operating)	527.37 psig
Estimated Finished Weight of Flange at given Thk.	1231.9 lbm
Estimated Unfinished Weight of Forging at given Thk	1580.5 lbm

---

Flange Stress results per WRC-538 at computed Sfmax (psi):

		Operating Actual	Operating Allowed	stress ratio	Gasket Seating Actual	Gasket Seating Allowed	stress ratio
Longitudinal Hub	Sh	66399.30	72000.00	0.922	66399.30	72000.00	0.922
Tangential Flange	St	49282.89	54000.00	0.913	49282.89	54000.00	0.913
Tangential Flange	Sto	23056.27	36000.00	0.640	23056.27	36000.00	0.640
Combined	Sh/f + St	108000.00	108000.00	1.000	108000.00	108000.00	1.000
Combined	Sr + St	52476.72	108000.00	0.486	52476.72	108000.00	0.486
Combined	Sh + Sto	89455.57	108000.00	0.828	89455.57	108000.00	0.828
Radial Flange	Sr	3193.83	72000.00	0.044	3193.83	72000.00	0.044
Maximum Stress Ratio				1.000			1.000

Coefficients for f and f2

	f	*f2*	*f3*
a	-0.71375912	-0.01447638	-0.06456312
b	-0.12846279	-0.27814745	-0.08232239
c	1.08037907	0.01035395	0.13691677
d	0.99766848	1.37984158	-0.77879888
e	1.21823466	-0.34346764	0.14909019
f	0.01024612	0.02536192	0.00660062
g	0.4262313	-0.0014508	0.0616252
h	1.4204976	2.25543162	0.74639834
i	-0.70278181	-0.60889597	-0.079595
j	-0.02483937	-0.15735462	0.09851673
k	-1.59460436	1.22516062	-0.1121436

$$f_n = \frac{\left[a + c\left(\frac{g1}{g0}\right) + e\left(\frac{h}{h0}\right) + g\left(\frac{g1}{g0}\right)^2 + i\left(\frac{h}{h0}\right)^2 + k\left(\frac{g1}{g0}\right)\left(\frac{h}{h0}\right)\right]}{\left[1 + b\left(\frac{g1}{g0}\right) + d\left(\frac{h}{h0}\right) + f\left(\frac{g1}{g0}\right)^2 + h\left(\frac{h}{h0}\right)^2 + j\left(\frac{g1}{g0}\right)\left(\frac{h}{h0}\right)\right]}$$

Hub Stress Correction Factor [f]:

```
  = max( 1, F1_(num) / F1_(den) )
  = max( 1, 1.5553/1.3753 )
  = 1.1308
```

Hub Stress Correction Factor [f2]:

```
  = max( 0.25, fn2 ) if h/ho < 0.35, else max ( 0.25, fn3 )
  = max( 0.25, 0.5297/1.3513 ) if h/ho < 0.35, else max( 0.25, 0.2971/0.7567 )
  = 0.3927
```

In this case, the hub ratio h/ho, 0.3742 was >= 0.35.

PV Elite iterates on the assembly bolt load stress, Sfmax, until it exceeds the limits provided by WRC 538.

Bolting and Gasket Calculations per ASME PCC-1 Appendix O:

Input Data:

```
 Maximum permissible bolt stress                          Sbmax     56000.0 psi
 Minimum permissible bolt stress                          Sbmin     32000.0 psi
 Max. permissible bolt stress prior to flange damage      Sfmax     58338.1 psi
 Target assembly gasket stress                              SgT     49500.0 psi
 Maximum permissible gasket stress                        Sgmax     55000.0 psi
 Minimum gasket operating stress                        Sgmin-O     14000.0 psi
 Minimum gasket seating stress                          Sgmin-S     20000.0 psi
 Nut Factor                                                   K       0.200
 Fraction of Gasket Load remaining after relaxation        Phig       0.700
```

```
 Root Area of a Single Bolt                                 Abs      1.4050 in^2
 Max. permissible single flange rotation for gasket   Thetagmax       1.000 deg
```

Calculated Results:

```
 Flange Material Ambient Yield Stress                       Sya     36000.0 psi
 Flange Material Operating Yield Stress                     Syo     31500.0 psi
 Single flange rotation at Sfmax                      Thetafmax       0.827 deg
```

Gasket Contact Area [Ag]:

```
  = pi/4( GO.D.^2 - GI.D.^2 )
  = pi/4( 46.85^2 - 45.276^2 )
  = 113.9 in^2
```

Target Bolt Stress [Sbsel]:

```
  = SGT * Ag / ( nb * Ab )            (O-1)
  = 49500 * 113.89/( 44 * 1.405 )
  = 91191.1 psi
```

Upper Bolt Stress Limit [Sbsel]:

```
  = min( Sbsel, Sbmax )               (O-4)
  = min( 56000, 56000 )
  = 56000.0 psi
```

Lower Bolt Stress Limit [Sbsel]:

```
  = max( Sbsel, Sbmin )               (O-5)
  = max( 56000, 32000 )
  = 56000.0 psi
```

Upper Bolt Stress Limit including the Flange [Sbsel]:

```
  = min( Sbsel, Sfmax )               (O-6)
  = min( 56000, 58338 )
  = 56000.0 psi
```

Gasket Assembly Stress [GAS]:

```
  = Sgmin-S( Ag / ( nb * Abs ) )      (O-7)
  = 20000( 113.89/( 44 * 1.405 ) )
  = 36844.9 psi
```

Since Sbsel >= GAS, check passes.

Gasket Operating Stress [GOS]:

```
  = (Sgmin-O * Ag + pi/4 * Pmax * GI.D.^2)/(PhiG * Abs * nb)  (O-8)
  = (14000*113.89+pi/4*151.56*45.276^2)/(0.7*1.405*44)
  = 42483.730 psi
```

Since Sbsel >= GOS, check passes.

Gasket Maximum Stress [GMS]:

```
  = Sgmax( Ag / ( nb * Abs ) )        (O-9)
  = 55000( 113.89/( 44 * 1.405 ) )
  = 101323.4 psi
```

Since Sbsel <= GMS, check passes.

Flange Rotation Limit [FRL]:

```
  = Sfmax( thetagmax / thetafmax )    (O-10)
  = 58338( 1/0.8268 )
  = 70558.8 psi
```

Since Sbsel <= FRL, check passes.

Assembly Bolt Torque [Tb]:

```
  = Sbsel * K * Abs * Phib/12         (O-2)
```

```
  = 56000 * 0.2 * 1.405 * 1.5/12
  = 1967.0 ft-lb

 Bolt Allowable Stress for: SA-193 B8 Cl. 2  SbB8  14639 psi
 Bolt Allowable Stress for: SA-193 B7M         Sb  20000 psi
```

Note: Since Sb >= SbB8, bolt allowable stress comparison check Passes.

Flange Rigidity Based on Required Thickness [ASME]:

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

$= 52.14 * Ma / Bsc * Cnv\_fac * V / (Lambda * Eamb * go^2 * ho * Ki)$
$= 52.14*181677/1*12*0.32/(3.4296*29400000*0.504^2*4.736*0.3)$
$= 0.999$ (should be <= 1)

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

$= 52.14 * Mo / Bsc * Cnv\_fac * V / (Lambda * Eop * goc^2 * ho * Ki)$
$= 52.14*94516/1*12*0.32/(3.4296*28180000*0.504^2*4.736*0.3)$
$= 0.542$ (should be <= 1)

Flange Rigidity Based on Given Thickness [ASME]:

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

$= 52.14 * Ma / Bsc * Cnv\_fac * V / (Lambda * Eamb * go^2 * ho * Ki)$
$= 52.14*181677/1*12*0.32/(4.8983*29400000*0.504^2*4.736*0.3)$
$= 0.699$ (should be <= 1)

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

$= 52.14 * Mo / Bsc * Cnv\_fac * V / (Lambda * Eop * goc^2 * ho * Ki)$
$= 52.14*94516/1*12*0.32/(4.8983*28180000*0.504^2*4.736*0.3)$
$= 0.379$ (should be <= 1)

Minimum Design Metal Temperature Results:
Thickness Ratio = 0.5312, Temperature Reduction per Fig. UCS 66.1 = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve C             -36 F
```

Internal Pressure Results Summary:

Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd psig	Nominal Thickness in	Total Corr Allowance in	Element Diameter in	Allowable Stress(SE) psi
COVER		196.666	4.921	...	54.724	20000
CHANNEL FLG1		196.666	5.787	...	44.5039	20000
CHANNEL		196.666	0.63	...	44.252	20000
CHANNEL FLG2		196.666	5.787	...	44.5039	20000
SHELL FLG		151.562	5.787	...	44.5039	20000
SHELL		151.562	0.63	...	44.252	20000
HEAD		151.562	0.551	...	44.252	20000

Element Required Thickness and MAWP :

From	To	Design Pressure psig	M.A.W.P. Corroded psig	M.A.P. New & Cold psig	Minimum Thickness in	Required Thickness in
COVER		195	345.94	463.42	4.44882	4.09746
CHANNEL FLG1		195	445.25	503.35	5.315	4.569
CHANNEL		195	558.23	559.9	0.63	0.21886
CHANNEL FLG2		195	445.25	503.34	5.315	4.569
SHELL FLG		150	445.36	527.37	5.315	4.569
SHELL		150	558.34	559.9	0.63	0.16844
HEAD		150	424.18	425.74	0.472	0.1678

Summary of Heat Exchanger Maximum Allowable Working Pressures :

Shell Side Tubesheet MAWP including Static Pres.: 280.14 = 281.81 – 1.666 psig
Tube Side Tubesheet MAWP including Static Pres.: 280.14 = 281.81 – 1.666 psig

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      =        280.14 psig
Shell Side MAPnc     =        377.46 psig
Channel Side  MAWP   =        280.14 psig
Channel Side  MAPnc  =        377.46 psig
```

Elements Suitable for Design Internal Pressure.

Internal Pressure Calculation Results:

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Cylindrical Shell From 30 To 40 SA-516 70 , UCS-66 Crv. D at 300 F

CHANNEL

Longitudinal Joint: User Defined

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (196.67*22.126)/(20000*1-0.6*196.67)
  = 0.2189 + 0.0000 = 0.2189 in
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 1.666 psig

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (20000*1*0.63)/(22.126+0.6*0.63)
  = 559.9 - 1.6661 = 558.23  psig
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (20000*1*0.63)/(22.126+0.6*0.63)
  = 559.9 psig
```

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

```
  = (P*(R+0.6*t))/(E*t)
  = (196.67*(22.126+0.6*0.63))/(1*0.63)
  = 7025.033 psi
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.404 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 0.63, tr = 0.3125, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.4961, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve D             -50 F
```

Cylindrical Shell From 60 To 70 SA-516 70 , UCS-66 Crv. D at 330 F

SHELL

Longitudinal   Joint: User Defined

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (151.56*22.126)/(20000*1-0.6*151.56)
  = 0.1684 + 0.0000 = 0.1684 in
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 1.562 psig

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (20000*1*0.63)/(22.126+0.6*0.63)
  = 559.9 - 1.5624 = 558.34  psig
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (20000*1*0.63)/(22.126+0.6*0.63)
  = 559.9 psig
```

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

```
  = (P*(R+0.6*t))/(E*t)
  = (151.56*(22.126+0.6*0.63))/(1*0.63)
  = 5413.899 psi
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.404 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 0.63, tr = 0.3125, c = 0 in, E✱ = 1

Thickness Ratio = tr * E✱/(tg - c) = 0.4961, Temp. Reduction = 0 F

Min Metal Temp. w/o impact per UCS-66, Curve D -50 F

Elliptical Head From 70 To 80 SA-516 70 , UCS-66 Crv. D at 330 F

HEAD

Longitudinal Joint: Seamless
Circumferential Joint: Spot Radiography per UW-11(a,5,b) Type 1

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
```
  = (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
  = (151.56*44.252*1)/(2*20000*1-0.2*151.56)
  = 0.1678 + 0.0000 = 0.1678 in
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
Less Operating Hydrostatic Head Pressure of 1.562 psig
```
  = (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
  = (2*20000*1*0.472)/(1*44.252+0.2*0.472)
  = 425.74 - 1.5624 = 424.18  psig
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
  = (2*20000*1*0.472)/(1*44.252+0.2*0.472)
  = 425.74 psig
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(Kcor*D+0.2*t))/(2*E*t)
  = (151.56*(1*44.252+0.2*0.472))/(2*1*0.472)
  = 7119.962 psi
```

Straight Flange Required Thickness:
```
  = (P*R)/(S*E-0.6*P) + c    per UG-27 (c)(1)
  = (151.56*22.126)/(20000*1-0.6*151.56)+0
  = 0.168 in
```

Straight Flange Maximum Allowable Working Pressure:
Less Operating Hydrostatic Head Pressure of 1.562 psig
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (20000 * 1 * 0.551 )/(22.126 + 0.6 * 0.551 )
  = 490.72 - 1.5624 = 489.16  psig
```

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 5.299 %
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 0.472, tr = 0.3104, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.6575, Temp. Reduction = 0 F

Min Metal Temp. w/o impact per UCS-66, Curve D -55 F

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 0.551, tr = 0.3125, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.5672, Temp. Reduction = 0 F

Min Metal Temp. w/o impact per UCS-66, Curve D -55 F

Hydrostatic Test Pressure Results:

Exchanger Shell Side Hydrostatic Test Pressures:

```
Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S        364.182  psig
Pressure per UG99b[35] = 1.30 * Design Pres * Sa/S     195.000  psig
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)     488.718  psig
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S        308.154  psig
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)   214.500  psig
Pressure per App 27-4  = M.A.W.P.                      280.140  psig
```

Exchanger Channel Side Hydrostatic Test Pressures:

```
Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S        364.182  psig
Pressure per UG99b[35] = 1.30 * Design Pres * Sa/S     253.500  psig
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)     488.718  psig
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S        308.154  psig
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)   278.850  psig
Pressure per App 27-4  = M.A.W.P.                      280.140  psig
```

Horizontal Test performed per: UG-99c

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 (psi & psig):

From To	Stress	Allowable	Ratio	Pressure
CHANNEL	17514.4	26000.0	0.674	490.32
SHELL	17514.4	26000.0	0.674	490.32
HEAD	23033.6	26000.0	0.886	490.32

Stress ratios for Nozzle and Pad Materials (psi):

Description	Pad/Nozzle	Ambient	Operating	Ratio
T2	Nozzle	17100.00	17100.00	1.000
T2	Pad	20000.00	20000.00	1.000
T1	Nozzle	17100.00	17100.00	1.000
T1	Pad	20000.00	20000.00	1.000
V1	Nozzle	20000.00	20000.00	1.000
D1	Nozzle	20000.00	20000.00	1.000
Aux1	Nozzle	20000.00	20000.00	1.000
Aux2	Nozzle	20000.00	20000.00	1.000
S1	Nozzle	20000.00	20000.00	1.000
S1	Pad	20000.00	20000.00	1.000
S2	Nozzle	17100.00	17100.00	1.000
S2	Pad	20000.00	20000.00	1.000
Aux3	Nozzle	20000.00	20000.00	1.000
Aux4	Nozzle	20000.00	20000.00	1.000
Minimum				1.000

Stress ratios for Pressurized Vessel Elements (psi):

Description	Ambient	Operating	Ratio
COVER	20000.00	20000.00	1.000
CHANNEL FLG1	20000.00	20000.00	1.000
CHANNEL	20000.00	20000.00	1.000
CHANNEL FLG2	20000.00	20000.00	1.000
SHELL FLG	20000.00	20000.00	1.000

SHELL	20000.00	20000.00	1.000
HEAD	20000.00	20000.00	1.000
Minimum			1.000

Stress ratios for Exchanger Materials (psi):

Description	Ambient	Operating	Ratio
Tube Material	16700.00	16400.00	1.018
Tubesheet Material	16700.00	12400.00	1.347
Minimum			1.018

Hoop Stress in Nozzle Wall during Pressure Test (psi):

Description	Ambient	Operating	Ratio
T2	4240.65	22230.00	0.191
T1	4240.65	22230.00	0.191
V1	1043.91	32400.00	0.032
D1	1043.91	32400.00	0.032
Aux1	1043.91	32400.00	0.032
Aux2	1043.91	32400.00	0.032
S1	5141.31	34200.00	0.150
S2	4240.65	22230.00	0.191
Aux3	1043.91	32400.00	0.032
Aux4	1043.91	32400.00	0.032

Elements Suitable for Test Pressure.

Field Test Pressure Calculations:

Hydrostatic Test Pressure Results:

Exchanger Shell Side Hydrostatic Test Pressures:

```
Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S        364.182  psig
Pressure per UG99b[35] = 1.30 * Design Pres * Sa/S     195.000  psig
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)     488.718  psig
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S        308.154  psig
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)   214.500  psig
Pressure per App 27-4  = M.A.W.P.                      280.140  psig
```

Exchanger Channel Side Hydrostatic Test Pressures:

```
Pressure per UG99b     = 1.30 * M.A.W.P. * Sa/S        364.182  psig
Pressure per UG99b[35] = 1.30 * Design Pres * Sa/S     253.500  psig
Pressure per UG99c     = 1.30 * M.A.P. - Head(Hyd)     488.718  psig
Pressure per UG100     = 1.10 * M.A.W.P. * Sa/S        308.154  psig
Pressure per PED       = max(1.43*DP, 1.25*DP*ratio)   278.850  psig
Pressure per App 27-4  = M.A.W.P.                      280.140  psig
```

Horizontal Test performed per: UG-99b

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 (psi & psig):

From To	Stress	Allowable	Ratio	Pressure

CHANNEL	13065.9	26000.0	0.503	365.78
SHELL	13065.9	26000.0	0.503	365.78
HEAD	17183.3	26000.0	0.661	365.78

Stress ratios for Nozzle and Pad Materials (psi):

Description	Pad/Nozzle	Ambient	Operating	Ratio
T2	Nozzle	17100.00	17100.00	1.000
T2	Pad	20000.00	20000.00	1.000
T1	Nozzle	17100.00	17100.00	1.000
T1	Pad	20000.00	20000.00	1.000
V1	Nozzle	20000.00	20000.00	1.000
D1	Nozzle	20000.00	20000.00	1.000
Aux1	Nozzle	20000.00	20000.00	1.000
Aux2	Nozzle	20000.00	20000.00	1.000
S1	Nozzle	20000.00	20000.00	1.000
S1	Pad	20000.00	20000.00	1.000
S2	Nozzle	17100.00	17100.00	1.000
S2	Pad	20000.00	20000.00	1.000
Aux3	Nozzle	20000.00	20000.00	1.000
Aux4	Nozzle	20000.00	20000.00	1.000
Minimum				1.000

Stress ratios for Pressurized Vessel Elements (psi):

Description	Ambient	Operating	Ratio
COVER	20000.00	20000.00	1.000
CHANNEL FLG1	20000.00	20000.00	1.000
CHANNEL	20000.00	20000.00	1.000
CHANNEL FLG2	20000.00	20000.00	1.000
SHELL FLG	20000.00	20000.00	1.000
SHELL	20000.00	20000.00	1.000
HEAD	20000.00	20000.00	1.000
Minimum			1.000

Stress ratios for Exchanger Materials (psi):

Description	Ambient	Operating	Ratio
Tube Material	16700.00	16400.00	1.018
Tubesheet Material	16700.00	12400.00	1.347
Minimum			1.018

Hoop Stress in Nozzle Wall during Pressure Test (psi):

Description	Ambient	Operating	Ratio
T2	3163.57	22230.00	0.142
T1	3163.57	22230.00	0.142
V1	778.76	32400.00	0.024
D1	778.76	32400.00	0.024
Aux1	778.76	32400.00	0.024
Aux2	778.76	32400.00	0.024
S1	3835.47	34200.00	0.112
S2	3163.57	22230.00	0.142
Aux3	778.76	32400.00	0.024
Aux4	778.76	32400.00	0.024

Elements Suitable for Test Pressure.

External Pressure Calculation Results :

External Pressure Calculations:

From	To	Section Length in	Outside Diameter in	Corroded Thickness in	Factor A	Factor B psi
10	20	No Calc	...	4.44882	No Calc	No Calc
20	30	No Calc	...	5.315	No Calc	No Calc
30	40	33.4646	45.512	0.63	0.0031253	16333.5
40	50	No Calc	...	5.315	No Calc	No Calc
50	60	No Calc	...	5.315	No Calc	No Calc
60	70	214.349	45.512	0.63	0.00041672	6042.41
70	80	No Calc	45.196	0.472	0.0014505	13910.4

External Pressure Calculations:

From	To	External Actual T. in	External Required T. in	External Design Pressure psig	External M.A.W.P. psig
10	20	4.44882	3.574	15	No Calc
20	30	5.315	5.315	15	No Calc
30	40	0.63	0.12798	15	301.46
40	50	5.315	5.315	15	No Calc
50	60	5.315	5.315	15	No Calc
60	70	0.63	0.27941	15	111.52
70	80	0.472	0.11702	15	161.41
Minimum					111.52

External Pressure Calculations:

From	To	Actual Length Bet. Stiffeners in	Allowable Length Bet. Stiffeners in	Ring Inertia Required in**4	Ring Inertia Available in**4
10	20	No Calc	No Calc	No Calc	No Calc
20	30	No Calc	No Calc	No Calc	No Calc
30	40	33.4646	1008.06	No Calc	No Calc
40	50	No Calc	No Calc	No Calc	No Calc
50	60	No Calc	No Calc	No Calc	No Calc
60	70	214.349	4547.97	No Calc	No Calc
70	80	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

ASME Code, Section VIII Division 1, 2021

Cylindrical Shell From 30 to 40 Ext. Chart: CS-2 at 300 F

CHANNEL
Elastic Modulus from Chart: CS-2 at 300 F: 29000000 psi

Results for Maximum Allowable Ext. Pressure						MAEP
Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
0.630	45.51	33.46	72.24	0.7353	0.0031253	16333.53

MAEP = (4*B)/(3*(Do/t)) = (4*16334)/(3*72.241) = 301.46 psig

Results for Required Thickness						Tca
Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
0.128	45.51	33.46	355.61	0.7353	0.0002759	4000.85

MAEP = (4*B)/(3*(Do/t)) = (4*4000.9)/(3*355.61) = 15.001 psig

Results for Maximum Stiffened Length						Slen
Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
0.630	45.51	1008.06	72.24	22.1494	0.0002193	3179.91

MAEP = (4*B)/(3*(Do/t)) = (4*3179.9)/(3*72.241) = 58.691 psig

---

Cylindrical Shell From 60 to 70 Ext. Chart: CS-2 at 300 F

SHELL
Elastic Modulus from Chart: CS-2 at 300 F: 29000000 psi

Results for Maximum Allowable Ext. Pressure						MAEP
Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
0.630	45.51	214.35	72.24	4.7097	0.0004167	6042.41

MAEP = (4*B)/(3*(Do/t)) = (4*6042.4)/(3*72.241) = 111.52 psig

Results for Required Thickness						Tca
Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
0.279	45.51	214.35	162.89	4.7097	0.0001264	1832.56

MAEP = (4*B)/(3*(Do/t)) = (4*1832.6)/(3*162.89) = 15.001 psig

Results for Maximum Stiffened Length						Slen
Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
0.630	45.51	4547.97	72.24	50.0000	0.0002175	3153.52

MAEP = (4*B)/(3*(Do/t)) = (4*3153.5)/(3*72.241) = 58.204 psig

---

Elliptical Head From 70 to 80 Ext. Chart: CS-2 at 300 F

HEAD
Elastic Modulus from Chart: CS-2 at 300 F: 29000000 psi

Results for Maximum Allowable Ext. Pressure				MAEP
Tca	Outer Dia	Do/t	Factor A	Factor B
0.472	45.20	95.75	0.0014505	13910.37

MAEP = B/(K0*Do/t) = 13910/(0.9 *95.754) = 161.41 psig

Results for Required Thickness				Tca
Tca	Outer Dia	Do/t	Factor A	Factor B
0.117	45.20	386.22	0.0003596	5214.41

MAEP = B/(K0*Do/t) = 5214.4/(0.9 *386.22) = 15.001 psig

Element and Detail Weights:

From	To	Element Metal Wgt. lbf	Element ID Volume ft3	Corroded Metal Wgt. lbf	Corroded ID Volume ft3	Extra due Misc % lbf
10	20	3240.84	...	3240.84	...	310.472
20	30	1337.17	6.80462	1337.17	6.80462	128.101
30	40	832.347	29.7847	832.347	29.7847	79.7388
40	50	1337.17	6.80462	1337.17	6.80462	128.101
50	60	1337.17	6.80462	1337.17	6.80462	128.101
60	70	5189.93	111.008	5189.93	111.008	497.195
70	80	414.081	8.34441	414.081	8.34441	39.669
Total		13688	169.55	13688	169.55	1311

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 lbf	X Offset, Dtl. Cent. in	Y Offset, Dtl. Cent. in	Z Offset Dtl. Cent. in	Description
10	Liqd	...	2.22441	5.36201	...	Liquid: 10
10	Insl	25.5015	2.26378	...	...	Ins: 10
20	Liqd	444.339	3.5435	0.25195	...	Liquid: 20
20	Insl	9.09734	3.51575	...	...	Ins: 20
20	Lini	71.1144	3.5435	...	...	OVERLAY
30	Liqd	1947.49	16.7323	0.12598	...	Liquid: 30
30	Insl	40.1717	16.7323	...	...	INS
30	Lini	166.117	16.7323	...	...	CLAD
30	Nozl	220.99	16.7323	25.2587	10.8767	T2
30	Nozl	220.993	16.7323	-25.2588	10.8766	T1
30	Nozl	38.0006	16.7323	20.8507	-10.0031	V1
30	Nozl	38.0006	16.7323	-20.8509	-10.0026	D1
30	Nozl	37.0202	5.78701	...	23.126	Aux1
30	Nozl	37.0202	5.7874	...	23.126	Aux2
40	Liqd	444.339	3.5435	0.25195	...	Liquid: 40
40	Insl	9.09734	3.51575	...	...	Ins: 40
40	Lini	71.1144	3.5435	...	...	OVERLAY
50	Liqd	416.669	3.5435	0.25195	...	Liquid: 50
50	Insl	9.09734	3.51575	...	...	Ins: 50
50	Lini	71.123	3.54348	...	...	overlay
60	Sadl	488.532	12.992	30.433	...	Sliding Saddle
60	Sadl	488.532	151.992	30.433	...	Fixed Saddle
60	Liqd	6811.25	104.331	0.12598	...	Liquid: 50
60	Insl	250.482	104.331	...	...	Ins: 60
60	Lini	1035.79	104.33	...	...	clad
60	Nozl	278.661	12.797	28.126	...	S1
60	Nozl	206.021	177.206	-27.501	...	S2
60	Nozl	35.3471	4.898	...	23.126	Aux3
60	Nozl	37.0185	4.898	...	23.126	Aux4
70	Liqd	511.949	5.68767	0.126	...	Liquid: 70
70	Insl	26.5889	6.53125	...	...	Ins: 70
70	Lini	117.122	6.53124	...	...	clad
40	FTsh	1621.84	9.58401	...	...	
40	Tube	12916	103.927	...	...	Tubes
50	Bafl	81.5715	26.3	...	...	Baffles
50	Bafl	81.5715	39.863	...	...	Baffles
50	Bafl	81.5715	53.426	...	...	Baffles
50	Bafl	81.5715	66.989	...	...	Baffles

```
    50|Bafl|     81.5715 |     80.552 |         ... |          ... |   Baffles
    50|Bafl|     81.5715 |     94.115 |         ... |          ... |   Baffles
    50|Bafl|     81.5715 |    107.678 |         ... |          ... |   Baffles
    50|Bafl|     81.5715 |    121.241 |         ... |          ... |   Baffles
    50|Bafl|     81.5715 |    134.804 |         ... |          ... |   Baffles
    50|Bafl|     81.5715 |    148.367 |         ... |          ... |   Baffles
    50|Bafl|     81.5715 |     161.93 |         ... |          ... |   Baffles
    50|Bafl|     81.8515 |    175.493 |         ... |          ... |   Baffles
 ---------------------------------------------------------------
```

Total Weight of Each Detail Type:

```
 Saddles                          977.1
 Liquid                         10576.0
 Insulation                       370.0
 Lining                          1532.4
 Nozzles                         1149.1
 Exchanger Components           15517.0
 Liquid in Tubes                 3593.7
 -------------------------------------------
 Sum of the Detail Weights      33715.3 lbf
```

Weight Summation Results: (lbf)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	15000.1	15000.1	15000.1	15000.1	15000.1	15000.1
Saddles	977.1	977.1	977.1	977.1	977.1	977.1
Nozzles	1149.1	1149.1	1149.1	1149.1	1149.1	1149.1
Exchanger	15517.0	15517.0	15517.0	15517.0	15517.0	15517.0
Insulation	...	...	370.0	370.0	370.0	370.0
Lining	1532.4	1532.4	1532.4	1532.4	1532.4	1532.4
Ope. Liquid	...	...	...	...	...	10576.0
Tube Ope Lqd	...	...	...	...	...	3593.7
Test Liquid	...	10580.0	...	...	...	...
Tube Tst Lqd	...	3427.1	...	...	...	...
Totals	34175.6	48182.8	34545.6	34545.6	34545.6	48715.3

Field Installation Options:

Miscellaneous Weight Percent input values:

```
 Saddles:      9.6%  Platforms:     0.0%  Rings:    0.0%  Nozzles:         9.6%
 Trays:        0.0%  Legs:          0.0%  Clips:    0.0%  Sup Lugs:        0.0%
 1/2 Pipes:    0.0%  Tubesheets:    9.6%  Tubes:   23.3%  Floating Heads:  0.0%
 Jackets:      0.0%  Shells etc:    9.6%
```

Note that the above values for the miscellaneous weight percents have 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             34175.6 lbf
 Shop Test Wt.    - Fabricated Weight + Water ( Full )                  48182.8 lbf
 Shipping Wt.     - Fab. Weight + removable Intls.+ Shipping App.       34545.6 lbf
 Erected  Wt.     - Fab. Wt + or - loose items (trays,platforms etc.)   34545.6 lbf
 Ope. Wt. no Liq  - Fab. Weight + Internals. + Details + Weights        34545.6 lbf
 Operating Wt.    - Empty Weight + Operating Liq. Uncorroded            48715.3 lbf
 Oper. Wt. + CA   - Corr Wt. + Operating Liquid                         48715.3 lbf
 Field Test Wt.   - Empty Weight + Water (Full)                         48359.6 lbf
```

Exchanger Tube Data

```
 Volume of Exchanger tubes  :                         54.9 ft3
 Weight of Ope Liq in tubes :                       3593.7 lbf
 Weight of Water in tubes   :                       3427.1 lbf
```

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

Outside Surface Areas of Elements:

From	To	Surface Area in^2
10	20	3198.07
20	30	2048.26
30	40	4784.77
40	50	2048.26
50	60	2048.26
60	70	29834.4
70	80	2514.71

Total 46476.742 in^2 [322.8 Square Feet]

Nozzle Flange MAWP Results: (psig & F)

Nozzle Description	Flange Rating Ope.	Flange Rating Ambient	Design Temp	Class	Grade/ Group	Equiv. Press	Max Pressure UG-44(b)	Max Pressure 50%	Max Pressure DNV
T2	655.0	740.0	300	300	GR 1.1	492.6	489.9	655.0	489.9
T1	655.0	740.0	300	300	GR 1.1	492.6	489.9	655.0	489.9
V1	655.0	740.0	300	300	GR 1.1	...	...	...	...
D1	655.0	740.0	300	300	GR 1.1	...	...	...	...
Aux1	655.0	740.0	300	300	GR 1.1	...	...	...	...
Aux2	655.0	740.0	300	300	GR 1.1	...	...	...	...
S1	649.0	740.0	330	300	GR 1.1	420.1	553.4	649.0	553.4
S2	649.0	740.0	330	300	GR 1.1	492.6	480.9	649.0	480.9
Aux3	649.0	740.0	330	300	GR 1.1	...	...	...	...
Aux4	649.0	740.0	330	300	GR 1.1	...	...	...	...

Shellside Flange Rating

```
Lowest Flange Pressure Rating was (Ope)[ShellSide]:    480.907  psig
Lowest Flange Pressure Rating was (Amb)[ShellSide]:    740.000  psig
```

Channelside Flange Rating

```
Lowest Flange Pressure Rating was (Ope)[TubeSide ]:    489.907  psig
Lowest Flange Pressure Rating was (Amb)[TubeSide ]:    740.000  psig
```

Selected Method for Derating ASME B16.5 Flange MAWP: ASME UG-44(b)

The UG-44(b) Method is based on the paper PVP 2013-97814. PV Elite uses the maximum loads from each load category to determine ME and FE. In many cases, the computed maximum allowable pressure will be greater than the flange rating. In these cases, the minimum of the rating from the table and the UG-44(b) method will be used. SA-193 B8 Cl. 2 bolts or ones with higher allowable stresses at the specified bolt size shall be used.

The axial force FE must put the nozzle in tension (-P for 107/297; +Fr for PD 5500 AnnexG) to be considered.

Nozzle Description	Gasket Dimension G in	Fm Value	Resolved Moment ME ft-lb	Axial Force FE lbf	MAWP PD psig	Maximum Pressure Pmax psig	Pass Fail
T2	11.905	0.50	12960	2580	280.1	489.9	Pass
T1	11.905	0.50	12960	2580	278.5	489.9	Pass
S1	14.065	0.50	18229	3060	280.1	553.4	Pass
S2	11.905	0.50	12960	2580	278.6	480.9	Pass

Evaluating Flange on Nozzle [T2]:

```
= 16*ME + 4*FE*G < pi*G^3[((PR - PD) + FM * PR)]
= 16(155516)+4*abs(2580)11.905 < pi*11.905^3[(655.0-280.1)+.500*655.000]
= 2611117.8 < 3723353.5   Check Passes
```

Maximum Pressure for Flange on Nozzle T2 [Pmax]:

```
= min( PR, FM * PR + PR - (16*ME + 4*FE * G) / ( pi * G^3 ))
= min( 655.000, 0.500 * 655.000 + 655.000 - 2611117.8/(pi * 11.905^3)
= min( 655.000, 489.907 )
= 489.907 psig
```

Evaluating Flange on Nozzle [T1]:

```
= 16*ME + 4*FE*G < pi*G^3[((PR - PD) + FM * PR)]
= 16(155516)+4*abs(2580)11.905 < pi*11.905^3[(655.0-278.5)+.500*655.000]
= 2611117.8 < 3731511.5   Check Passes
```

Maximum Pressure for Flange on Nozzle T1 [Pmax]:

```
  = min( PR, FM * PR + PR - (16*ME + 4*FE * G) / ( pi * G^3 ))
  = min( 655.000, 0.500 * 655.000 + 655.000 - 2611117.8/(pi * 11.905^3)
  = min( 655.000, 489.907 )
  = 489.907 psig
```

Evaluating Flange on Nozzle [S1]:

```
  = 16*ME + 4*FE*G < pi*G^3[((PR - PD) + FM * PR)]
  = 16(218749)+4*abs(3060)14.065 < pi*14.065^3[(649.0-280.1)+.500*649.000]
  = 3672147.5 < 6060771.5  Check Passes
```

Maximum Pressure for Flange on Nozzle S1 [Pmax]:

```
  = min( PR, FM * PR + PR - (16*ME + 4*FE * G) / ( pi * G^3 ))
  = min( 649.000, 0.500 * 649.000 + 649.000 - 3672147.5/(pi * 14.065^3)
  = min( 649.000, 553.402 )
  = 553.402 psig
```

Evaluating Flange on Nozzle [S2]:

```
  = 16*ME + 4*FE*G < pi*G^3[((PR - PD) + FM * PR)]
  = 16(155516)+4*abs(2580)11.905 < pi*11.905^3[(649.0-278.6)+.500*649.000]
  = 2611117.8 < 3683616.8  Check Passes
```

Maximum Pressure for Flange on Nozzle S2 [Pmax]:

```
  = min( PR, FM * PR + PR - (16*ME + 4*FE * G) / ( pi * G^3 ))
  = min( 649.000, 0.500 * 649.000 + 649.000 - 2611117.8/(pi * 11.905^3)
  = min( 649.000, 480.907 )
  = 480.907 psig
```

Pressure Ratings are per ASME B16.5 2017 Edition

Wind Load Calculation Results:

Input Values:

```
Wind Design Code                                   ASCE/SEI 7-16
Wind Load Reduction Scale Factor                           0.600
Basic Wind Speed                    [V]                      101  mile/hr
Surface Roughness Category                      C: Open Terrain
Importance Factor                                            1.0
Type of Surface                               Moderately Smooth
Base Elevation                                               988  in
Percent Wind for Hydrotest                                  50.0
Using User defined Wind Press. Vs Elev.                        N
Height of Hill or Escarpment     H or Hh                       0  in
Distance Upwind of Crest              Lh                       0  in
Distance from Crest to the Vessel      x                       0  in
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
Site Elevation above Sea Level                                 0  in
```

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*0.187*0.9136)/(1+1.7*3.4*0.187)))
  = min(0.85, 0.8835 )
  = 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

 User Entered Importance Factor is                      1.000
 Force Coefficient                                 [Cf] 0.585
 Structure Height to Diameter ratio                     6.129
```

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 26.11-1
Alpha = 9.5 : Zg = 10800 in

Effective Height [z]:

```
  = Centroid Height + Vessel Base Elevation
  = 40 + 988 = 1028 in
  = 85.667 ft. Imperial Units
```

Velocity Pressure coefficient evaluated at height z [Kz]:

Because z(85.667 ft.) > 15 ft.

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

$= 2.01(85.667/900)^{2/9.5}$

= 1.2251

Type of Hill: No Hill

```
PV Elite 24        Licensee: WCE
FileName : 1.18-X-262-04     ---------------------------------
Wind Load Calculation:                  Step:    11    8:44am   Jan 17,2023
```

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

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

Topographical Factor [Kzt]:
$= (1 + K1 * K2 * K3)^2$
$= (1 + 0 * 0 * 0)^2$
= 1

Velocity Pressure evaluated at height z, Imperial Units [qz]:
$= \max(16, 0.00256 * Kz * Kzt * Kd * Ke * V(mph)^2)$
$= \max(16, 0.00256 * 1.2251 * 1 * 1 * 1 * 101^2)$
= 32.0 psf

Force on the first element [F]:
= qz * G * Cf * WindArea
= 31.992 * 0.85 * 0.5855 * 2.4432
= 38.9 lbf

Element	Hgt (z) in	K1	K2	K3	Kz	Kzt	qz psf
COVER	1028.0	0.000	0.000	0.000	1.225	1.000	31.992
CHANNEL FLG1	1028.0	0.000	0.000	0.000	1.225	1.000	31.992
CHANNEL	1028.0	0.000	0.000	0.000	1.225	1.000	31.992
CHANNEL FLG2	1028.0	0.000	0.000	0.000	1.225	1.000	31.992
SHELL FLG	1028.0	0.000	0.000	0.000	1.225	1.000	31.992
SHELL	1028.0	0.000	0.000	0.000	1.225	1.000	31.992
HEAD	1028.0	0.000	0.000	0.000	1.225	1.000	31.992

Wind Load Calculation:

From	To	Wind Height in	Wind Diameter in	Wind Area in^2	Wind Pressure psf	Element Wind Load lbf
10	20	1028	79.0819	351.821	31.992	23.3388
20	30	1028	65.0482	460.996	31.992	30.5812
30	40	1028	66.4614	2224.1	31.992	147.541
40	50	1028	65.0482	460.996	31.992	30.5812
50	60	1028	65.0482	460.996	31.992	30.5812
60	70	1028	66.4614	13867.9	31.992	919.96
70	80	1028	66.0285	625.471	31.992	41.492

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 Results:

Earthquake Load Calculation:

Input Values:

```
Seismic Design Code                                   ASCE/SEI 7-16
Seismic Load Reduction Scale Factor                           0.700
Importance Factor                                             1.500
Table Value Fa                                                1.000
Table Value Fv                                                1.721
Max. Mapped Res. Acceleration      [Ss]                       1.616
Max. Eff. Ground Acceleration       [S]                       0.579
Force Modification Factor R                                   2.500
Site Class                                                        D
Component Elevation Ratio           z/h                       1.000
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 )                              1.077
User Value of Sd1 (used if > 0 )                              0.996
Moment Reduction Factor Tau                                   1.000
```

Seismic Analysis Results:

```
Sms = Fa * Ss = 1 * 1.616 = 1.616
Sm1 = Fv * S1 = 1.721 * 0.579 = 0.9965
Sds = 2/3 * Sms = 2/3 * 1.616 = 1.0773

Sds = Max( 0.8*Sds, SdsUser )
    = Max( 0.8619, 1.077 )
    = 1.077

Sd1 = 2/3 * Sm1 = 2/3 * 0.9965 = 0.6643

Sd1 = Max( 0.8*Sd1, Sd1User )
    = Max( 0.5314, 0.996 )
    = 0.996
```

Check Approximate Fundamental Period from 12.8-7 [Ta]:

= Ct * hn^x where Ct = 0.020, x = 0.75 and hn = Structural Height (ft.)
= 0.020 *($5.6135^{0.75}$)
= 0.073 seconds

The Coefficient Cu from Table 12.8-1 is : 1.400

Fundamental Period (1/Frequency) [T]:

```
= ( 1/Natural Frequency ) = ( 1/33 )
= 0.030
```

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

```
= Minimum Value of(1.4 * 0.07294, 0.0303 ) per 12.8.2
= 0.030
```

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

```
= 0.4 * Ap * Sds * W * ( 1 + 2*(z/h) ) / ( R / Ie )
= 0.4 * 1 * 1.077 * 48715 *( 1 + 2*1 )/( 2.5/1.5 )
= 37775.828 lbf
```

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

```
= 1.6 * Sds * I * W
= 1.6 * 1.077 * 1.5 * 48715 = 125919 lbf
```

Check the Minimum value of Fp per equation 13.3-3:
= 0.3 * 1.077 * 1.5 * 48715
= 23609.895 lbf

Compute the Total Base Shear V = Fp, [V]:
= 37775.828 lbf

Final Base Shear, V = 26443.08 lbf

Earthquake Load Calculation:

From	To	Earthquake Height in	Earthquake Weight lbf	Element Ope Load lbf
10	20	27.362	5412.82	3533.79
20	30	22.2519	5412.82	2873.83
30	40	22.126	5412.82	2857.56
40	50	22.2519	5412.82	2873.83
50	60	22.2519	5412.82	2873.83
60	Sadl	22.126	5412.82	2857.56
Sadl	70	22.126	5412.82	2857.56
60	70	22.126	5412.82	2857.56
70	80	22.126	5412.82	2857.56

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

Shop/Field Installation Options :

Insulation is installed in the Shop.
Lining is installed in the Shop.

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

```
Center of Gravity of the Saddles                       147.518 in
Center of Gravity of the Liquid                        132.782 in
Center of Gravity of the Insulation                    141.008 in
Center of Gravity of the Lining                        144.572 in
Center of Gravity of the Nozzles                        80.921 in
Center of Gravity of the Tubesheet(s)                   55.273 in
Center of Gravity of the Tubes                         149.616 in
Center of Gravity of the Baffles                       158.857 in

Center of Gravity of Bare Shell New and Cold            86.739 in
Center of Gravity of Bare Shell Corroded                86.739 in

Vessel CG in the Operating Condition                   121.759 in
Vessel CG in the Fabricated (Shop/Empty) Condition     115.487 in
Vessel CG in the Test Condition                        122.052 in
```

Rigging Analysis Results:

Lifting Weight based the calculated Empty Weight.

```
Total Effective Length of Vessel for this analysis      269.84 in
Total vessel weight (No Liquid)                 Twt   34545.65 lbf
Impact weight multiplication factor             Imp       1.50
Design lifting weight,  DWT = Imp * Twt               51818.47 lbf
Distance to the Lug on the Left End                     100.39 in
Distance to the Lug on the Right End                    187.01 in
Design Reaction force at the Left End Lug             42788.80 lbf
Design Reaction force at the Right End Lug             9029.67 lbf

CG Distance from the Left End Lug/Trunnion               15.09 in
CG Distance from the Nearer Lifting Lug/Trunnion         15.09 in

Compressive Allowable Increase Factor                     1.00
```

Critical Values:

	Max Stress psi	Elevation in	Allowables psi	
Bending	2359.61	100.91	16578.89	(UG-23)
Shear	380.25	59.17	14000.00	(0.7*S)

The compressive bending allowable stress is the minimum of the tensile allowable and the compressive allowable times the specified compressive allowable increase factor.

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

Distance in	Bending Moment ft-lb	Bending Stress psi	Shear Force lbf	Shear Stress psi
0.00	0.0	0.0	4989.9	45.5
5.87	2753.6	33.2	11899.1	133.2
24.92	24283.2	296.4	18808.2	211.7
49.25	60918.5	735.2	25717.3	287.9
57.76	79416.3	958.5	32626.4	365.2
267.84	2791.8	45.7	767.7	11.6

Unity Check (Actual Stress / Allowable Stress):

Maximum Unity Check is 0.1423 at elevation 100.91 in - Must be <=1

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

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

ASME VIII Division 2 Horizontal Vessel Analysis, Left Saddle:

Horizontal Vessel Stress Calculations : Bundle Pull, New Condition

Note:
Wear Pad Width (9.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

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

```
  = min( b + 1.56*sqrt( Rm * t ), 2a )
  = min( 7.4252 + 1.56*sqrt( 22.441 * 0.63 ), 2 * 20.354 )
  = 13.2908 in
```

Input and Calculated Values:

```
 Vessel Mean Radius                              Rm       22.44  in
 Shell Thickness used in this Case                t       0.630  in
 Stiffened Vessel Length per 4.15.6               L      217.75  in
 Distance from Saddle to Vessel tangent      a1 or a      20.35  in

 Saddle Width                                b1 or b       7.43  in
 Saddle Bearing Angle                 delta or theta     120.00  degrees

 Shell Allowable Stress used in Calculation          20000.00  psi
 Head Allowable Stress used in Calculation           20000.00  psi
 Circumferential Efficiency in Plane of Saddle           1.00
 Circumferential Efficiency at Mid-Span                  1.00

 Distance from Saddle Base to Centerline          B      40.00  in
 Coefficient of Friction                         mu       0.40

 Tube Bundle Pull out Force                          23280.00  lbf
 Tube Bundle Pull out Force Impact Factor               1.500
 Apply Bundle Pull out Force to Fixed Saddle only          No

 Saddle Force Q, + Bundle Pull, Force                24745.05  lbf

 Pressure used in Analysis                        P      0.000  psig

 Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                             psi |          psi |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan       -874.87 |    -34200.00 |
 Long. Stress at Top    of Midspan        874.87 |     20000.00 |
 Long. Stress at Bottom of Midspan        874.87 |     20000.00 |
 Long. Stress at Top    of Saddles        173.77 |     20000.00 |
 Long. Stress at Bottom of Saddles        -96.31 |    -34200.00 |
 Long. Stress at Bottom of Saddles         96.31 |     20000.00 |
 ----------------------------------------------------------------
 Tangential Shear in Shell               1665.97 |     16000.00 |
 Circ. Stress at Horn of Saddle          4991.95 |     30000.00 |
 Circ. Compressive Stress in Shell        224.68 |     20000.00 |
 ----------------------------------------------------------------
```

Intermediate Results: Saddle Reaction Q due to Bundle pull out Force:

Saddle Reaction Force due to Bundle Pull out Force [Fwl]:

```
  = Bundle Pull Out Force * Impact Factor * B / Ls
  = 23280 * 1.5 * 40/139
  = 10048.9 lbf
```

Load Combination Results for Tube Bundle Pull Out [Q]:

```
  = Saddle Load + max( Fwl, Fwt, Fsl, Fst )
```

```
  = 14696 + max( 10049, 0, 0, 0 )
  = 24745.1 lbf
```

Summary of Loads at the base of this Saddle:

```
 Vertical Load (including saddle weight)          25233.58  lbf
 Transverse Shear Load Saddle                         0.00  lbf
 Longitudinal Shear Load Saddle                   34920.00  lbf
```

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:

```
  = Baseplate Length
  = 40.000 in
```

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  = 0.0455     K8  = 0.3405
 K9  = 0.2711     K10 = 0.0581     K1* = 0.1923
```

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

Moment per Equation 4.15.1 [M1]:

```
  = -Q*a [1 - (1- a/L + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -24745*20.354[1-(1-20.354/217.75+(22.441²-0²)/
    (2*20.354*217.75))/(1+(4*0)/(3*217.75))]
  = -1538.8 ft-lb
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 24745*217.75/4(1+2(22.441²-0²)/(217.75²))/(1+(4*0)/
    (3*217.75))-4*20.354/217.75
  = 72666.9 ft-lb
```

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 0 * 22.441/(2*0.63 ) - 872003/(pi*22.441²*0.63 )
  = -874.87 psi
```

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 0 * 22.441/(2 * 0.63 ) + 872003/(pi * 22.441² * 0.63 )
  = 874.87 psi
```

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma✱3]:

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 0*22.441/(2*0.63)--18465/(0.1066*pi*22.441²*0.63)
  = 173.77 psi
```

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma✱4]:

```
  = P * Rm/(2t) + M1/(K1✱ * pi * Rm² * t)
  = 0*22.441/(2*0.63)+-18465/(0.1923*pi*22.441²*0.63)
  = -96.31 psi
```

Maximum Shear Force in the Saddle (4.15.3) [T]:

```
  = Q(L-2a)/(L+(4*h2/3))
  = 24745( 217.75 - 2 * 20.354 )/(217.75 +( 4 * 0/3))
  = 20119.0 lbf
```

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:

```
  = K2 * T / ( Rm * t )
  = 1.1707 * 20119/( 22.441 * 0.63 )
```

```
  = 1665.97 psi
```

Decay Length (4.15.20) [x1,x2]:

```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 22.441 * 0.63 )
  = 2.933 in
```

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:

```
  = -K5 * Q * k / ( t( b + X1 + X2 ) )
  = -0.7603 * 24745 * 0.1/( 0.63( 7.4252 + 2.9328 + 2.9328 ) )
  = -224.68 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:

```
  = -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -24745/(4 * 0.63(7.4252 + 2.9328 + 2.9328 )) -
     3 * 0.04548 * 24745/(2*0.63²)
  = -4991.95 psi
```

Effective reinforcing plate width (4.15.24) [B1]:

```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 7.4252 + 1.56 * sqrt( 22.441 * 0.63 ), 2 * 20.354 )
  = 13.29 in
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	40.0000	in
Baseplate Thickness	Bpthk	1.2598	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	0.5510	in
Web Thickness	Webtk	0.5510	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	33270.0	psi
Height of Web at Center	Hw,c	17.0	in
Friction Coefficient	mu	0.400	

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

Inertia of Shell [ShellInertia]:

```
  = (( 1.56 * sqrt( R * t ) + WearPlateWidth )t³ )/12
  = (( 1.56 * sqrt( 22.126 * 0.63 ) + 9 )0.63³ )/12
  = 0.309 in**4
```

Resolved Inertia for the Shell [I,shell]:

```
  = ShellInertia + AShell( C1 - Y )²
  = 0.3089 + 9.3393( 8.0278 - 0.315 )²
  = 555.882 in**4
```

	B in	D in	Y in	A in^2	AY in^3	I + AD^2 in**4
Shell	14.8243	0.6300	0.3150	9.3393	2.9419	555.8818
Wearplate	9.0000	0.6300	0.9450	5.6700	5.3582	284.6299
Web	0.5510	15.3542	8.9371	8.4601	75.6091	173.2018
BasePlate	9.0000	1.2598	17.2441	11.3386	195.5232	964.5957
Totals	...	...	...	34.8080	279.4323	1978.3096

Distance to Centroid [C1]:

```
  = AY / A
  = 279.43/34.808
  = 8.028 in
```

Angle [beta]:

```
  = 180 - Saddle Angle/2
  = 180 - 120/2
```

```
  = 120.0
```

Saddle Splitting Coefficient [K1]:
```
  = ( 1 + cos(beta) - 0.5*sin(beta)² )/(pi - beta + sin(beta)cos(beta) )
  = ( 1 + cos(120 ) - 0.5*sin(120 )² )/(pi - 2.0944 + sin(120 )cos(120 ) )
  = 0.2035
```

Saddle Splitting Force [Fh]:
```
  = K1 * Q
  = 0.2035 * 24745
  = 5036.1543 lbf

 Tension Stress, St = ( Fh/As )       =        197.7389  psi
 Allowed Stress, Sa = 0.6 * Yield Str =      19962.0000  psi
```

Saddle Splitting Dimension [d]:
```
  = B - R * sin(theta/2)/(theta/2 in radians)
  = 40 - 22.126 * sin(120/2)/1.0472
  = 21.702 in

 Bending Moment, M  = Fh * d          =       9107.8672  ft-lb

 Bending Stress, Sb = ( M * C1 / I  ) =        443.5073  psi
 Allowed Stress, Sa = 2/3 * Yield Str =      22180.0000  psi
```

Minimum Thickness of Baseplate per Moss:
```
  = sqrt( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))
  = sqrt( 3(24745 + 488.53 )9/( 2 * 40 * 22180 ))
  = 0.620 in
```

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 - 120/2 )( 22.126 + 0.63 + 0.63 )
  = 40.506 in
```

Distance between Ribs [e]:
```
  = Web Length / ( Nribs - 1 )
  = 40.506/( 3 - 1 )
  = 20.253 in
```

Baseplate Pressure Area [Ap]:
```
  = e * Bpwid / 2
  = 20.253 * 9/2
  = 91.138 in^2
```

Bearing Pressure [Bp]:
```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 24745/( 40 * 9 )
  = 68.736 lbf/in^2
```

Axial Load [P]:
```
  = Ap * Bp
  = 91.138 * 68.736
  = 6264.474 lbf
```

Area of the Rib and Web [Ar]:
```
  = Rib Area + Web Area
  = 3.7877 + 5.5797
  = 9.367 in^2
```

Compressive Stress [Sc]:
```
  = P/Ar
```

= 6264.5/9.3673
= 668.757 psi

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	33.4385
Web	10.1264	0.5510	0.2755	5.5797	1.5372	12.7153
Totals	...	...	...	9.3673	16.6429	46.1538

Rib dimension [D]:
= Saddle Width - Web Thickness
= 7.4252 - 0.551
= 6.874 in

Distance to Centroid from Datum [ytot]:
= AY / A
= 16.643/9.3673
= 1.777 in

Distance to Centroid [C1]:
= max(ytot, Saddle Width - ytot)
= max(1.7767, 7.4252 - 1.7767)
= 5.649 in

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(46.154/9.3673)
= 2.220 in

Length of Outer Rib, step 1, [Lw]:
= 2 * sin(saddle bearing angle / 2)(radius + shlthk + wpdthk)
= 2 * sin(120/2)(22.126 + 0.63 + 0.63)
= 40.506 in

Length of Outer Rib, step 2, [Bd]:
= Baseplate length - clearance
= 40 - 2
= 38.000 in

Length of Outer Rib, step 3, [Dd]:
= (Lw - Bd)/2
= (40.506 - 38)/2
= 1.253 in

Length of Outer Rib [L]:
= sqrt(Rl^2 + Dd^2)
= sqrt(27.076^2 + 1.2529^2)
= 27.076 in

Intermediate Term [Cc]:
= sqrt(2 * pi^2 * Elastic Modulus / Yield Stress)
= sqrt(2 * pi^2 * 28999900/33270)
= 131.171

Slenderness ratio [KL/r]:
= KL/r
= 1 * 27.076/2.2197
= 12.198

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 34920/( 2 * 40 ) * 20.253 * 27.076/2
  = 9973.475 ft-lb
```

Compressive Allowable, KL/r < Cc(12.198 < 131.17) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.198 )²/(2 * 131.17² ))33270/
    ( 5/3+3*(12.198 )/(8* 131.17 )-( 12.198³)/(8*131.17³)
  = 19469 psi
```

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

```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 668.76/19469 +( 119682 * 5.6485/46.154 )/22180
  = 0.695
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	44.0158
Web	20.2529	0.5510	0.2755	11.1593	3.0744	10.1595
Totals	...	...	...	14.9470	18.1801	54.1753

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 18.18/14.947
  = 1.216 in
```

Distance to Centroid [C1]:

```
  = max( ytot, abs( Saddle Width - ytot ) )
  = max( 1.2163, abs( 7.4252 - 1.2163 ) )
  = 6.209 in
```

Length of Inner Rib [L]:

```
  = Saddle Height - Outside Radius - Bpthk
  = 40 - cos( 23.386/2 )( 1.2598 + 0 + 0 ) - 0
  = 15.354 in
```

Radius of Gyration [r]:

```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 54.175/14.947 )
  = 1.904 in
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 15.354/1.9038
  = 8.065
```

Unit Force [Force,u]:

```
  = Fl / ( 2 * Baseplate Length )
  = 34920/( 2 * 40 )
  = 436.500 lbf/in
```

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

```
  = Unit Force * e * L
  = 436.5 * 20.253 * 15.354
  = 135736.625 in.lbs
```

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

```
  = Bending Moment / Section Modulus
  = 135737/8.7254
  = 15556.454 psi
```

Compressive Allowable, KL/r < Cc(8.065 < 131.17) per AISC E2-1 [Sca]:
$= (1-(Klr)^2/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)$
$= (1-(8.065)^2/(2 * 131.17^2))33270/$
$(5/3+3*(8.065)/(8* 131.17)-(8.065^3)/(8*131.17^3)$
= 19653 psi

AISC Unity Check of Inside Ribs (must be <= 1)
= Sc/Sca + (Mbase,c * C1/I)/Sba
= 820.83/19653 +(135737 * 6.2089/54.175)/22180
= 0.743

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

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-36	
Bolt Allowable Stress	Stba	21754.90	psi
Bolt Corrosion Allowance	Bca	0.0630	in
Distance from Bolts to Edge	Edgedis	4.0000	in
Nominal Bolt Diameter	Bnd	1.7500	in
Thread Series	Series	TEMA	
BasePlate Allowable Stress	S	20000.00	psi
Area Available in a Single Bolt	BltArea	1.6782	in^2
Saddle Load QO (Weight)	QO	25233.6	lbf
Saddle Load QL (Wind/Seismic contribution)	QL	10048.9	lbf
Maximum Transverse Force	Ft	0.0	lbf
Maximum Longitudinal Force	Fl	10048.9	lbf
Saddle Bolted to Steel Foundation		No	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:
= Fl / (Bolt Area * Number of Bolts)
= 10049/(1.6782 * 2)
= 2993.9 psi. Must be less than 13052.9 psi.

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:
= Ft / (Bolt Area * Number of Bolts)
= 0/(1.6782 * 2)
= 0.0 psi. Must be less than 13052.9 psi.

<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 / (BoltShearAllowable * Nbolts)
= 10049/(13053 * 2)
= 0.3849 in^2

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
= B * Ft + Sum of X Moments
= 3.3333 * 0 + 0
= 0.00 ft-lb

Eccentricity (e):
= Rmom / QO
= 0/25234
= 0.00 in < 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, 0.3849, 0 ]
  = 0.3849 in^2
```

ASME VIII Division 2 Horizontal Vessel Analysis, Right Saddle:

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

Note:
Wear Pad Width (9.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

Minimum Wear Plate Width to be considered in analysis [b1]:
```
  = min( b + 1.56*sqrt( Rm * t ), 2a )
  = min( 7.4252 + 1.56*sqrt( 22.441 * 0.63 ), 2 * 58.638 )
  = 13.2908 in
```

Input and Calculated Values:

```
 Vessel Mean Radius                               Rm       22.44  in
 Shell Thickness used in this Case                 t       0.630  in
 Stiffened Vessel Length per 4.15.6                L      217.75  in
 Distance from Saddle to Vessel tangent      a1 or a       58.64  in

 Saddle Width                                b1 or b        7.43  in
 Saddle Bearing Angle                 delta or theta      120.00  degrees

 Inside Depth of Head                       Hi or h2       11.06  in

 Shell Allowable Stress used in Calculation             20000.00  psi
 Head Allowable Stress used in Calculation              20000.00  psi
 Circumferential Efficiency in Plane of Saddle              1.00
 Circumferential Efficiency at Mid-Span                     1.00

 Distance from Saddle Base to Centerline           B       40.00  in
 Coefficient of Friction                          mu        0.00

 Tube Bundle Pull out Force                             23280.00  lbf
 Tube Bundle Pull out Force Impact Factor                  1.500
 Apply Bundle Pull out Force to Fixed Saddle only             No

 Saddle Force Q, + Bundle Pull, Force                    8823.53  lbf

 Pressure used in Analysis                         P       0.000  psig

 Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                             psi |          psi |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan         60.51 |     20000.00 |
 Long. Stress at Bottom of Midspan        -60.51 |    -34200.00 |
 Long. Stress at Bottom of Midspan         60.51 |     20000.00 |
 Long. Stress at Top    of Saddles       1468.86 |     20000.00 |
 Long. Stress at Bottom of Saddles       -814.13 |    -34200.00 |
 Long. Stress at Bottom of Saddles        814.13 |     20000.00 |
 ----------------------------------------------------------------
 Tangential Shear in Shell                315.74 |     16000.00 |
 Circ. Stress at Horn of Saddle          2025.87 |     30000.00 |
 Circ. Compressive Stress in Shell         80.11 |     20000.00 |
 ----------------------------------------------------------------
```

Intermediate Results: Saddle Reaction Q due to Bundle pull out Force:

Saddle Reaction Force due to Bundle Pull out Force [Fwl]:
```
  = Bundle Pull Out Force * Impact Factor * B / Ls
  = 23280 * 1.5 * 40/139
  = 10048.9 lbf
```

Load Combination Results for Tube Bundle Pull Out [Q]:
```
  = Saddle Load + max( Fwl, Fwt, Fsl, Fst )
  = -1225.4 + max( 10049, 0, 0, 0 )
  = 8823.5 lbf
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	9312.06	lbf
Transverse Shear Load Saddle	0.00	lbf
Longitudinal Shear Load Saddle	34920.00	lbf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:
```
  = Baseplate Length
  = 40.000 in
```

The Computed K values from Table 4.15.1:

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

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

Moment per Equation 4.15.1 [M1]:
```
  = -Q*a [1 - (1- a/L + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -8823.5*58.638[1-(1-58.638/217.75+(22.441²-11.063²)/
    (2*58.638*217.75))/(1+(4*11.063)/(3*217.75))]
  = -13007.0 ft-lb
```

Moment per Equation 4.15.4 [M2]:
```
  = Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 8823.5*217.75/4(1+2(22.441²-11.063²)/(217.75²))/(1+(4*11.063)/
    (3*217.75))-4*58.638/217.75
  = -5025.7 ft-lb
```

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:
```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 0 * 22.441/(2*0.63 ) - -60309/(pi*22.441²*0.63 )
  = 60.51 psi
```

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:
```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 0 * 22.441/(2 * 0.63 ) + -60309/(pi * 22.441² * 0.63 )
  = -60.51 psi
```

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma✱3]:
```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 0*22.441/(2*0.63)--156084/(0.1066*pi*22.441²*0.63)
  = 1468.86 psi
```

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma✱4]:
```
  = P * Rm/(2t) + M1/(K1✱ * pi * Rm² * t)
  = 0*22.441/(2*0.63)+-156084/(0.1923*pi*22.441²*0.63)
  = -814.13 psi
```

Maximum Shear Force in the Saddle (4.15.3) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 8823.5( 217.75 - 2 * 58.638 )/(217.75 +( 4 * 11.063/3))
  = 3813.0 lbf
```

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 3813/( 22.441 * 0.63 )
  = 315.74 psi
```

Decay Length (4.15.20) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 22.441 * 0.63 )
  = 2.933 in
```

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:
```
  = -K5 * Q * k / ( t( b + X1 + X2 ) )
  = -0.7603 * 8823.5 * 0.1/( 0.63( 7.4252 + 2.9328 + 2.9328 ) )
  = -80.11 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:
```
  = -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -8823.5/(4 * 0.63(7.4252 + 2.9328 + 2.9328 )) -
     3 * 0.05285 * 8823.5/(2*0.63²)
  = -2025.87 psi
```

Effective reinforcing plate width (4.15.24) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 7.4252 + 1.56 * sqrt( 22.441 * 0.63 ), 2 * 58.638 )
  = 13.29 in
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	40.0000	in
Baseplate Thickness	Bpthk	1.2598	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	0.5510	in
Web Thickness	Webtk	0.5510	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	38000.0	psi
Height of Web at Center	Hw,c	17.0	in
Friction Coefficient	mu	0.000	

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

Inertia of Shell [ShellInertia]:
```
  = (( 1.56 * sqrt( R * t ) + WearPlateWidth )t³ )/12
  = (( 1.56 * sqrt( 22.126 * 0.63 ) + 9 )0.63³ )/12
  = 0.309 in**4
```

Resolved Inertia for the Shell [I,shell]:
```
  = ShellInertia + AShell( C1 - Y )²
  = 0.3089 + 9.3393( 8.0278 - 0.315 )²
  = 555.882 in**4
```

	B in	D in	Y in	A in^2	AY in^3	I + AD^2 in**4
Shell	14.8243	0.6300	0.3150	9.3393	2.9419	555.8818
Wearplate	9.0000	0.6300	0.9450	5.6700	5.3582	284.6299
Web	0.5510	15.3542	8.9371	8.4601	75.6091	173.2018
BasePlate	9.0000	1.2598	17.2441	11.3386	195.5232	964.5957
Totals	...	...	...	34.8080	279.4323	1978.3096

Distance to Centroid [C1]:
```
  = AY / A
  = 279.43/34.808
  = 8.028 in
```

Angle [beta]:
```
  = 180 - Saddle Angle/2
  = 180 - 120/2
  = 120.0
```

Saddle Splitting Coefficient [K1]:
```
  = ( 1 + cos(beta) - 0.5*sin(beta)² )/(pi - beta + sin(beta)cos(beta) )
  = ( 1 + cos(120 ) - 0.5*sin(120 )² )/(pi - 2.0944 + sin(120 )cos(120 ) )
  = 0.2035
```

Saddle Splitting Force [Fh]:
```
  = K1 * Q
  = 0.2035 * 8823.5
  = 1795.7792 lbf
```

```
 Tension Stress, St = ( Fh/As )       =         70.5092  psi
 Allowed Stress, Sa = 0.6 * Yield Str =      22800.0000  psi
```

Saddle Splitting Dimension [d]:
```
  = B - R * sin(theta/2)/(theta/2 in radians)
  = 40 - 22.126 * sin(120/2)/1.0472
  = 21.702 in
```

```
 Bending Moment, M  = Fh * d          =       3247.6602  ft-lb

 Bending Stress, Sb = ( M * C1 / I  ) =        158.1447  psi
 Allowed Stress, Sa = 2/3 * Yield Str =      25333.3340  psi
```

Minimum Thickness of Baseplate per Moss:
```
  = sqrt( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))
  = sqrt( 3(8823.5 + 488.53 )9/( 2 * 40 * 25333 ))
  = 0.352 in
```

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 - 120/2 )( 22.126 + 0.63 + 0.63 )
  = 40.506 in
```

Distance between Ribs [e]:
```
  = Web Length / ( Nribs - 1 )
  = 40.506/( 3 - 1 )
  = 20.253 in
```

Baseplate Pressure Area [Ap]:
```
  = e * Bpwid / 2
  = 20.253 * 9/2
  = 91.138 in^2
```

Bearing Pressure [Bp]:
```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 8823.5/( 40 * 9 )
  = 24.510 lbf/in^2
```

Axial Load [P]:
```
  = Ap * Bp
  = 91.138 * 24.51
```

= 2233.770 lbf

Area of the Rib and Web [Ar]:
= Rib Area + Web Area
= 3.7877 + 5.5797
= 9.367 in^2

Compressive Stress [Sc]:
= P/Ar
= 2233.8/9.3673
= 238.464 psi

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	33.4385
Web	10.1264	0.5510	0.2755	5.5797	1.5372	12.7153
Totals	...	...	...	9.3673	16.6429	46.1538

Rib dimension [D]:
= Saddle Width - Web Thickness
= 7.4252 - 0.551
= 6.874 in

Distance to Centroid from Datum [ytot]:
= AY / A
= 16.643/9.3673
= 1.777 in

Distance to Centroid [C1]:
= max(ytot, Saddle Width - ytot)
= max(1.7767, 7.4252 - 1.7767)
= 5.649 in

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(46.154/9.3673)
= 2.220 in

Length of Outer Rib, step 1, [Lw]:
= 2 * sin(saddle bearing angle / 2)(radius + shlthk + wpdthk)
= 2 * sin(120/2)(22.126 + 0.63 + 0.63)
= 40.506 in

Length of Outer Rib, step 2, [Bd]:
= Baseplate length - clearance
= 40 - 2
= 38.000 in

Length of Outer Rib, step 3, [Dd]:
= (Lw - Bd)/2
= (40.506 - 38)/2
= 1.253 in

Length of Outer Rib [L]:
= sqrt(Rl^2 + Dd^2)
= sqrt(27.076^2 + 1.2529^2)
= 27.076 in

Intermediate Term [Cc]:
= sqrt(2 * pi² * Elastic Modulus / Yield Stress)

```
  = sqrt( 2 * pi² * 28999900/38000 )
  = 122.736
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 27.076/2.2197
  = 12.198
```

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 34920/( 2 * 40 ) * 20.253 * 27.076/2
  = 9973.475 ft-lb
```

Compressive Allowable, KL/r < Cc(12.198 < 122.74) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.198 )²/(2 * 122.74² ))38000/
    ( 5/3+3*(12.198 )/(8* 122.74 )-( 12.198³)/(8*122.74³)
  = 22193 psi
```

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

```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 238.46/22193 +( 119682 * 5.6485/46.154 )/25333
  = 0.589
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	44.0158
Web	20.2529	0.5510	0.2755	11.1593	3.0744	10.1595
Totals	...	...	...	14.9470	18.1801	54.1753

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 18.18/14.947
  = 1.216 in
```

Distance to Centroid [C1]:

```
  = max( ytot, abs( Saddle Width - ytot ) )
  = max( 1.2163, abs( 7.4252 - 1.2163 ) )
  = 6.209 in
```

Length of Inner Rib [L]:

```
  = Saddle Height - Outside Radius - Bpthk
  = 40 - cos( 23.386/2 )( 1.2598 + 0 + 0 ) - 0
  = 15.354 in
```

Radius of Gyration [r]:

```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 54.175/14.947 )
  = 1.904 in
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 15.354/1.9038
  = 8.065
```

Unit Force [Force,u]:

```
  = Fl / ( 2 * Baseplate Length )
  = 34920/( 2 * 40 )
  = 436.500 lbf/in
```

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

```
= Unit Force * e * L
= 436.5 * 20.253 * 15.354
= 135736.625 in.lbs
```

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

```
= Bending Moment / Section Modulus
= 135737/8.7254
= 15556.454 psi
```

Compressive Allowable, KL/r < Cc(8.065 < 122.74) per AISC E2-1 [Sca]:

```
= ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= ( 1-( 8.065 )²/(2 * 122.74² ))38000/
  ( 5/3+3*(8.065 )/(8* 122.74 )-( 8.065³)/(8*122.74³)
= 22420 psi
```

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

```
= Sc/Sca + ( Mbase,c * C1/I )/Sba
= 292.69/22420 +( 135737 * 6.2089/54.175 )/25333
= 0.627
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-36	
Bolt Allowable Stress	Stba	21754.90	psi
Bolt Corrosion Allowance	Bca	0.0630	in
Distance from Bolts to Edge	Edgedis	4.0000	in
Nominal Bolt Diameter	Bnd	1.7500	in
Thread Series	Series	TEMA	
BasePlate Allowable Stress	S	20000.00	psi
Area Available in a Single Bolt	BltArea	1.6782	in^2
Saddle Load QO (Weight)	QO	9312.1	lbf
Saddle Load QL (Wind/Seismic contribution)	QL	10048.9	lbf
Maximum Transverse Force	Ft	0.0	lbf
Maximum Longitudinal Force	Fl	10048.9	lbf
Saddle Bolted to Steel Foundation		No	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:

```
= Fl / ( Bolt Area * Number of Bolts )
= 10049/( 1.6782 * 2 )
= 2993.9 psi.  Must be less than 13052.9 psi.
```

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:

```
= Ft / ( Bolt Area * Number of Bolts )
= 0/( 1.6782 * 2 )
= 0.0 psi.  Must be less than 13052.9 psi.
```

Bolt Area Calculation per Dennis R. Moss

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

```
= (QL - QO) / (Stba * Rnbolts)
= (10049 - 9312.1 )/(21755 * 2 )
= 0.0169 in^2
```

Bolt Area due to Shear Load [Bltarears]:

```
= Fl / ( BoltShearAllowable * Nbolts )
= 10049/(13053 * 2 )
= 0.3849 in^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
  = B * Ft + Sum of X Moments
  = 3.3333 * 0 + 0
  = 0.00 ft-lb
```

Eccentricity (e):

```
  = Rmom / QO
  = 0/9312.1
  = 0.00 in < 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[0.01694, 0.3849, 0 ]
  = 0.3849 in^2
```

ASME VIII Division 2 Horizontal Vessel Analysis, Left Saddle:

Horizontal Vessel Stress Calculations : Bundle Pull, Corroded Condition

Note:
Wear Pad Width (9.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

Minimum Wear Plate Width to be considered in analysis [b1]:
```
  = min( b + 1.56*sqrt( Rm * t ), 2a )
  = min( 7.4252 + 1.56*sqrt( 22.441 * 0.63 ), 2 * 20.354 )
  = 13.2908 in
```

Input and Calculated Values:

```
 Vessel Mean Radius                              Rm       22.44  in
 Shell Thickness used in this Case                t       0.630  in
 Stiffened Vessel Length per 4.15.6               L      217.75  in
 Distance from Saddle to Vessel tangent     a1 or a       20.35  in

 Saddle Width                               b1 or b        7.43  in
 Saddle Bearing Angle                delta or theta      120.00  degrees

 Shell Allowable Stress used in Calculation         20000.00  psi
 Head Allowable Stress used in Calculation          20000.00  psi
 Circumferential Efficiency in Plane of Saddle          1.00
 Circumferential Efficiency at Mid-Span                 1.00

 Distance from Saddle Base to Centerline       B      40.00  in
 Coefficient of Friction                      mu       0.40

 Tube Bundle Pull out Force                         23280.00  lbf
 Tube Bundle Pull out Force Impact Factor              1.500
 Apply Bundle Pull out Force to Fixed Saddle only         No

 Saddle Force Q, + Bundle Pull, Force               24745.05  lbf

 Pressure used in Analysis                     P       0.000  psig

 Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                             psi |          psi |
 ---------------------------------------------------------------
 Long. Stress at Top    of Midspan       -874.87 |    -34200.00 |
 Long. Stress at Top    of Midspan        874.87 |     20000.00 |
 Long. Stress at Bottom of Midspan        874.87 |     20000.00 |
 Long. Stress at Top    of Saddles        173.77 |     20000.00 |
 Long. Stress at Bottom of Saddles        -96.31 |    -34200.00 |
 Long. Stress at Bottom of Saddles         96.31 |     20000.00 |
 ---------------------------------------------------------------
 Tangential Shear in Shell               1665.97 |     16000.00 |
 Circ. Stress at Horn of Saddle          4991.95 |     30000.00 |
 Circ. Compressive Stress in Shell        224.68 |     20000.00 |
 ---------------------------------------------------------------
```

Intermediate Results: Saddle Reaction Q due to Bundle pull out Force:

Saddle Reaction Force due to Bundle Pull out Force [Fwl]:
```
  = Bundle Pull Out Force * Impact Factor * B / Ls
  = 23280 * 1.5 * 40/139
  = 10048.9 lbf
```

Load Combination Results for Tube Bundle Pull Out [Q]:
```
  = Saddle Load + max( Fwl, Fwt, Fsl, Fst )
```

```
  = 14696 + max( 10049, 0, 0, 0 )
  = 24745.1 lbf
```

Summary of Loads at the base of this Saddle:

```
 Vertical Load (including saddle weight)             25233.58  lbf
 Transverse Shear Load Saddle                            0.00  lbf
 Longitudinal Shear Load Saddle                      34920.00  lbf
```

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:

```
  = Baseplate Length
  = 40.000 in
```

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  = 0.0455     K8  = 0.3405
 K9  = 0.2711     K10 = 0.0581     K1* = 0.1923
```

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

Moment per Equation 4.15.1 [M1]:

```
  = -Q*a [1 - (1- a/L + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -24745*20.354[1-(1-20.354/217.75+(22.441²-0²)/
    (2*20.354*217.75))/(1+(4*0)/(3*217.75))]
  = -1538.8 ft-lb
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 24745*217.75/4(1+2(22.441²-0²)/(217.75²))/(1+(4*0)/
    (3*217.75))-4*20.354/217.75
  = 72666.9 ft-lb
```

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 0 * 22.441/(2*0.63 ) - 872003/(pi*22.441²*0.63 )
  = -874.87 psi
```

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 0 * 22.441/(2 * 0.63 ) + 872003/(pi * 22.441² * 0.63 )
  = 874.87 psi
```

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma✱3]:

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 0*22.441/(2*0.63)--18465/(0.1066*pi*22.441²*0.63)
  = 173.77 psi
```

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma✱4]:

```
  = P * Rm/(2t) + M1/(K1✱ * pi * Rm² * t)
  = 0*22.441/(2*0.63)+-18465/(0.1923*pi*22.441²*0.63)
  = -96.31 psi
```

Maximum Shear Force in the Saddle (4.15.3) [T]:

```
  = Q(L-2a)/(L+(4*h2/3))
  = 24745( 217.75 - 2 * 20.354 )/(217.75 +( 4 * 0/3))
  = 20119.0 lbf
```

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:

```
  = K2 * T / ( Rm * t )
  = 1.1707 * 20119/( 22.441 * 0.63 )
```

```
  = 1665.97 psi
```

Decay Length (4.15.20) [x1,x2]:

```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 22.441 * 0.63 )
  = 2.933 in
```

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:

```
  = -K5 * Q * k / ( t( b + X1 + X2 ) )
  = -0.7603 * 24745 * 0.1/( 0.63( 7.4252 + 2.9328 + 2.9328 ) )
  = -224.68 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:

```
  = -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -24745/(4 * 0.63(7.4252 + 2.9328 + 2.9328 )) -
     3 * 0.04548 * 24745/(2*0.63²)
  = -4991.95 psi
```

Effective reinforcing plate width (4.15.24) [B1]:

```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 7.4252 + 1.56 * sqrt( 22.441 * 0.63 ), 2 * 20.354 )
  = 13.29 in
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	40.0000	in
Baseplate Thickness	Bpthk	1.2598	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	0.5510	in
Web Thickness	Webtk	0.5510	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	33270.0	psi
Height of Web at Center	Hw,c	17.0	in
Friction Coefficient	mu	0.400	

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

Inertia of Shell [ShellInertia]:

```
  = (( 1.56 * sqrt( R * t ) + WearPlateWidth )t^3 )/12
  = (( 1.56 * sqrt( 22.126 * 0.63 ) + 9 )0.63^3 )/12
  = 0.309 in**4
```

Resolved Inertia for the Shell [I,shell]:

```
  = ShellInertia + AShell( C1 - Y )^2
  = 0.3089 + 9.3393( 8.0278 - 0.315 )^2
  = 555.882 in**4
```

	B in	D in	Y in	A in^2	AY in^3	I + AD^2 in**4
Shell	14.8243	0.6300	0.3150	9.3393	2.9419	555.8818
Wearplate	9.0000	0.6300	0.9450	5.6700	5.3582	284.6299
Web	0.5510	15.3542	8.9371	8.4601	75.6091	173.2018
BasePlate	9.0000	1.2598	17.2441	11.3386	195.5232	964.5957
Totals	...	...	...	34.8080	279.4323	1978.3096

Distance to Centroid [C1]:

```
  = AY / A
  = 279.43/34.808
  = 8.028 in
```

Angle [beta]:

```
  = 180 - Saddle Angle/2
  = 180 - 120/2
```

```
  = 120.0
```

Saddle Splitting Coefficient [K1]:

```
  = ( 1 + cos(beta) - 0.5*sin(beta)² )/(pi - beta + sin(beta)cos(beta) )
  = ( 1 + cos(120 ) - 0.5*sin(120 )² )/(pi - 2.0944 + sin(120 )cos(120 ) )
  = 0.2035
```

Saddle Splitting Force [Fh]:

```
  = K1 * Q
  = 0.2035 * 24745
  = 5036.1543 lbf

 Tension Stress, St = ( Fh/As )       =        197.7389  psi
 Allowed Stress, Sa = 0.6 * Yield Str =      19962.0000  psi
```

Saddle Splitting Dimension [d]:

```
  = B - R * sin(theta/2)/(theta/2 in radians)
  = 40 - 22.126 * sin(120/2)/1.0472
  = 21.702 in

 Bending Moment, M  = Fh * d          =       9107.8672  ft-lb

 Bending Stress, Sb = ( M * C1 / I  ) =        443.5073  psi
 Allowed Stress, Sa = 2/3 * Yield Str =      22180.0000  psi
```

Minimum Thickness of Baseplate per Moss:

```
  = sqrt( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))
  = sqrt( 3(24745 + 488.53 )9/( 2 * 40 * 22180 ))
  = 0.620 in
```

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 - 120/2 )( 22.126 + 0.63 + 0.63 )
  = 40.506 in
```

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 40.506/( 3 - 1 )
  = 20.253 in
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 20.253 * 9/2
  = 91.138 in^2
```

Bearing Pressure [Bp]:

```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 24745/( 40 * 9 )
  = 68.736 lbf/in^2
```

Axial Load [P]:

```
  = Ap * Bp
  = 91.138 * 68.736
  = 6264.474 lbf
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 3.7877 + 5.5797
  = 9.367 in^2
```

Compressive Stress [Sc]:

```
  = P/Ar
```

```
  = 6264.5/9.3673
  = 668.757 psi
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	33.4385
Web	10.1264	0.5510	0.2755	5.5797	1.5372	12.7153
Totals	...	...	...	9.3673	16.6429	46.1538

Rib dimension [D]:
```
  = Saddle Width - Web Thickness
  = 7.4252 - 0.551
  = 6.874 in
```

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 16.643/9.3673
  = 1.777 in
```

Distance to Centroid [C1]:
```
  = max( ytot, Saddle Width - ytot )
  = max( 1.7767, 7.4252 - 1.7767 )
  = 5.649 in
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 46.154/9.3673 )
  = 2.220 in
```

Length of Outer Rib, step 1, [Lw]:
```
  = 2 * sin( saddle bearing angle / 2 )( radius + shlthk + wpdthk )
  = 2 * sin( 120/2 )( 22.126 + 0.63 + 0.63 )
  = 40.506 in
```

Length of Outer Rib, step 2, [Bd]:
```
  = Baseplate length - clearance
  = 40 - 2
  = 38.000 in
```

Length of Outer Rib, step 3, [Dd]:
```
  = ( Lw - Bd )/2
  = ( 40.506 - 38 )/2
  = 1.253 in
```

Length of Outer Rib [L]:

$= \text{sqrt}(Rl^2 + Dd^2)$

$= \text{sqrt}(27.076^2 + 1.2529^2)$

= 27.076 in

Intermediate Term [Cc]:
```
  = sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
  = sqrt( 2 * pi² * 28999900/33270 )
  = 131.171
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 27.076/2.2197
  = 12.198
```

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 34920/( 2 * 40 ) * 20.253 * 27.076/2
  = 9973.475 ft-lb
```

Compressive Allowable, KL/r < Cc(12.198 < 131.17) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.198 )²/(2 * 131.17² ))33270/
    ( 5/3+3*(12.198 )/(8* 131.17 )-( 12.198³)/(8*131.17³)
  = 19469 psi
```

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

```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 668.76/19469 +( 119682 * 5.6485/46.154 )/22180
  = 0.695
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	44.0158
Web	20.2529	0.5510	0.2755	11.1593	3.0744	10.1595
Totals	...	...	...	14.9470	18.1801	54.1753

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 18.18/14.947
  = 1.216 in
```

Distance to Centroid [C1]:

```
  = max( ytot, abs( Saddle Width - ytot ) )
  = max( 1.2163, abs( 7.4252 - 1.2163 ) )
  = 6.209 in
```

Length of Inner Rib [L]:

```
  = Saddle Height - Outside Radius - Bpthk
  = 40 - cos( 23.386/2 )( 1.2598 + 0 + 0 ) - 0
  = 15.354 in
```

Radius of Gyration [r]:

```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 54.175/14.947 )
  = 1.904 in
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 15.354/1.9038
  = 8.065
```

Unit Force [Force,u]:

```
  = Fl / ( 2 * Baseplate Length )
  = 34920/( 2 * 40 )
  = 436.500 lbf/in
```

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

```
  = Unit Force * e * L
  = 436.5 * 20.253 * 15.354
  = 135736.625 in.lbs
```

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

```
  = Bending Moment / Section Modulus
  = 135737/8.7254
  = 15556.454 psi
```

Compressive Allowable, KL/r < Cc(8.065 < 131.17) per AISC E2-1 [Sca]:

```
= ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= ( 1-( 8.065 )²/(2 * 131.17² ))33270/
  ( 5/3+3*(8.065 )/(8* 131.17 )-( 8.065³)/(8*131.17³)
= 19653 psi
```

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

```
= Sc/Sca + ( Mbase,c * C1/I )/Sba
= 820.83/19653 +( 135737 * 6.2089/54.175 )/22180
= 0.743
```

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

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-36	
Bolt Allowable Stress	Stba	21754.90	psi
Bolt Corrosion Allowance	Bca	0.0630	in
Distance from Bolts to Edge	Edgedis	4.0000	in
Nominal Bolt Diameter	Bnd	1.7500	in
Thread Series	Series	TEMA	
BasePlate Allowable Stress	S	20000.00	psi
Area Available in a Single Bolt	BltArea	1.6782	in^2
Saddle Load QO (Weight)	QO	25233.6	lbf
Saddle Load QL (Wind/Seismic contribution)	QL	10048.9	lbf
Maximum Transverse Force	Ft	0.0	lbf
Maximum Longitudinal Force	Fl	10048.9	lbf
Saddle Bolted to Steel Foundation		No	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:

```
= Fl / ( Bolt Area * Number of Bolts )
= 10049/( 1.6782 * 2 )
= 2993.9 psi.  Must be less than 13052.9 psi.
```

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:

```
= Ft / ( Bolt Area * Number of Bolts )
= 0/( 1.6782 * 2 )
= 0.0 psi.  Must be less than 13052.9 psi.
```

<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 / ( BoltShearAllowable * Nbolts )
= 10049/(13053 * 2 )
= 0.3849 in^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
= B * Ft + Sum of X Moments
= 3.3333 * 0 + 0
= 0.00 ft-lb
```

Eccentricity (e):

```
= Rmom / QO
= 0/25234
= 0.00 in < 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, 0.3849, 0 ]
  = 0.3849 in^2
```

ASME VIII Division 2 Horizontal Vessel Analysis, Right Saddle:

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

Note:
Wear Pad Width (9.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

Minimum Wear Plate Width to be considered in analysis [b1]:
```
  = min( b + 1.56*sqrt( Rm * t ), 2a )
  = min( 7.4252 + 1.56*sqrt( 22.441 * 0.63 ), 2 * 58.638 )
  = 13.2908 in
```

Input and Calculated Values:

```
 Vessel Mean Radius                                 Rm        22.44  in
 Shell Thickness used in this Case                   t        0.630  in
 Stiffened Vessel Length per 4.15.6                  L       217.75  in
 Distance from Saddle to Vessel tangent         a1 or a       58.64  in

 Saddle Width                                   b1 or b        7.43  in
 Saddle Bearing Angle                    delta or theta      120.00  degrees

 Inside Depth of Head                          Hi or h2       11.06  in

 Shell Allowable Stress used in Calculation                20000.00  psi
 Head Allowable Stress used in Calculation                 20000.00  psi
 Circumferential Efficiency in Plane of Saddle                 1.00
 Circumferential Efficiency at Mid-Span                        1.00

 Distance from Saddle Base to Centerline             B        40.00  in
 Coefficient of Friction                            mu         0.00

 Tube Bundle Pull out Force                                23280.00  lbf
 Tube Bundle Pull out Force Impact Factor                     1.500
 Apply Bundle Pull out Force to Fixed Saddle only                No

 Saddle Force Q, + Bundle Pull, Force                       8823.53  lbf

 Pressure used in Analysis                           P        0.000  psig

 Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                             psi |          psi |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan         60.51 |     20000.00 |
 Long. Stress at Bottom of Midspan        -60.51 |    -34200.00 |
 Long. Stress at Bottom of Midspan         60.51 |     20000.00 |
 Long. Stress at Top    of Saddles       1468.86 |     20000.00 |
 Long. Stress at Bottom of Saddles       -814.13 |    -34200.00 |
 Long. Stress at Bottom of Saddles        814.13 |     20000.00 |
 ----------------------------------------------------------------
 Tangential Shear in Shell                315.74 |     16000.00 |
 Circ. Stress at Horn of Saddle          2025.87 |     30000.00 |
 Circ. Compressive Stress in Shell         80.11 |     20000.00 |
 ----------------------------------------------------------------
```

Intermediate Results: Saddle Reaction Q due to Bundle pull out Force:

Saddle Reaction Force due to Bundle Pull out Force [Fwl]:
```
= Bundle Pull Out Force * Impact Factor * B / Ls
= 23280 * 1.5 * 40/139
= 10048.9 lbf
```

Load Combination Results for Tube Bundle Pull Out [Q]:
```
= Saddle Load + max( Fwl, Fwt, Fsl, Fst )
= -1225.4 + max( 10049, 0, 0, 0 )
= 8823.5 lbf
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	9312.06	lbf
Transverse Shear Load Saddle	0.00	lbf
Longitudinal Shear Load Saddle	34920.00	lbf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:
```
= Baseplate Length
= 40.000 in
```

The Computed K values from Table 4.15.1:

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

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

Moment per Equation 4.15.1 [M1]:
```
= -Q*a [1 - (1- a/L + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
= -8823.5*58.638[1-(1-58.638/217.75+(22.441²-11.063²)/
  (2*58.638*217.75))/(1+(4*11.063)/(3*217.75))]
= -13007.0 ft-lb
```

Moment per Equation 4.15.4 [M2]:
```
= Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
= 8823.5*217.75/4(1+2(22.441²-11.063²)/(217.75²))/(1+(4*11.063)/
  (3*217.75))-4*58.638/217.75
= -5025.7 ft-lb
```

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:
```
= P * Rm/(2t) - M2/(pi*Rm²t)
= 0 * 22.441/(2*0.63 ) - -60309/(pi*22.441²*0.63 )
= 60.51 psi
```

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:
```
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 0 * 22.441/(2 * 0.63 ) + -60309/(pi * 22.441² * 0.63 )
= -60.51 psi
```

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma✱3]:
```
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 0*22.441/(2*0.63)--156084/(0.1066*pi*22.441²*0.63)
= 1468.86 psi
```

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma✱4]:
```
= P * Rm/(2t) + M1/(K1✱ * pi * Rm² * t)
= 0*22.441/(2*0.63)+-156084/(0.1923*pi*22.441²*0.63)
= -814.13 psi
```

Maximum Shear Force in the Saddle (4.15.3) [T]:
= Q(L-2a)/(L+(4*h2/3))
= 8823.5(217.75 - 2 * 58.638)/(217.75 +(4 * 11.063/3))
= 3813.0 lbf

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:
= K2 * T / (Rm * t)
= 1.1707 * 3813/(22.441 * 0.63)
= 315.74 psi

Decay Length (4.15.20) [x1,x2]:
= 0.78 * sqrt(Rm * t)
= 0.78 * sqrt(22.441 * 0.63)
= 2.933 in

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:
= -K5 * Q * k / (t(b + X1 + X2))
= -0.7603 * 8823.5 * 0.1/(0.63(7.4252 + 2.9328 + 2.9328))
= -80.11 psi

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:
= -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
= -8823.5/(4 * 0.63(7.4252 + 2.9328 + 2.9328)) -
3 * 0.05285 * 8823.5/(2*0.63²)
= -2025.87 psi

Effective reinforcing plate width (4.15.24) [B1]:
= min(b + 1.56 * sqrt(Rm * t), 2a)
= min(7.4252 + 1.56 * sqrt(22.441 * 0.63), 2 * 58.638)
= 13.29 in

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	40.0000	in
Baseplate Thickness	Bpthk	1.2598	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	0.5510	in
Web Thickness	Webtk	0.5510	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	38000.0	psi
Height of Web at Center	Hw,c	17.0	in
Friction Coefficient	mu	0.000	

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

Inertia of Shell [ShellInertia]:
= ((1.56 * sqrt(R * t) + WearPlateWidth)t^3)/12
= ((1.56 * sqrt(22.126 * 0.63) + 9)0.63^3)/12
= 0.309 in**4

Resolved Inertia for the Shell [I,shell]:
= ShellInertia + AShell(C1 - Y $)^2$
= 0.3089 + 9.3393(8.0278 - 0.315 $)^2$
= 555.882 in**4

	B in	D in	Y in	A in^2	AY in^3	I + AD^2 in**4
Shell	14.8243	0.6300	0.3150	9.3393	2.9419	555.8818
Wearplate	9.0000	0.6300	0.9450	5.6700	5.3582	284.6299
Web	0.5510	15.3542	8.9371	8.4601	75.6091	173.2018
BasePlate	9.0000	1.2598	17.2441	11.3386	195.5232	964.5957
Totals	...	...	...	34.8080	279.4323	1978.3096

Distance to Centroid [C1]:
```
  = AY / A
  = 279.43/34.808
  = 8.028 in
```

Angle [beta]:
```
  = 180 - Saddle Angle/2
  = 180 - 120/2
  = 120.0
```

Saddle Splitting Coefficient [K1]:
```
  = ( 1 + cos(beta) - 0.5*sin(beta)² )/(pi - beta + sin(beta)cos(beta) )
  = ( 1 + cos(120 ) - 0.5*sin(120 )² )/(pi - 2.0944 + sin(120 )cos(120 ) )
  = 0.2035
```

Saddle Splitting Force [Fh]:
```
  = K1 * Q
  = 0.2035 * 8823.5
  = 1795.7792 lbf

 Tension Stress, St = ( Fh/As )       =         70.5092  psi
 Allowed Stress, Sa = 0.6 * Yield Str =      22800.0000  psi
```

Saddle Splitting Dimension [d]:
```
  = B - R * sin(theta/2)/(theta/2 in radians)
  = 40 - 22.126 * sin(120/2)/1.0472
  = 21.702 in

 Bending Moment, M  = Fh * d          =       3247.6602  ft-lb

 Bending Stress, Sb = ( M * C1 / I  ) =        158.1447  psi
 Allowed Stress, Sa = 2/3 * Yield Str =      25333.3340  psi
```

Minimum Thickness of Baseplate per Moss:
```
  = sqrt( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))
  = sqrt( 3(8823.5 + 488.53 )9/( 2 * 40 * 25333 ))
  = 0.352 in
```

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 - 120/2 )( 22.126 + 0.63 + 0.63 )
  = 40.506 in
```

Distance between Ribs [e]:
```
  = Web Length / ( Nribs - 1 )
  = 40.506/( 3 - 1 )
  = 20.253 in
```

Baseplate Pressure Area [Ap]:
```
  = e * Bpwid / 2
  = 20.253 * 9/2
  = 91.138 in^2
```

Bearing Pressure [Bp]:
```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 8823.5/( 40 * 9 )
  = 24.510 lbf/in^2
```

Axial Load [P]:
```
  = Ap * Bp
  = 91.138 * 24.51
```

= 2233.770 lbf

Area of the Rib and Web [Ar]:
= Rib Area + Web Area
= 3.7877 + 5.5797
= 9.367 in^2

Compressive Stress [Sc]:
= P/Ar
= 2233.8/9.3673
= 238.464 psi

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	33.4385
Web	10.1264	0.5510	0.2755	5.5797	1.5372	12.7153
Totals	...	...	...	9.3673	16.6429	46.1538

Rib dimension [D]:
= Saddle Width - Web Thickness
= 7.4252 - 0.551
= 6.874 in

Distance to Centroid from Datum [ytot]:
= AY / A
= 16.643/9.3673
= 1.777 in

Distance to Centroid [C1]:
= max(ytot, Saddle Width - ytot)
= max(1.7767, 7.4252 - 1.7767)
= 5.649 in

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(46.154/9.3673)
= 2.220 in

Length of Outer Rib, step 1, [Lw]:
= 2 * sin(saddle bearing angle / 2)(radius + shlthk + wpdthk)
= 2 * sin(120/2)(22.126 + 0.63 + 0.63)
= 40.506 in

Length of Outer Rib, step 2, [Bd]:
= Baseplate length - clearance
= 40 - 2
= 38.000 in

Length of Outer Rib, step 3, [Dd]:
= (Lw - Bd)/2
= (40.506 - 38)/2
= 1.253 in

Length of Outer Rib [L]:
= sqrt(Rl^2 + Dd^2)
= sqrt(27.076^2 + 1.2529^2)
= 27.076 in

Intermediate Term [Cc]:
= sqrt(2 * pi^2 * Elastic Modulus / Yield Stress)

```
  = sqrt( 2 * pi² * 28999900/38000 )
  = 122.736
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 27.076/2.2197
  = 12.198
```

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 34920/( 2 * 40 ) * 20.253 * 27.076/2
  = 9973.475 ft-lb
```

Compressive Allowable, KL/r < Cc(12.198 < 122.74) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.198 )²/(2 * 122.74² ))38000/
    ( 5/3+3*(12.198 )/(8* 122.74 )-( 12.198³)/(8*122.74³)
  = 22193 psi
```

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

```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 238.46/22193 +( 119682 * 5.6485/46.154 )/25333
  = 0.589
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	44.0158
Web	20.2529	0.5510	0.2755	11.1593	3.0744	10.1595
Totals	...	...	...	14.9470	18.1801	54.1753

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 18.18/14.947
  = 1.216 in
```

Distance to Centroid [C1]:

```
  = max( ytot, abs( Saddle Width - ytot ) )
  = max( 1.2163, abs( 7.4252 - 1.2163 ) )
  = 6.209 in
```

Length of Inner Rib [L]:

```
  = Saddle Height - Outside Radius - Bpthk
  = 40 - cos( 23.386/2 )( 1.2598 + 0 + 0 ) - 0
  = 15.354 in
```

Radius of Gyration [r]:

```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 54.175/14.947 )
  = 1.904 in
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 15.354/1.9038
  = 8.065
```

Unit Force [Force,u]:

```
  = Fl / ( 2 * Baseplate Length )
  = 34920/( 2 * 40 )
  = 436.500 lbf/in
```

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

```
  = Unit Force * e * L
  = 436.5 * 20.253 * 15.354
  = 135736.625 in.lbs
```

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

```
  = Bending Moment / Section Modulus
  = 135737/8.7254
  = 15556.454 psi
```

Compressive Allowable, KL/r < Cc(8.065 < 122.74) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 8.065 )²/(2 * 122.74² ))38000/
    ( 5/3+3*(8.065 )/(8* 122.74 )-( 8.065³)/(8*122.74³)
  = 22420 psi
```

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

```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 292.69/22420 +( 135737 * 6.2089/54.175 )/25333
  = 0.627
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-36	
Bolt Allowable Stress	Stba	21754.90	psi
Bolt Corrosion Allowance	Bca	0.0630	in
Distance from Bolts to Edge	Edgedis	4.0000	in
Nominal Bolt Diameter	Bnd	1.7500	in
Thread Series	Series	TEMA	
BasePlate Allowable Stress	S	20000.00	psi
Area Available in a Single Bolt	BltArea	1.6782	in^2
Saddle Load QO (Weight)	QO	9312.1	lbf
Saddle Load QL (Wind/Seismic contribution)	QL	10048.9	lbf
Maximum Transverse Force	Ft	0.0	lbf
Maximum Longitudinal Force	Fl	10048.9	lbf
Saddle Bolted to Steel Foundation		No	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:

```
  = Fl / ( Bolt Area * Number of Bolts )
  = 10049/( 1.6782 * 2 )
  = 2993.9 psi.  Must be less than 13052.9 psi.
```

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:

```
  = Ft / ( Bolt Area * Number of Bolts )
  = 0/( 1.6782 * 2 )
  = 0.0 psi.  Must be less than 13052.9 psi.
```

Bolt Area Calculation per Dennis R. Moss

Bolt Area Requirement Due to Longitudinal Load [Bltarearl]:

```
  = (QL - QO) / (Stba * Rnbolts)
  = (10049 - 9312.1 )/(21755 * 2 )
  = 0.0169 in^2
```

Bolt Area due to Shear Load [Bltarears]:

```
  = Fl / ( BoltShearAllowable * Nbolts )
  = 10049/(13053 * 2 )
  = 0.3849 in^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

= B * Ft + Sum of X Moments
= 3.3333 * 0 + 0
= 0.00 ft-lb

Eccentricity (e):
= Rmom / QO
= 0/9312.1
= 0.00 in < 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[0.01694, 0.3849, 0]
= 0.3849 in^2

SHIPPING CALCULATION ONLY FOR BASEPLATE CHECKING

ASME VIII Division 2 Horizontal Vessel Analysis, Left Saddle:

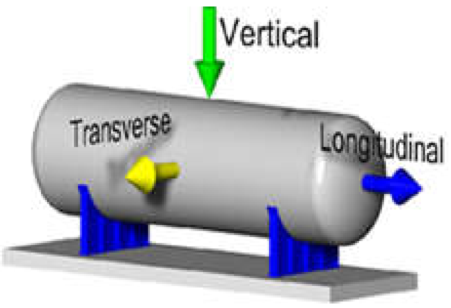
Horizontal Vessel Stress Calculations : Road Transport

Note:
Wear Pad Width (9.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

Minimum Wear Plate Width to be considered in analysis [b1]:
```
  = min( b + 1.56*sqrt( Rm * t ), 2a )
  = min( 7.4252 + 1.56*sqrt( 22.441 * 0.63 ), 2 * 20.354 )
  = 13.2908 in
```

Input and Calculated Values:

```
 Vessel Mean Radius                              Rm       22.44  in
 Shell Thickness used in this Case                t       0.630  in
 Stiffened Vessel Length per 4.15.6               L      217.75  in
 Distance from Saddle to Vessel tangent     a1 or a       20.35  in

 Saddle Width                               b1 or b        7.43  in
 Saddle Bearing Angle                delta or theta      120.00  degrees

 Shell Allowable Stress used in Calculation            20000.00  psi
 Head Allowable Stress used in Calculation             20000.00  psi
 Circumferential Efficiency in Plane of Saddle             1.00
 Circumferential Efficiency at Mid-Span                    1.00

 Distance from Saddle Base to Centerline          B       40.00  in
 Coefficient of Friction                         mu        0.40

 Saddle Force Q for this Transportation Case           74235.16  lbf
 Shipping Longitudinal Acceleration              gx        1.50  g
 Shipping Transverse Acceleration                gz        1.50  g
 Shipping Vertical Acceleration                  gy        2.00  g
 Vertical Acceleration Acting with Transverse    gw        1.00  g
 Internal Pressure during Transport                        5.08  psig
 Transportation Wind Load Scalar Factor        wlsf        1.00
 Transportation Wind Velocity                    wv        89.5  mile/hr
```




```
 Horizontal Vessel Analysis Results:        Actual |      Allowable |
                                               psi |            psi |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan        -2534.20 |      -34200.00 |
 Long. Stress at Top    of Midspan         2534.20 |       20000.00 |
 Long. Stress at Bottom of Midspan         2715.02 |       20000.00 |
 Long. Stress at Top    of Saddles          611.72 |       20000.00 |
 Long. Stress at Bottom of Saddles         -198.53 |      -34200.00 |
 Long. Stress at Bottom of Saddles          198.53 |       20000.00 |
```

```
 ----------------------------------------------------------------
 Tangential Shear in Shell             4997.91 |     16000.00 |
 Circ. Stress at Horn of Saddle       14975.86 |     30000.00 |
 Circ. Compressive Stress in Shell      674.03 |     20000.00 |
 ----------------------------------------------------------------
```

Intermediate Results: Saddle Reaction Q due to Road Transport Load:

Transverse Force due to Wind during Transport [Ft_w]:

```
  = Transverse Area * 0.00256 * wv^2 * wlsf
  = 128.14 * 0.00256 * 89.479^2 * 1
  = 2626.5 lbf
```

Longitudinal Force due to Wind during Transport [Fl_w]:

```
  = pi * D^2/4 * 0.00256 * wv^2 * wlsf * Wind Dia. Mult
  = pi * 4.0427^2/4 * 0.00256 * 89.479^2 * 1 * 1.37
  = 360.4 lbf
```

Transverse Force due to Lateral Acceleration [Ft]:

```
  = gz * saddle Load * gw + Ft_w
  = 1.5 * 24745 * 1 + 2626.5
  = 39744.1 lbf
```

Longitudinal Force due to Axial Acceleration [Fl]:

```
  = gx * saddle Load * gw + Fl_w
  = 1.5 * 24745 * 1 + 360.44
  = 37478.0 lbf
```

Transverse Saddle Reaction Force due to Lateral Acceleration [Fwt]:

```
  = Ft/Num of Saddles * B / E
  = 39744/2 * 40/40
  = 19872.0 lbf
```

Saddle Reaction Force due to Transport Load [Fwl]:

```
  = Fl * B / Ls
  = 37478 * 40/139
  = 10785.0 lbf
```

Saddle Reaction Force due to Vertical Transportation Acceleration [Fsl]:

```
  = Saddle Load * gy
  = 24745 * 2
  = 49490.102 lbf
```

Load Combination Results due to Transport Loading [Q]:

```
  = Saddle Load + max( Fwl, Fwt, Fsl )
  = 24745 + max( 10785, 19872, 49490 )
  = 74235.2 lbf
```

Summary of Loads at the base of this Saddle:

```
 Vertical Load (including saddle weight)          74723.69  lbf
 Transverse Shear Load Saddle                     19872.03  lbf
 Longitudinal Shear Load Saddle                   37478.02  lbf
```

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:

```
  = Baseplate Length
  = 40.000 in
```

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  = 0.0455     K8  = 0.3405
```

```
K9  = 0.2711     K10 = 0.0581     K1* = 0.1923
```

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

Moment per Equation 4.15.1 [M1]:
```
 = -Q*a [1 - (1- a/L + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
 = -74235*20.354[1-(1-20.354/217.75+(22.441²-0²)/
   (2*20.354*217.75))/(1+(4*0)/(3*217.75))]
 = -4616.3 ft-lb
```

Moment per Equation 4.15.4 [M2]:
```
 = Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
 = 74235*217.75/4(1+2(22.441²-0²)/(217.75²))/(1+(4*0)/
   (3*217.75))-4*20.354/217.75
 = 218000.7 ft-lb
```

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:
```
 = P * Rm/(2t) - M2/(pi*Rm²t)
 = 5.0764 * 22.441/(2*0.63 ) - 2616008/(pi*22.441²*0.63 )
 = -2534.20 psi
```

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:
```
 = P * Rm/(2t) + M2/(pi * Rm² * t)
 = 5.0764 * 22.441/(2 * 0.63 ) + 2616008/(pi * 22.441² * 0.63 )
 = 2715.02 psi
```

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma✱3]:
```
 = P * Rm/(2t) - M1/(K1*pi*Rm²t)
 = 5.0764*22.441/(2*0.63)--55395/(0.1066*pi*22.441²*0.63)
 = 611.72 psi
```

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma✱4]:
```
 = P * Rm/(2t) + M1/(K1✱ * pi * Rm² * t)
 = 5.0764*22.441/(2*0.63)+-55395/(0.1923*pi*22.441²*0.63)
 = -198.53 psi
```

Maximum Shear Force in the Saddle (4.15.3) [T]:
```
 = Q(L-2a)/(L+(4*h2/3))
 = 74235( 217.75 - 2 * 20.354 )/(217.75 +( 4 * 0/3))
 = 60356.9 lbf
```

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:
```
 = K2 * T / ( Rm * t )
 = 1.1707 * 60357/( 22.441 * 0.63 )
 = 4997.91 psi
```

Decay Length (4.15.20) [x1,x2]:
```
 = 0.78 * sqrt( Rm * t )
 = 0.78 * sqrt( 22.441 * 0.63 )
 = 2.933 in
```

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:
```
 = -K5 * Q * k / ( t( b + X1 + X2 ) )
 = -0.7603 * 74235 * 0.1/( 0.63( 7.4252 + 2.9328 + 2.9328 ) )
 = -674.03 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:
```
 = -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
 = -74235/(4 * 0.63(7.4252 + 2.9328 + 2.9328 )) -
    3 * 0.04548 * 74235/(2*0.63²)
 = -14975.86 psi
```

Effective reinforcing plate width (4.15.24) [B1]:

```
= min( b + 1.56 * sqrt( Rm * t ), 2a  )
= min( 7.4252 + 1.56 * sqrt( 22.441 * 0.63 ), 2 * 20.354 )
= 13.29 in
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	40.0000	in
Baseplate Thickness	Bpthk	1.2598	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	0.5510	in
Web Thickness	Webtk	0.5510	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	33270.0	psi
Height of Web at Center	Hw,c	17.0	in
Friction Coefficient	mu	0.400	

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

Inertia of Shell [ShellInertia]:

$$= ((1.56 * \mathrm{sqrt}(R * t) + WearPlateWidth)t^3)/12$$
$$= ((1.56 * \mathrm{sqrt}(22.126 * 0.63) + 9)0.63^3)/12$$
$$= 0.309 \text{ in**4}$$

Resolved Inertia for the Shell [I,shell]:

$$= ShellInertia + AShell(C1 - Y)^2$$
$$= 0.3089 + 9.3393(8.0278 - 0.315)^2$$
$$= 555.882 \text{ in**4}$$

	B in	D in	Y in	A in^2	AY in^3	I + AD^2 in**4
Shell	14.8243	0.6300	0.3150	9.3393	2.9419	555.8818
Wearplate	9.0000	0.6300	0.9450	5.6700	5.3582	284.6299
Web	0.5510	15.3542	8.9371	8.4601	75.6091	173.2018
BasePlate	9.0000	1.2598	17.2441	11.3386	195.5232	964.5957
Totals	...	...	...	34.8080	279.4323	1978.3096

Distance to Centroid [C1]:

```
= AY / A
= 279.43/34.808
= 8.028 in
```

Angle [beta]:

```
= 180 - Saddle Angle/2
= 180 - 120/2
= 120.0
```

Saddle Splitting Coefficient [K1]:

$$= (1 + \cos(beta) - 0.5*\sin(beta)^2)/(\pi - beta + \sin(beta)\cos(beta))$$
$$= (1 + \cos(120) - 0.5*\sin(120)^2)/(\pi - 2.0944 + \sin(120)\cos(120))$$
$$= 0.2035$$

Saddle Splitting Force [Fh]:

```
= K1 * Q
= 0.2035 * 74235
= 15108.4639 lbf
```

```
Tension Stress, St = ( Fh/As )       =        593.2167  psi
Allowed Stress, Sa = 0.6 * Yield Str =      19962.0000  psi
```

Saddle Splitting Dimension [d]:

```
= B - R * sin(theta/2)/(theta/2 in radians)
= 40 - 22.126 * sin(120/2)/1.0472
= 21.702 in
```

```
Bending Moment, M  = Fh * d          =      27323.6035  ft-lb

Bending Stress, Sb = ( M * C1 / I  ) =       1330.5222  psi
Allowed Stress, Sa = 2/3 * Yield Str =      22180.0000  psi
```

Minimum Thickness of Baseplate per Moss:

```
  = sqrt( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))
  = sqrt( 3(74235 + 488.53 )9/( 2 * 40 * 22180 ))
  = 1.066 in
```

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 - 120/2 )( 22.126 + 0.63 + 0.63 )
  = 40.506 in
```

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 40.506/( 3 - 1 )
  = 20.253 in
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 20.253 * 9/2
  = 91.138 in^2
```

Bearing Pressure [Bp]:

```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 74235/( 40 * 9 )
  = 206.209 lbf/in^2
```

Axial Load [P]:

```
  = Ap * Bp
  = 91.138 * 206.21
  = 18793.424 lbf
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 3.7877 + 5.5797
  = 9.367 in^2
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 18793/9.3673
  = 2006.270 psi
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	33.4385
Web	10.1264	0.5510	0.2755	5.5797	1.5372	12.7153
Totals	...	...	...	9.3673	16.6429	46.1538

Rib dimension [D]:

```
  = Saddle Width - Web Thickness
  = 7.4252 - 0.551
  = 6.874 in
```

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 16.643/9.3673
  = 1.777 in
```

Distance to Centroid [C1]:
```
  = max( ytot, Saddle Width - ytot )
  = max( 1.7767, 7.4252 - 1.7767 )
  = 5.649 in
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 46.154/9.3673 )
  = 2.220 in
```

Length of Outer Rib, step 1, [Lw]:
```
  = 2 * sin( saddle bearing angle / 2 )( radius + shlthk + wpdthk )
  = 2 * sin( 120/2 )( 22.126 + 0.63 + 0.63 )
  = 40.506 in
```

Length of Outer Rib, step 2, [Bd]:
```
  = Baseplate length - clearance
  = 40 - 2
  = 38.000 in
```

Length of Outer Rib, step 3, [Dd]:
```
  = ( Lw - Bd )/2
  = ( 40.506 - 38 )/2
  = 1.253 in
```

Length of Outer Rib [L]:
  = sqrt(Rl^2 + Dd^2)
  = sqrt(27.076^2 + 1.2529^2)
  = 27.076 in

Intermediate Term [Cc]:
```
  = sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
  = sqrt( 2 * pi² * 28999900/33270 )
  = 131.171
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 27.076/2.2197
  = 12.198
```

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 37478/( 2 * 40 ) * 20.253 * 27.076/2
  = 10704.069 ft-lb
```

Compressive Allowable, KL/r < Cc(12.198 < 131.17) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.198 )²/(2 * 131.17² ))33270/
    ( 5/3+3*(12.198 )/(8* 131.17 )-( 12.198³)/(8*131.17³)
  = 19469 psi
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 2006.3/19469 +( 128449 * 5.6485/46.154 )/22180
  = 0.812
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

B	D	Y	A	AY	Io

Rib	0.5510	6.8742	3.9881	3.7877	15.1057	44.0158
Web	20.2529	0.5510	0.2755	11.1593	3.0744	10.1595
Totals	...	...	...	14.9470	18.1801	54.1753

Distance to Centroid from Datum [ytot]:
= AY / A
= 18.18/14.947
= 1.216 in

Distance to Centroid [C1]:
= max(ytot, abs(Saddle Width - ytot))
= max(1.2163, abs(7.4252 - 1.2163))
= 6.209 in

Length of Inner Rib [L]:
= Saddle Height - Outside Radius - Bpthk
= 40 - cos(23.386/2)(1.2598 + 0 + 0) - 0
= 15.354 in

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(54.175/14.947)
= 1.904 in

Slenderness ratio [KL/r]:
= KL/r
= 1 * 15.354/1.9038
= 8.065

Unit Force [Force,u]:
= Fl / (2 * Baseplate Length)
= 37478/(2 * 40)
= 468.475 lbf/in

Moment at base of inner Rib [Mbase,c]:
= Unit Force * e * L
= 468.48 * 20.253 * 15.354
= 145679.844 in.lbs

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
= Bending Moment / Section Modulus
= 145680/8.7254
= 16696.023 psi

Compressive Allowable, KL/r < Cc(8.065 < 131.17) per AISC E2-1 [Sca]:
= ($1-(Klr)^2/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)$)
= ($1-(8.065)^2/(2 * 131.17^2))33270/$
($5/3+3*(8.065)/(8* 131.17)-(8.065^3)/(8*131.17^3)$)
= 19653 psi

AISC Unity Check of Inside Ribs (must be <= 1)
= Sc/Sca + (Mbase,c * C1/I)/Sba
= 2462.5/19653 +(145680 * 6.2089/54.175)/22180
= 0.878

ASME VIII Division 2 Horizontal Vessel Analysis, Right Saddle:

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

Note:
Wear Pad Width (9.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

Minimum Wear Plate Width to be considered in analysis [b1]:
```
  = min( b + 1.56*sqrt( Rm * t ), 2a )
  = min( 7.4252 + 1.56*sqrt( 22.441 * 0.63 ), 2 * 58.638 )
  = 13.2908 in
```

Input and Calculated Values:

```
 Vessel Mean Radius                            Rm       22.44  in
 Shell Thickness used in this Case              t       0.630  in
 Stiffened Vessel Length per 4.15.6             L      217.75  in
 Distance from Saddle to Vessel tangent   a1 or a       58.64  in

 Saddle Width                             b1 or b        7.43  in
 Saddle Bearing Angle              delta or theta      120.00  degrees

 Inside Depth of Head                    Hi or h2       11.06  in

 Shell Allowable Stress used in Calculation         20000.00  psi
 Head Allowable Stress used in Calculation          20000.00  psi
 Circumferential Efficiency in Plane of Saddle          1.00
 Circumferential Efficiency at Mid-Span                 1.00

 Distance from Saddle Base to Centerline        B       40.00  in
 Coefficient of Friction                       mu        0.00

 Saddle Force Q for this Transportation Case        26470.58  lbf
 Shipping Longitudinal Acceleration            gx        1.50  g
 Shipping Transverse Acceleration              gz        1.50  g
 Shipping Vertical Acceleration                gy        2.00  g
 Vertical Acceleration Acting with Transverse  gw        1.00  g
 Internal Pressure during Transport                      5.08  psig
 Transportation Wind Load Scalar Factor      wlsf        1.00
 Transportation Wind Velocity                  wv        89.5  mile/hr

 Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                             psi |          psi |
 ---------------------------------------------------------------
 Long. Stress at Top    of Midspan        271.93 |     20000.00 |
 Long. Stress at Bottom of Midspan        -91.11 |    -34200.00 |
 Long. Stress at Bottom of Midspan         91.11 |     20000.00 |
 Long. Stress at Top    of Saddles       4496.99 |     20000.00 |
 Long. Stress at Bottom of Saddles      -2351.99 |    -34200.00 |
 Long. Stress at Bottom of Saddles       2351.99 |     20000.00 |
 ---------------------------------------------------------------
 Tangential Shear in Shell                947.22 |     16000.00 |
 Circ. Stress at Horn of Saddle          6077.62 |     30000.00 |
 Circ. Compressive Stress in Shell        240.34 |     20000.00 |
 ---------------------------------------------------------------
```

Intermediate Results: Saddle Reaction Q due to Road Transport Load:

Transverse Force due to Wind during Transport [Ft_w]:
```
  = Transverse Area * 0.00256 * wv^2 * wlsf
  = 128.14 * 0.00256 * 89.479^2 * 1
  = 2626.5 lbf
```

Longitudinal Force due to Wind during Transport [Fl_w]:
```
  = pi * D^2/4 * 0.00256 * wv^2 * wlsf * Wind Dia. Mult
  = pi * 4.0427^2/4 * 0.00256 * 89.479^2 * 1 * 1.37
  = 360.4 lbf
```

Transverse Force due to Lateral Acceleration [Ft]:
```
  = gz * saddle Load * gw + Ft_w
  = 1.5 * 8823.5 * 1 + 2626.5
```

= 15861.8 lbf

Longitudinal Force due to Axial Acceleration [Fl]:
= gx * saddle Load * gw + Fl_w
= 1.5 * 8823.5 * 1 + 360.44
= 13595.7 lbf

Transverse Saddle Reaction Force due to Lateral Acceleration [Fwt]:
= Ft/Num of Saddles * B / E
= 15862/2 * 40/40
= 7930.9 lbf

Saddle Reaction Force due to Transport Load [Fwl]:
= Fl * B / Ls
= 13596 * 40/139
= 3912.4 lbf

Saddle Reaction Force due to Vertical Transportation Acceleration [Fsl]:
= Saddle Load * gy
= 8823.5 * 2
= 17647.055 lbf

Load Combination Results due to Transport Loading [Q]:
= Saddle Load + max(Fwl, Fwt, Fsl)
= 8823.5 + max(3912.4, 7930.9, 17647)
= 26470.6 lbf

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	26959.11	lbf
Transverse Shear Load Saddle	7930.89	lbf
Longitudinal Shear Load Saddle	13595.73	lbf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:
= Baseplate Length
= 40.000 in

The Computed K values from Table 4.15.1:

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

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

Moment per Equation 4.15.1 [M1]:
= -Q*a [1 - (1- a/L + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
= -26471*58.638[1-(1-58.638/217.75+(22.441²-11.063²)/
(2*58.638*217.75))/(1+(4*11.063)/(3*217.75))]
= -39020.9 ft-lb

Moment per Equation 4.15.4 [M2]:
= Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/(3L))-4a/L
= 26471*217.75/4(1+2(22.441²-11.063²)/(217.75²))/(1+(4*11.063)/
(3*217.75))-4*58.638/217.75
= -15077.2 ft-lb

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:
= P * Rm/(2t) - M2/(pi*Rm²t)
= 5.0764 * 22.441/(2*0.63) - -180926/(pi*22.441²*0.63)
= 271.93 psi

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:
```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 5.0764 * 22.441/(2 * 0.63 ) + -180926/(pi * 22.441² * 0.63 )
  = -91.11 psi
```

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma✱3]:
```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 5.0764*22.441/(2*0.63)--468251/(0.1066*pi*22.441²*0.63)
  = 4496.99 psi
```

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma✱4]:
```
  = P * Rm/(2t) + M1/(K1✱ * pi * Rm² * t)
  = 5.0764*22.441/(2*0.63)+-468251/(0.1923*pi*22.441²*0.63)
  = -2351.99 psi
```

Maximum Shear Force in the Saddle (4.15.3) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 26471( 217.75 - 2 * 58.638 )/(217.75 +( 4 * 11.063/3))
  = 11439.0 lbf
```

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 11439/( 22.441 * 0.63 )
  = 947.22 psi
```

Decay Length (4.15.20) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 22.441 * 0.63 )
  = 2.933 in
```

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:
```
  = -K5 * Q * k / ( t( b + X1 + X2 ) )
  = -0.7603 * 26471 * 0.1/( 0.63( 7.4252 + 2.9328 + 2.9328 ) )
  = -240.34 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:
```
  = -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -26471/(4 * 0.63(7.4252 + 2.9328 + 2.9328 )) -
     3 * 0.05285 * 26471/(2*0.63²)
  = -6077.62 psi
```

Effective reinforcing plate width (4.15.24) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 7.4252 + 1.56 * sqrt( 22.441 * 0.63 ), 2 * 58.638 )
  = 13.29 in
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	40.0000	in
Baseplate Thickness	Bpthk	1.2598	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	0.5510	in
Web Thickness	Webtk	0.5510	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	38000.0	psi
Height of Web at Center	Hw,c	17.0	in
Friction Coefficient	mu	0.000	

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

Inertia of Shell [ShellInertia]:
  $= ((1.56 * \text{sqrt}(R * t) + \text{WearPlateWidth})t^3)/12$

= ((1.56 * sqrt(22.126 * 0.63) + 9)0.63^3)/12
= 0.309 in**4

Resolved Inertia for the Shell [I,shell]:
= ShellInertia + AShell(C1 - Y)^2
= 0.3089 + 9.3393(8.0278 - 0.315)^2
= 555.882 in**4

	B in	D in	Y in	A in^2	AY in^3	I + AD^2 in**4
Shell	14.8243	0.6300	0.3150	9.3393	2.9419	555.8818
Wearplate	9.0000	0.6300	0.9450	5.6700	5.3582	284.6299
Web	0.5510	15.3542	8.9371	8.4601	75.6091	173.2018
BasePlate	9.0000	1.2598	17.2441	11.3386	195.5232	964.5957
Totals	...	...	...	34.8080	279.4323	1978.3096

Distance to Centroid [C1]:
= AY / A
= 279.43/34.808
= 8.028 in

Angle [beta]:
= 180 - Saddle Angle/2
= 180 - 120/2
= 120.0

Saddle Splitting Coefficient [K1]:
= (1 + cos(beta) - 0.5*sin(beta)²)/(pi - beta + sin(beta)cos(beta))
= (1 + cos(120) - 0.5*sin(120)²)/(pi - 2.0944 + sin(120)cos(120))
= 0.2035

Saddle Splitting Force [Fh]:
= K1 * Q
= 0.2035 * 26471
= 5387.3374 lbf

```
Tension Stress, St = ( Fh/As )       =      211.5277  psi
Allowed Stress, Sa = 0.6 * Yield Str =    22800.0000  psi
```

Saddle Splitting Dimension [d]:
= B - R * sin(theta/2)/(theta/2 in radians)
= 40 - 22.126 * sin(120/2)/1.0472
= 21.702 in

```
Bending Moment, M  = Fh * d          =     9742.9805  ft-lb

Bending Stress, Sb = ( M * C1 / I  ) =      474.4342  psi
Allowed Stress, Sa = 2/3 * Yield Str =    25333.3340  psi
```

Minimum Thickness of Baseplate per Moss:
= sqrt(3(Q + Saddle_Wt)BasePlateWidth / (2 * BasePlateLength * AllStress))
= sqrt(3(26471 + 488.53)9/(2 * 40 * 25333))
= 0.599 in

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 - 120/2)(22.126 + 0.63 + 0.63)
= 40.506 in

Distance between Ribs [e]:
= Web Length / (Nribs - 1)

```
  = 40.506/( 3 - 1 )
  = 20.253 in
```

Baseplate Pressure Area [Ap]:
```
  = e * Bpwid / 2
  = 20.253 * 9/2
  = 91.138 in^2
```

Bearing Pressure [Bp]:
```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 26471/( 40 * 9 )
  = 73.529 lbf/in^2
```

Axial Load [P]:
```
  = Ap * Bp
  = 91.138 * 73.529
  = 6701.311 lbf
```

Area of the Rib and Web [Ar]:
```
  = Rib Area + Web Area
  = 3.7877 + 5.5797
  = 9.367 in^2
```

Compressive Stress [Sc]:
```
  = P/Ar
  = 6701.3/9.3673
  = 715.391 psi
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	33.4385
Web	10.1264	0.5510	0.2755	5.5797	1.5372	12.7153
Totals	...	...	...	9.3673	16.6429	46.1538

Rib dimension [D]:
```
  = Saddle Width - Web Thickness
  = 7.4252 - 0.551
  = 6.874 in
```

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 16.643/9.3673
  = 1.777 in
```

Distance to Centroid [C1]:
```
  = max( ytot, Saddle Width - ytot )
  = max( 1.7767, 7.4252 - 1.7767 )
  = 5.649 in
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 46.154/9.3673 )
  = 2.220 in
```

Length of Outer Rib, step 1, [Lw]:
```
  = 2 * sin( saddle bearing angle / 2 )( radius + shlthk + wpdthk )
  = 2 * sin( 120/2 )( 22.126 + 0.63 + 0.63 )
  = 40.506 in
```

Length of Outer Rib, step 2, [Bd]:

```
  = Baseplate length - clearance
  = 40 - 2
  = 38.000 in
```

Length of Outer Rib, step 3, [Dd]:

```
  = ( Lw - Bd )/2
  = ( 40.506 - 38 )/2
  = 1.253 in
```

Length of Outer Rib [L]:

```
  = sqrt( Rl² + Dd² )
  = sqrt( 27.076² + 1.2529² )
  = 27.076 in
```

Intermediate Term [Cc]:

```
  = sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
  = sqrt( 2 * pi² * 28999900/38000 )
  = 122.736
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 27.076/2.2197
  = 12.198
```

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 13596/( 2 * 40 ) * 20.253 * 27.076/2
  = 3883.066 ft-lb
```

Compressive Allowable, KL/r < Cc(12.198 < 122.74) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.198 )²/(2 * 122.74² ))38000/
    ( 5/3+3*(12.198 )/(8* 122.74 )-( 12.198³)/(8*122.74³)
  = 22193 psi
```

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

```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 715.39/22193 +( 46597 * 5.6485/46.154 )/25333
  = 0.257
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	44.0158
Web	20.2529	0.5510	0.2755	11.1593	3.0744	10.1595
Totals	...	...	...	14.9470	18.1801	54.1753

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 18.18/14.947
  = 1.216 in
```

Distance to Centroid [C1]:

```
  = max( ytot, abs( Saddle Width - ytot ) )
  = max( 1.2163, abs( 7.4252 - 1.2163 ) )
  = 6.209 in
```

Length of Inner Rib [L]:

```
  = Saddle Height - Outside Radius - Bpthk
  = 40 - cos( 23.386/2 )( 1.2598 + 0 + 0 ) - 0
  = 15.354 in
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 54.175/14.947 )
  = 1.904 in
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 15.354/1.9038
  = 8.065
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 13596/( 2 * 40 )
  = 169.947 lbf/in
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 169.95 * 20.253 * 15.354
  = 52847.609 in.lbs
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 52848/8.7254
  = 6056.740 psi
```

Compressive Allowable, KL/r < Cc(8.065 < 122.74) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 8.065 )²/(2 * 122.74² ))38000/
    ( 5/3+3*(8.065 )/(8* 122.74 )-( 8.065³)/(8*122.74³)
  = 22420 psi
```

AISC Unity Check of Inside Ribs (must be <= 1)
```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 878.07/22420 +( 52848 * 6.2089/54.175 )/25333
  = 0.278
```

SHIPPING CALCULATION ONLY FOR BASEPLATE CHECKING

ASME VIII Division 2 Horizontal Vessel Analysis, Left Saddle:

Horizontal Vessel Stress Calculations : Ocean Transport

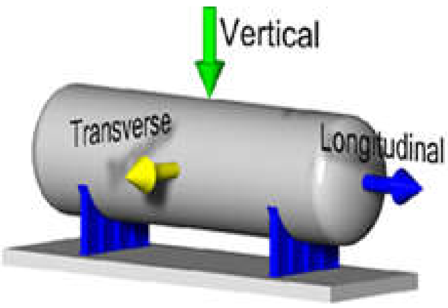
Note:
Wear Pad Width (9.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

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

```
  = min( b + 1.56*sqrt( Rm * t ), 2a )
  = min( 7.4252 + 1.56*sqrt( 22.441 * 0.63 ), 2 * 20.354 )
  = 13.2908 in
```

Input and Calculated Values:

```
 Vessel Mean Radius                              Rm       22.44  in
 Shell Thickness used in this Case                t       0.630  in
 Stiffened Vessel Length per 4.15.6               L      217.75  in
 Distance from Saddle to Vessel tangent     a1 or a       20.35  in

 Saddle Width                               b1 or b        7.43  in
 Saddle Bearing Angle                delta or theta      120.00  degrees

 Shell Allowable Stress used in Calculation            20000.00  psi
 Head Allowable Stress used in Calculation             20000.00  psi
 Circumferential Efficiency in Plane of Saddle             1.00
 Circumferential Efficiency at Mid-Span                    1.00

 Distance from Saddle Base to Centerline          B       40.00  in
 Coefficient of Friction                         mu        0.40

 Saddle Force Q for this Transportation Case           74235.16  lbf
 Shipping Longitudinal Acceleration              gx        1.50  g
 Shipping Transverse Acceleration                gz        1.50  g
 Shipping Vertical Acceleration                  gy        2.00  g
 Vertical Acceleration Acting with Transverse    gw        1.00  g
 Internal Pressure during Transport                        5.08  psig
 Transportation Wind Load Scalar Factor        wlsf        1.00
 Transportation Wind Velocity                    wv        89.5  mile/hr
```



Horizontal Vessel Analysis Results:	Actual psi	Allowable psi
Long. Stress at Top of Midspan	-2534.20	-34200.00
Long. Stress at Top of Midspan	2534.20	20000.00
Long. Stress at Bottom of Midspan	2715.02	20000.00
Long. Stress at Top of Saddles	611.72	20000.00
Long. Stress at Bottom of Saddles	-198.53	-34200.00
Long. Stress at Bottom of Saddles	198.53	20000.00

Tangential Shear in Shell	4997.91	16000.00
Circ. Stress at Horn of Saddle	14975.86	30000.00
Circ. Compressive Stress in Shell	674.03	20000.00

Intermediate Results: Saddle Reaction Q due to Ocean Transport Load:

Transverse Force due to Wind during Transport [Ft_w]:

```
= Transverse Area * 0.00256 * wv^2 * wlsf
= 128.14 * 0.00256 * 89.479^2 * 1
= 2626.5 lbf
```

Longitudinal Force due to Wind during Transport [Fl_w]:

```
= pi * D^2/4 * 0.00256 * wv^2 * wlsf * Wind Dia. Mult
= pi * 4.0427^2/4 * 0.00256 * 89.479^2 * 1 * 1.37
= 360.4 lbf
```

Transverse Force due to Axial Acceleration [Ft]:

```
= gx * saddle Load * gw + Ft_w
= 1.5 * 24745 * 1 + 2626.5
= 39744.1 lbf
```

Longitudinal Force due to Axial Acceleration [Fl]:

```
= gz * saddle Load * gw + Fl_w
= 1.5 * 24745 * 1 + 360.44
= 37478.0 lbf
```

Transverse Saddle Reaction Force due to Lateral Acceleration [Fwt]:

```
= Ft/Num of Saddles * B / E
= 39744/2 * 40/40
= 19872.0 lbf
```

Saddle Reaction Force due to Transport Load [Fwl]:

```
= Fl * B / Ls
= 37478 * 40/139
= 10785.0 lbf
```

Saddle Reaction Force due to Vertical Transportation Acceleration [Fsl]:

```
= Saddle Load * gy
= 24745 * 2
= 49490.102 lbf
```

Load Combination Results due to Transport Loading [Q]:

```
= Saddle Load + max( Fwl, Fwt, Fsl )
= 24745 + max( 10785, 19872, 49490 )
= 74235.2 lbf
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	74723.69	lbf
Transverse Shear Load Saddle	19872.03	lbf
Longitudinal Shear Load Saddle	37478.02	lbf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:

```
= Baseplate Length
= 40.000 in
```

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 = 0.0455	K8 = 0.3405

K9 = 0.2711 K10 = 0.0581 K1* = 0.1923

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

Moment per Equation 4.15.1 [M1]:
= -Q*a [1 - (1- a/L + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
= -74235*20.354[1-(1-20.354/217.75+(22.441²-0²)/
(2*20.354*217.75))/(1+(4*0)/(3*217.75))]
= -4616.3 ft-lb

Moment per Equation 4.15.4 [M2]:
= Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/(3L))-4a/L
= 74235*217.75/4(1+2(22.441²-0²)/(217.75²))/(1+(4*0)/
(3*217.75))-4*20.354/217.75
= 218000.7 ft-lb

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:
= P * Rm/(2t) - M2/(pi*Rm²t)
= 5.0764 * 22.441/(2*0.63) - 2616008/(pi*22.441²*0.63)
= -2534.20 psi

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 5.0764 * 22.441/(2 * 0.63) + 2616008/(pi * 22.441² * 0.63)
= 2715.02 psi

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma*3]:
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 5.0764*22.441/(2*0.63)--55395/(0.1066*pi*22.441²*0.63)
= 611.72 psi

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma*4]:
= P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
= 5.0764*22.441/(2*0.63)+-55395/(0.1923*pi*22.441²*0.63)
= -198.53 psi

Maximum Shear Force in the Saddle (4.15.3) [T]:
= Q(L-2a)/(L+(4*h2/3))
= 74235(217.75 - 2 * 20.354)/(217.75 +(4 * 0/3))
= 60356.9 lbf

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:
= K2 * T / (Rm * t)
= 1.1707 * 60357/(22.441 * 0.63)
= 4997.91 psi

Decay Length (4.15.20) [x1,x2]:
= 0.78 * sqrt(Rm * t)
= 0.78 * sqrt(22.441 * 0.63)
= 2.933 in

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:
= -K5 * Q * k / (t(b + X1 + X2))
= -0.7603 * 74235 * 0.1/(0.63(7.4252 + 2.9328 + 2.9328))
= -674.03 psi

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:
= -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
= -74235/(4 * 0.63(7.4252 + 2.9328 + 2.9328)) -
3 * 0.04548 * 74235/(2*0.63²)
= -14975.86 psi

Effective reinforcing plate width (4.15.24) [B1]:

```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 7.4252 + 1.56 * sqrt( 22.441 * 0.63 ), 2 * 20.354 )
  = 13.29 in
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	40.0000	in
Baseplate Thickness	Bpthk	1.2598	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	0.5510	in
Web Thickness	Webtk	0.5510	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	33270.0	psi
Height of Web at Center	Hw,c	17.0	in
Friction Coefficient	mu	0.400	

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

Inertia of Shell [ShellInertia]:

$$= ((1.56 * sqrt(R * t) + WearPlateWidth)t^3)/12$$
$$= ((1.56 * sqrt(22.126 * 0.63) + 9)0.63^3)/12$$
$$= 0.309 \text{ in**4}$$

Resolved Inertia for the Shell [I,shell]:

$$= ShellInertia + AShell(C1 - Y)^2$$
$$= 0.3089 + 9.3393(8.0278 - 0.315)^2$$
$$= 555.882 \text{ in**4}$$

	B in	D in	Y in	A in^2	AY in^3	I + AD^2 in**4
Shell	14.8243	0.6300	0.3150	9.3393	2.9419	555.8818
Wearplate	9.0000	0.6300	0.9450	5.6700	5.3582	284.6299
Web	0.5510	15.3542	8.9371	8.4601	75.6091	173.2018
BasePlate	9.0000	1.2598	17.2441	11.3386	195.5232	964.5957
Totals	...	...	...	34.8080	279.4323	1978.3096

Distance to Centroid [C1]:

```
  = AY / A
  = 279.43/34.808
  = 8.028 in
```

Angle [beta]:

```
  = 180 - Saddle Angle/2
  = 180 - 120/2
  = 120.0
```

Saddle Splitting Coefficient [K1]:

$$= (1 + cos(beta) - 0.5*sin(beta)^2)/(pi - beta + sin(beta)cos(beta))$$
$$= (1 + cos(120) - 0.5*sin(120)^2)/(pi - 2.0944 + sin(120)cos(120))$$
$$= 0.2035$$

Saddle Splitting Force [Fh]:

```
  = K1 * Q
  = 0.2035 * 74235
  = 15108.4639 lbf
```

```
 Tension Stress, St = ( Fh/As )       =        593.2167  psi
 Allowed Stress, Sa = 0.6 * Yield Str =      19962.0000  psi
```

Saddle Splitting Dimension [d]:

```
  = B - R * sin(theta/2)/(theta/2 in radians)
  = 40 - 22.126 * sin(120/2)/1.0472
  = 21.702 in
```

```
Bending Moment, M  = Fh * d          =      27323.6035  ft-lb

Bending Stress, Sb = ( M * C1 / I  ) =       1330.5222  psi
Allowed Stress, Sa = 2/3 * Yield Str =      22180.0000  psi
```

Minimum Thickness of Baseplate per Moss:

```
  = sqrt( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))
  = sqrt( 3(74235 + 488.53 )9/( 2 * 40 * 22180 ))
  = 1.066 in
```

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 - 120/2 )( 22.126 + 0.63 + 0.63 )
  = 40.506 in
```

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 40.506/( 3 - 1 )
  = 20.253 in
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 20.253 * 9/2
  = 91.138 in^2
```

Bearing Pressure [Bp]:

```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 74235/( 40 * 9 )
  = 206.209 lbf/in^2
```

Axial Load [P]:

```
  = Ap * Bp
  = 91.138 * 206.21
  = 18793.424 lbf
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 3.7877 + 5.5797
  = 9.367 in^2
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 18793/9.3673
  = 2006.270 psi
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	33.4385
Web	10.1264	0.5510	0.2755	5.5797	1.5372	12.7153
Totals	...	...	...	9.3673	16.6429	46.1538

Rib dimension [D]:

```
  = Saddle Width - Web Thickness
  = 7.4252 - 0.551
  = 6.874 in
```

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 16.643/9.3673
  = 1.777 in
```

Distance to Centroid [C1]:
```
  = max( ytot, Saddle Width - ytot )
  = max( 1.7767, 7.4252 - 1.7767 )
  = 5.649 in
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 46.154/9.3673 )
  = 2.220 in
```

Length of Outer Rib, step 1, [Lw]:
```
  = 2 * sin( saddle bearing angle / 2 )( radius + shlthk + wpdthk )
  = 2 * sin( 120/2 )( 22.126 + 0.63 + 0.63 )
  = 40.506 in
```

Length of Outer Rib, step 2, [Bd]:
```
  = Baseplate length - clearance
  = 40 - 2
  = 38.000 in
```

Length of Outer Rib, step 3, [Dd]:
```
  = ( Lw - Bd )/2
  = ( 40.506 - 38 )/2
  = 1.253 in
```

Length of Outer Rib [L]:
  = sqrt(Rl^2 + Dd^2)
  = sqrt(27.076^2 + 1.2529^2)
  = 27.076 in

Intermediate Term [Cc]:
  = sqrt(2 * pi^2 * Elastic Modulus / Yield Stress)
  = sqrt(2 * pi^2 * 28999900/33270)
  = 131.171

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 27.076/2.2197
  = 12.198
```

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 37478/( 2 * 40 ) * 20.253 * 27.076/2
  = 10704.069 ft-lb
```

Compressive Allowable, KL/r < Cc(12.198 < 131.17) per AISC E2-1 [Sca]:
  = (1-$(Klr)^2$/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)
  = (1-(12.198 $)^2$/(2 * 131.17^2))33270/
    (5/3+3*(12.198)/(8* 131.17)-(12.198^3)/(8*131.17^3)
  = 19469 psi

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 2006.3/19469 +( 128449 * 5.6485/46.154 )/22180
  = 0.812
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

B	D	Y	A	AY	Io

Rib	0.5510	6.8742	3.9881	3.7877	15.1057	44.0158
Web	20.2529	0.5510	0.2755	11.1593	3.0744	10.1595
Totals	...	...	...	14.9470	18.1801	54.1753

Distance to Centroid from Datum [ytot]:

```
= AY / A
= 18.18/14.947
= 1.216 in
```

Distance to Centroid [C1]:

```
= max( ytot, abs( Saddle Width - ytot ) )
= max( 1.2163, abs( 7.4252 - 1.2163 ) )
= 6.209 in
```

Length of Inner Rib [L]:

```
= Saddle Height - Outside Radius - Bpthk
= 40 - cos( 23.386/2 )( 1.2598 + 0 + 0 ) - 0
= 15.354 in
```

Radius of Gyration [r]:

```
= sqrt( Total Inertia / Total Area )
= sqrt( 54.175/14.947 )
= 1.904 in
```

Slenderness ratio [KL/r]:

```
= KL/r
= 1 * 15.354/1.9038
= 8.065
```

Unit Force [Force,u]:

```
= Fl / ( 2 * Baseplate Length )
= 37478/( 2 * 40 )
= 468.475 lbf/in
```

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

```
= Unit Force * e * L
= 468.48 * 20.253 * 15.354
= 145679.844 in.lbs
```

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

```
= Bending Moment / Section Modulus
= 145680/8.7254
= 16696.023 psi
```

Compressive Allowable, KL/r < Cc(8.065 < 131.17) per AISC E2-1 [Sca]:

```
= ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= ( 1-( 8.065 )²/(2 * 131.17² ))33270/
  ( 5/3+3*(8.065 )/(8* 131.17 )-( 8.065³)/(8*131.17³)
= 19653 psi
```

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

```
= Sc/Sca + ( Mbase,c * C1/I )/Sba
= 2462.5/19653 +( 145680 * 6.2089/54.175 )/22180
= 0.878
```

ASME VIII Division 2 Horizontal Vessel Analysis, Right Saddle:

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

Note:
Wear Pad Width (9.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

Minimum Wear Plate Width to be considered in analysis [b1]:
```
  = min( b + 1.56*sqrt( Rm * t ), 2a )
  = min( 7.4252 + 1.56*sqrt( 22.441 * 0.63 ), 2 * 58.638 )
  = 13.2908 in
```

Input and Calculated Values:

```
 Vessel Mean Radius                            Rm       22.44  in
 Shell Thickness used in this Case              t       0.630  in
 Stiffened Vessel Length per 4.15.6             L      217.75  in
 Distance from Saddle to Vessel tangent   a1 or a       58.64  in

 Saddle Width                             b1 or b        7.43  in
 Saddle Bearing Angle              delta or theta      120.00  degrees

 Inside Depth of Head                    Hi or h2       11.06  in

 Shell Allowable Stress used in Calculation         20000.00  psi
 Head Allowable Stress used in Calculation          20000.00  psi
 Circumferential Efficiency in Plane of Saddle          1.00
 Circumferential Efficiency at Mid-Span                 1.00

 Distance from Saddle Base to Centerline        B      40.00  in
 Coefficient of Friction                       mu       0.00

 Saddle Force Q for this Transportation Case        26470.58  lbf
 Shipping Longitudinal Acceleration            gx       1.50  g
 Shipping Transverse Acceleration              gz       1.50  g
 Shipping Vertical Acceleration                gy       2.00  g
 Vertical Acceleration Acting with Transverse  gw       1.00  g
 Internal Pressure during Transport                     5.08  psig
 Transportation Wind Load Scalar Factor      wlsf       1.00
 Transportation Wind Velocity                  wv       89.5  mile/hr

 Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                             psi |          psi |
 ---------------------------------------------------------------
 Long. Stress at Top    of Midspan        271.93 |     20000.00 |
 Long. Stress at Bottom of Midspan        -91.11 |    -34200.00 |
 Long. Stress at Bottom of Midspan         91.11 |     20000.00 |
 Long. Stress at Top    of Saddles       4496.99 |     20000.00 |
 Long. Stress at Bottom of Saddles      -2351.99 |    -34200.00 |
 Long. Stress at Bottom of Saddles       2351.99 |     20000.00 |
 ---------------------------------------------------------------
 Tangential Shear in Shell                947.22 |     16000.00 |
 Circ. Stress at Horn of Saddle          6077.62 |     30000.00 |
 Circ. Compressive Stress in Shell        240.34 |     20000.00 |
 ---------------------------------------------------------------
```

Intermediate Results: Saddle Reaction Q due to Ocean Transport Load:

Transverse Force due to Wind during Transport [Ft_w]:
```
  = Transverse Area * 0.00256 * wv^2 * wlsf
  = 128.14 * 0.00256 * 89.479^2 * 1
  = 2626.5 lbf
```

Longitudinal Force due to Wind during Transport [Fl_w]:
```
  = pi * D^2/4 * 0.00256 * wv^2 * wlsf * Wind Dia. Mult
  = pi * 4.0427^2/4 * 0.00256 * 89.479^2 * 1 * 1.37
  = 360.4 lbf
```

Transverse Force due to Axial Acceleration [Ft]:
```
  = gx * saddle Load * gw + Ft_w
  = 1.5 * 8823.5 * 1 + 2626.5
```

```
  = 15861.8 lbf
```

Longitudinal Force due to Axial Acceleration [Fl]:

```
  = gz * saddle Load * gw + Fl_w
  = 1.5 * 8823.5 * 1 + 360.44
  = 13595.7 lbf
```

Transverse Saddle Reaction Force due to Lateral Acceleration [Fwt]:

```
  = Ft/Num of Saddles * B / E
  = 15862/2 * 40/40
  = 7930.9 lbf
```

Saddle Reaction Force due to Transport Load [Fwl]:

```
  = Fl * B / Ls
  = 13596 * 40/139
  = 3912.4 lbf
```

Saddle Reaction Force due to Vertical Transportation Acceleration [Fsl]:

```
  = Saddle Load * gy
  = 8823.5 * 2
  = 17647.055 lbf
```

Load Combination Results due to Transport Loading [Q]:

```
  = Saddle Load + max( Fwl, Fwt, Fsl )
  = 8823.5 + max( 3912.4, 7930.9, 17647 )
  = 26470.6 lbf
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	26959.11	lbf
Transverse Shear Load Saddle	7930.89	lbf
Longitudinal Shear Load Saddle	13595.73	lbf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:

```
  = Baseplate Length
  = 40.000 in
```

The Computed K values from Table 4.15.1:

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

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

Moment per Equation 4.15.1 [M1]:

```
  = -Q*a [1 - (1- a/L + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -26471*58.638[1-(1-58.638/217.75+(22.441²-11.063²)/
    (2*58.638*217.75))/(1+(4*11.063)/(3*217.75))]
  = -39020.9 ft-lb
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 26471*217.75/4(1+2(22.441²-11.063²)/(217.75²))/(1+(4*11.063)/
    (3*217.75))-4*58.638/217.75
  = -15077.2 ft-lb
```

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 5.0764 * 22.441/(2*0.63 ) - -180926/(pi*22.441²*0.63 )
  = 271.93 psi
```

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:
```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 5.0764 * 22.441/(2 * 0.63 ) + -180926/(pi * 22.441² * 0.63 )
  = -91.11 psi
```

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma✱3]:
```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 5.0764*22.441/(2*0.63)--468251/(0.1066*pi*22.441²*0.63)
  = 4496.99 psi
```

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma✱4]:
```
  = P * Rm/(2t) + M1/(K1✱ * pi * Rm² * t)
  = 5.0764*22.441/(2*0.63)+-468251/(0.1923*pi*22.441²*0.63)
  = -2351.99 psi
```

Maximum Shear Force in the Saddle (4.15.3) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 26471( 217.75 - 2 * 58.638 )/(217.75 +( 4 * 11.063/3))
  = 11439.0 lbf
```

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 11439/( 22.441 * 0.63 )
  = 947.22 psi
```

Decay Length (4.15.20) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 22.441 * 0.63 )
  = 2.933 in
```

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:
```
  = -K5 * Q * k / ( t( b + X1 + X2 ) )
  = -0.7603 * 26471 * 0.1/( 0.63( 7.4252 + 2.9328 + 2.9328 ) )
  = -240.34 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:
```
  = -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -26471/(4 * 0.63(7.4252 + 2.9328 + 2.9328 )) -
     3 * 0.05285 * 26471/(2*0.63²)
  = -6077.62 psi
```

Effective reinforcing plate width (4.15.24) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 7.4252 + 1.56 * sqrt( 22.441 * 0.63 ), 2 * 58.638 )
  = 13.29 in
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	40.0000	in
Baseplate Thickness	Bpthk	1.2598	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	0.5510	in
Web Thickness	Webtk	0.5510	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	38000.0	psi
Height of Web at Center	Hw,c	17.0	in
Friction Coefficient	mu	0.000	

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

Inertia of Shell [ShellInertia]:
  = ((1.56 * sqrt(R * t) + WearPlateWidth)t^3)/12

= ((1.56 * sqrt(22.126 * 0.63) + 9)0.63^3)/12
= 0.309 in**4

Resolved Inertia for the Shell [I,shell]:
= ShellInertia + AShell(C1 - Y $)^2$
= 0.3089 + 9.3393(8.0278 - 0.315 $)^2$
= 555.882 in**4

	B in	D in	Y in	A in^2	AY in^3	I + AD^2 in**4
Shell	14.8243	0.6300	0.3150	9.3393	2.9419	555.8818
Wearplate	9.0000	0.6300	0.9450	5.6700	5.3582	284.6299
Web	0.5510	15.3542	8.9371	8.4601	75.6091	173.2018
BasePlate	9.0000	1.2598	17.2441	11.3386	195.5232	964.5957
Totals	...	...	...	34.8080	279.4323	1978.3096

Distance to Centroid [C1]:
= AY / A
= 279.43/34.808
= 8.028 in

Angle [beta]:
= 180 - Saddle Angle/2
= 180 - 120/2
= 120.0

Saddle Splitting Coefficient [K1]:
= (1 + cos(beta) - 0.5*sin(beta)²)/(pi - beta + sin(beta)cos(beta))
= (1 + cos(120) - 0.5*sin(120)²)/(pi - 2.0944 + sin(120)cos(120))
= 0.2035

Saddle Splitting Force [Fh]:
= K1 * Q
= 0.2035 * 26471
= 5387.3374 lbf

Tension Stress, St = (Fh/As) = 211.5277 psi
Allowed Stress, Sa = 0.6 * Yield Str = 22800.0000 psi

Saddle Splitting Dimension [d]:
= B - R * sin(theta/2)/(theta/2 in radians)
= 40 - 22.126 * sin(120/2)/1.0472
= 21.702 in

Bending Moment, M = Fh * d = 9742.9805 ft-lb

Bending Stress, Sb = (M * C1 / I) = 474.4342 psi
Allowed Stress, Sa = 2/3 * Yield Str = 25333.3340 psi

Minimum Thickness of Baseplate per Moss:
= sqrt(3(Q + Saddle_Wt)BasePlateWidth / (2 * BasePlateLength * AllStress))
= sqrt(3(26471 + 488.53)9/(2 * 40 * 25333))
= 0.599 in

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 - 120/2)(22.126 + 0.63 + 0.63)
= 40.506 in

Distance between Ribs [e]:
= Web Length / (Nribs - 1)

= 40.506/(3 - 1)
= 20.253 in

Baseplate Pressure Area [Ap]:
= e * Bpwid / 2
= 20.253 * 9/2
= 91.138 in^2

Bearing Pressure [Bp]:
= Q / (BasePlateLength * BasePlateWidth)
= 26471/(40 * 9)
= 73.529 lbf/in^2

Axial Load [P]:
= Ap * Bp
= 91.138 * 73.529
= 6701.311 lbf

Area of the Rib and Web [Ar]:
= Rib Area + Web Area
= 3.7877 + 5.5797
= 9.367 in^2

Compressive Stress [Sc]:
= P/Ar
= 6701.3/9.3673
= 715.391 psi

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	33.4385
Web	10.1264	0.5510	0.2755	5.5797	1.5372	12.7153
Totals	...	...	...	9.3673	16.6429	46.1538

Rib dimension [D]:
= Saddle Width - Web Thickness
= 7.4252 - 0.551
= 6.874 in

Distance to Centroid from Datum [ytot]:
= AY / A
= 16.643/9.3673
= 1.777 in

Distance to Centroid [C1]:
= max(ytot, Saddle Width - ytot)
= max(1.7767, 7.4252 - 1.7767)
= 5.649 in

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(46.154/9.3673)
= 2.220 in

Length of Outer Rib, step 1, [Lw]:
= 2 * sin(saddle bearing angle / 2)(radius + shlthk + wpdthk)
= 2 * sin(120/2)(22.126 + 0.63 + 0.63)
= 40.506 in

Length of Outer Rib, step 2, [Bd]:

```
  = Baseplate length - clearance
  = 40 - 2
  = 38.000 in
```

Length of Outer Rib, step 3, [Dd]:
```
  = ( Lw - Bd )/2
  = ( 40.506 - 38 )/2
  = 1.253 in
```

Length of Outer Rib [L]:
```
  = sqrt( Rl² + Dd² )
  = sqrt( 27.076² + 1.2529² )
  = 27.076 in
```

Intermediate Term [Cc]:
```
  = sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
  = sqrt( 2 * pi² * 28999900/38000 )
  = 122.736
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 27.076/2.2197
  = 12.198
```

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 13596/( 2 * 40 ) * 20.253 * 27.076/2
  = 3883.066 ft-lb
```

Compressive Allowable, KL/r < Cc(12.198 < 122.74) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.198 )²/(2 * 122.74² ))38000/
    ( 5/3+3*(12.198 )/(8* 122.74 )-( 12.198³)/(8*122.74³)
  = 22193 psi
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 715.39/22193 +( 46597 * 5.6485/46.154 )/25333
  = 0.257
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	44.0158
Web	20.2529	0.5510	0.2755	11.1593	3.0744	10.1595
Totals	...	...	...	14.9470	18.1801	54.1753

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 18.18/14.947
  = 1.216 in
```

Distance to Centroid [C1]:
```
  = max( ytot, abs( Saddle Width - ytot ) )
  = max( 1.2163, abs( 7.4252 - 1.2163 ) )
  = 6.209 in
```

Length of Inner Rib [L]:
```
  = Saddle Height - Outside Radius - Bpthk
  = 40 - cos( 23.386/2 )( 1.2598 + 0 + 0 ) - 0
  = 15.354 in
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 54.175/14.947 )
  = 1.904 in
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 15.354/1.9038
  = 8.065
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 13596/( 2 * 40 )
  = 169.947 lbf/in
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 169.95 * 20.253 * 15.354
  = 52847.609 in.lbs
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 52848/8.7254
  = 6056.740 psi
```

Compressive Allowable, KL/r < Cc(8.065 < 122.74) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 8.065 )²/(2 * 122.74² ))38000/
    ( 5/3+3*(8.065 )/(8* 122.74 )-( 8.065³)/(8*122.74³)
  = 22420 psi
```

AISC Unity Check of Inside Ribs (must be <= 1)
```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 878.07/22420 +( 52848 * 6.2089/54.175 )/25333
  = 0.278
```

ASME VIII Division 2 Horizontal Vessel Analysis, Left Saddle:

Horizontal Vessel Stress Calculations : Operating Case

Note:
Wear Pad Width (9.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

Minimum Wear Plate Width to be considered in analysis [b1]:
```
  = min( b + 1.56*sqrt( Rm * t ), 2a )
  = min( 7.4252 + 1.56*sqrt( 22.441 * 0.63 ), 2 * 20.354 )
  = 13.2908 in
```

Input and Calculated Values:

```
 Vessel Mean Radius                              Rm       22.44  in
 Shell Thickness used in this Case                t       0.630  in
 Stiffened Vessel Length per 4.15.6               L      217.75  in
 Distance from Saddle to Vessel tangent     a1 or a       20.35  in

 Saddle Width                               b1 or b        7.43  in
 Saddle Bearing Angle                delta or theta      120.00  degrees

 Shell Allowable Stress used in Calculation          20000.00  psi
 Head Allowable Stress used in Calculation           20000.00  psi
 Circumferential Efficiency in Plane of Saddle           1.00
 Circumferential Efficiency at Mid-Span                  1.00

 Distance from Saddle Base to Centerline         B       40.00  in
 Coefficient of Friction                        mu        0.40

 Saddle Force Q, Operating Case                      72561.55  lbf

 Pressure used in Analysis                       P      150.777  psig

 Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                             psi |          psi |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan        119.94 |     20000.00 |
 Long. Stress at Bottom of Midspan       5250.82 |     20000.00 |
 Long. Stress at Top    of Saddles       3194.94 |     20000.00 |
 Long. Stress at Bottom of Saddles       2402.95 |     20000.00 |
 ----------------------------------------------------------------
 Tangential Shear in Shell               4885.23 |     16000.00 |
 Circ. Stress at Horn of Saddle         14638.23 |     25000.00 |
 Circ. Compressive Stress in Shell        658.83 |     20000.00 |
 ----------------------------------------------------------------
```

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( 1224.1/2 + 0 ) * 40/40
  = 1836.1 lbf
```

Saddle Reaction Force due to Wind Fl [Fwl]:
```
  = max( Fl, Sum of X Forces) * B / Ls
  = max( 462.44, 0 ) * 40/139
  = 133.1 lbf
```

Saddle Reaction Force due to Earthquake Fl [Fsl]:
```
  = max( Fl, Sum of X Forces ) * B / Ls
  = max( 26443, 0 ) * 40/139
```

```
  = 7609.5 lbf
```

Saddle Reaction Force due to Earthquake Ft [Fst]:

```
  = Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3( 26443/2 + 0 ) * 40/40
  = 39664.6 lbf
```

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

```
  = Saddle Load + max( Fwl, Fwt, Fsl, Fst )
  = 32897 + max( 133.08, 1836.1, 7609.5, 39665 )
  = 72561.5 lbf
```

Longitudinal Wind Force [Fl]:

  = WindScalar * WindPress(Platform Area + (pi/4(OD * WindDiaMult)^2))
  = 0.6 * 31.992(0 + pi/4(4.0427 * 1.37)^2)
  = 462.443 lbf

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	73050.08	lbf
Transverse Shear Load Saddle	13221.54	lbf
Longitudinal Shear Load Saddle	26443.08	lbf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:

```
  = Baseplate Length
  = 40.000 in
```

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 = 0.0455	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	

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

Moment per Equation 4.15.1 [M1]:

```
  = -Q*a [1 - (1- a/L + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -72562*20.354[1-(1-20.354/217.75+(22.441²-0²)/
    (2*20.354*217.75))/(1+(4*0)/(3*217.75))]
  = -4512.2 ft-lb
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 72562*217.75/4(1+2(22.441²-0²)/(217.75²))/(1+(4*0)/
    (3*217.75))-4*20.354/217.75
  = 213086.0 ft-lb
```

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 150.78 * 22.441/(2*0.63 ) - 2557031/(pi*22.441²*0.63 )
  = 119.94 psi
```

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 150.78 * 22.441/(2 * 0.63 ) + 2557031/(pi * 22.441² * 0.63 )
  = 5250.82 psi
```

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma✱3]:

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 150.78*22.441/(2*0.63)--54146/(0.1066*pi*22.441²*0.63)
  = 3194.94 psi
```

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma✱4]:
```
  = P * Rm/(2t) + M1/(K1✱ * pi * Rm² * t)
  = 150.78*22.441/(2*0.63)+-54146/(0.1923*pi*22.441²*0.63)
  = 2402.95 psi
```

Maximum Shear Force in the Saddle (4.15.3) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 72562( 217.75 - 2 * 20.354 )/(217.75 +( 4 * 0/3))
  = 58996.2 lbf
```

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 58996/( 22.441 * 0.63 )
  = 4885.23 psi
```

Decay Length (4.15.20) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 22.441 * 0.63 )
  = 2.933 in
```

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:
```
  = -K5 * Q * k / ( t( b + X1 + X2 ) )
  = -0.7603 * 72562 * 0.1/( 0.63( 7.4252 + 2.9328 + 2.9328 ) )
  = -658.83 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:
```
  = -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -72562/(4 * 0.63(7.4252 + 2.9328 + 2.9328 )) -
     3 * 0.04548 * 72562/(2*0.63²)
  = -14638.23 psi
```

Effective reinforcing plate width (4.15.24) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 7.4252 + 1.56 * sqrt( 22.441 * 0.63 ), 2 * 20.354 )
  = 13.29 in
```

Distance between Saddle Supports [Ls]:
```
  = 139.0 in
```

Free Un-Restrained Thermal Expansion between the Saddles [Exp]:
```
  = Alpha * Ls( Design Temperature - Ambient Temperature )
  = 0.69600E-05 * 139( 330 - 70 )
  = 0.252 in
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	40.0000	in
Baseplate Thickness	Bpthk	1.2598	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	0.5510	in
Web Thickness	Webtk	0.5510	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	33270.0	psi
Height of Web at Center	Hw,c	17.0	in
Friction Coefficient	mu	0.400	

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

Inertia of Shell [ShellInertia]:
```
  = (( 1.56 * sqrt( R * t ) + WearPlateWidth )t^3 )/12
  = (( 1.56 * sqrt( 22.126 * 0.63 ) + 9 )0.63^3 )/12
  = 0.309 in**4
```

Resolved Inertia for the Shell [I,shell]:

= ShellInertia + AShell(C1 - Y)^2
= 0.3089 + 9.3393(8.0278 - 0.315)^2
= 555.882 in**4

	B	D	Y	A	AY	I + AD^2
	in	in	in	in^2	in^3	in**4
Shell	14.8243	0.6300	0.3150	9.3393	2.9419	555.8818
Wearplate	9.0000	0.6300	0.9450	5.6700	5.3582	284.6299
Web	0.5510	15.3542	8.9371	8.4601	75.6091	173.2018
BasePlate	9.0000	1.2598	17.2441	11.3386	195.5232	964.5957
Totals	...	...	...	34.8080	279.4323	1978.3096

Distance to Centroid [C1]:
= AY / A
= 279.43/34.808
= 8.028 in

Angle [beta]:
= 180 - Saddle Angle/2
= 180 - 120/2
= 120.0

Saddle Splitting Coefficient [K1]:
= (1 + cos(beta) - 0.5*sin(beta)^2)/(pi - beta + sin(beta)cos(beta))
= (1 + cos(120) - 0.5*sin(120)^2)/(pi - 2.0944 + sin(120)cos(120))
= 0.2035

Saddle Splitting Force [Fh]:
= K1 * Q
= 0.2035 * 72562
= 14767.8486 lbf

```
Tension Stress, St = ( Fh/As )       =       579.8428  psi
Allowed Stress, Sa = 0.6 * Yield Str =     19962.0000  psi
```

Saddle Splitting Dimension [d]:
= B - R * sin(theta/2)/(theta/2 in radians)
= 40 - 22.126 * sin(120/2)/1.0472
= 21.702 in

```
Bending Moment, M  = Fh * d          =     26707.6016  ft-lb

Bending Stress, Sb = ( M * C1 / I  ) =      1300.5260  psi
Allowed Stress, Sa = 2/3 * Yield Str =     22180.0000  psi
```

Minimum Thickness of Baseplate per Moss:
= sqrt(3(Q + Saddle_Wt)BasePlateWidth / (2 * BasePlateLength * AllStress))
= sqrt(3(72562 + 488.53)9/(2 * 40 * 22180))
= 1.054 in

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 - 120/2)(22.126 + 0.63 + 0.63)
= 40.506 in

Distance between Ribs [e]:
= Web Length / (Nribs - 1)
= 40.506/(3 - 1)
= 20.253 in

Baseplate Pressure Area [Ap]:

```
= e * Bpwid / 2
= 20.253 * 9/2
= 91.138 in^2
```

Bearing Pressure [Bp]:
```
= Q / ( BasePlateLength * BasePlateWidth )
= 72562/( 40 * 9 )
= 201.560 lbf/in^2
```

Axial Load [P]:
```
= Ap * Bp
= 91.138 * 201.56
= 18369.730 lbf
```

Area of the Rib and Web [Ar]:
```
= Rib Area + Web Area
= 3.7877 + 5.5797
= 9.367 in^2
```

Compressive Stress [Sc]:
```
= P/Ar
= 18370/9.3673
= 1961.039 psi
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	33.4385
Web	10.1264	0.5510	0.2755	5.5797	1.5372	12.7153
Totals	...	...	...	9.3673	16.6429	46.1538

Rib dimension [D]:
```
= Saddle Width - Web Thickness
= 7.4252 - 0.551
= 6.874 in
```

Distance to Centroid from Datum [ytot]:
```
= AY / A
= 16.643/9.3673
= 1.777 in
```

Distance to Centroid [C1]:
```
= max( ytot, Saddle Width - ytot )
= max( 1.7767, 7.4252 - 1.7767 )
= 5.649 in
```

Radius of Gyration [r]:
```
= sqrt( Total Inertia / Total Area )
= sqrt( 46.154/9.3673 )
= 2.220 in
```

Length of Outer Rib, step 1, [Lw]:
```
= 2 * sin( saddle bearing angle / 2 )( radius + shlthk + wpdthk )
= 2 * sin( 120/2 )( 22.126 + 0.63 + 0.63 )
= 40.506 in
```

Length of Outer Rib, step 2, [Bd]:
```
= Baseplate length - clearance
= 40 - 2
= 38.000 in
```

Length of Outer Rib, step 3, [Dd]:
= (Lw - Bd)/2
= (40.506 - 38)/2
= 1.253 in

Length of Outer Rib [L]:
= sqrt(Rl^2 + Dd^2)
= sqrt(27.076^2 + 1.2529^2)
= 27.076 in

Intermediate Term [Cc]:
= sqrt(2 * pi² * Elastic Modulus / Yield Stress)
= sqrt(2 * pi² * 28999900/33270)
= 131.171

Slenderness ratio [KL/r]:
= KL/r
= 1 * 27.076/2.2197
= 12.198

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * L / 2
= 26443/(2 * 40) * 20.253 * 27.076/2
= 7552.389 ft-lb

Compressive Allowable, KL/r < Cc(12.198 < 131.17) per AISC E2-1 [Sca]:
= (1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= (1-(12.198)²/(2 * 131.17²))33270/
(5/3+3*(12.198)/(8* 131.17)-(12.198³)/(8*131.17³)
= 19469 psi

AISC Unity Check of Outside Ribs (must be <= 1)
= Sc/Sca + (Rm * C1 / I)/Sba
= 1961/19469 +(90629 * 5.6485/46.154)/22180
= 0.601

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	44.0158
Web	20.2529	0.5510	0.2755	11.1593	3.0744	10.1595
Totals	...	...	...	14.9470	18.1801	54.1753

Distance to Centroid from Datum [ytot]:
= AY / A
= 18.18/14.947
= 1.216 in

Distance to Centroid [C1]:
= max(ytot, abs(Saddle Width - ytot))
= max(1.2163, abs(7.4252 - 1.2163))
= 6.209 in

Length of Inner Rib [L]:
= Saddle Height - Outside Radius - Bpthk
= 40 - cos(23.386/2)(1.2598 + 0 + 0) - 0
= 15.354 in

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(54.175/14.947)
= 1.904 in

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 15.354/1.9038
  = 8.065
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 26443/( 2 * 40 )
  = 330.539 lbf/in
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 330.54 * 20.253 * 15.354
  = 102786.219 in.lbs
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 102786/8.7254
  = 11780.086 psi
```

Compressive Allowable, KL/r < Cc(8.065 < 131.17) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 8.065 )²/(2 * 131.17² ))33270/
    ( 5/3+3*(8.065 )/(8* 131.17 )-( 8.065³)/(8*131.17³)
  = 19653 psi
```

AISC Unity Check of Inside Ribs (must be <= 1)
```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 2407/19653 +( 102786 * 6.2089/54.175 )/22180
  = 0.654
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-36	
Bolt Allowable Stress	Stba	21754.90	psi
Bolt Corrosion Allowance	Bca	0.0630	in
Distance from Bolts to Edge	Edgedis	4.0000	in
Nominal Bolt Diameter	Bnd	1.7500	in
Thread Series	Series	TEMA	
BasePlate Allowable Stress	S	20000.00	psi
Area Available in a Single Bolt	BltArea	1.6782	in^2
Saddle Load QO (Weight)	QO	33385.5	lbf
Saddle Load QL (Wind/Seismic contribution)	QL	7609.5	lbf
Maximum Transverse Force	Ft	13221.5	lbf
Maximum Longitudinal Force	Fl	26443.1	lbf
Saddle Bolted to Steel Foundation		No	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:
```
  = Fl / ( Bolt Area * Number of Bolts )
  = 26443/( 1.6782 * 2 )
  = 7878.3 psi.  Must be less than 13052.9 psi.
```

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:
```
  = Ft / ( Bolt Area * Number of Bolts )
  = 13222/( 1.6782 * 2 )
  = 3939.2 psi.  Must be less than 13052.9 psi.
```

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 / ( BoltShearAllowable * Nbolts )
  = 26443/(13053 * 2 )
  = 1.0129 in^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 3.3333 * 13222 + 0
  = 44071.80 ft-lb
```

Eccentricity (e):
```
  = Rmom / QO
  = 528862/33385
  = 15.84 in > Bplen/6 --> Uplift in Transverse direction

 f = Bplen / 2 - Edgedis
   = 40/2 - 4
   = 16.00 in
```

Modular Ratio Of Steel/Concrete (n1):
```
  = ES / EC
  = 29500000/3122018
  = 9.45

 K1 = 3 (e - 0.5 * Bplen)
    = 3(15.841 - 0.5*40 )
    = -12.48 in

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 9.449 * 1.6782/9 *(16 + 15.841 )
    = 336.61 in ²

 K3 = -K2 * (0.5 * Bplen + f)
    = -336.61 *(0.5 * 40 + 16 )
    = -12118.08 in ³
```

Iteratively Solving for the Effective Bearing Length:
```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + -12.477 * Y² + 336.61 * Y + -12118 = 0
 Y  = 22.08 in

 Num = (Bplen / 2 - Y / 3 - e)
     = (40/2 - 22.083/3 - 15.841 )
     = -3.20

 Denom = (Bplen / 2 - Y / 3 + f)
       = (40/2 - 22.083/3 + 16 )
       = 28.64
```

Total Bolt Tension Force [Tforce]:
```
  = - QO * Num / Denom
  = - 33385 * -3.2021/28.639
  = 3732.80 lbf
```

Bolt Area Required due to Transverse Load [Bltareart]:
```
  = Tforce / (Stba * Nbt)
  = 3732.8/( 21755 * 1 )
  = 0.1716 in^2
```

Required Area of a Single Bolt [Bltarear]:

```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0, 1.0129, 0.1716 ]
  = 1.0129 in^2
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)

```
  = 2(QO + Tforce) / (Y * Bpwid)
  = 2(33385 + 3732.8 )/(22.083 * 9 )
  = 373.52 psig
```

Distance from Baseplate Edge to the Web [ADIST]:

```
  = (Bplen - Weblngth) / 2
  = (40 - 38 )/2
  = 1.0000 in
```

Overturning Moment due To Bolt Tension [Mt]:

```
  = Tforce * Adist
  = 3732.8 * 1
  = 311.07 ft-lb
```

Equivalent Bearing Pressure (f1):

```
  = fc * (Y - Adist) / Y
  = 373.52 *(22.083 - 1 )/22.083
  = 356.61 psig
```

Overturning Moment due to Bearing Pressure [Mc]:

```
  = (Adist² * Bpwid / 6) * (f1 + 2 * fc)
  = (0.08333² * 0.75/6) *(51351 + 2 * 53787 )
  = 137.96 ft-lb
```

Baseplate Required Thickness [Treq]:

```
  = sqrt(6 * max(Mt,Mc) / (Bpwid * Sba))
  = sqrt(6 * max(3732.8,1655.5 )/(9 * 30000 ))
  = 0.2880 in
```

MDMT Calculations for: Fixed Saddle, Saddle to Wearplate Junction, Curve: D

Govrn. thk, tg = 0.63, tr = 0.3125, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.4961, Temp. Reduction = 0 F

```
Min Metal Temp. w/o impact per UCS-66, Curve D            -50 F
```

ASME VIII Division 2 Horizontal Vessel Analysis, Right Saddle:

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

Note:
Wear Pad Width (9.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

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

```
  = min( b + 1.56*sqrt( Rm * t ), 2a )
  = min( 7.4252 + 1.56*sqrt( 22.441 * 0.63 ), 2 * 58.638 )
  = 13.2908 in
```

Input and Calculated Values:

Vessel Mean Radius	Rm	22.44	in
Shell Thickness used in this Case	t	0.630	in
Stiffened Vessel Length per 4.15.6	L	217.75	in

```
 Distance from Saddle to Vessel tangent   a1 or a       58.64  in

 Saddle Width                            b1 or b        7.43  in
 Saddle Bearing Angle             delta or theta      120.00  degrees

 Inside Depth of Head                    Hi or h2      11.06  in

 Shell Allowable Stress used in Calculation         20000.00  psi
 Head Allowable Stress used in Calculation          20000.00  psi
 Circumferential Efficiency in Plane of Saddle          1.00
 Circumferential Efficiency at Mid-Span                 1.00

 Distance from Saddle Base to Centerline       B      40.00  in
 Coefficient of Friction                      mu       0.00

 Saddle Force Q, Operating Case                     54505.98  lbf

 Pressure used in Analysis                     P     150.777  psig

 Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                             psi |          psi |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan       3059.15 |     20000.00 |
 Long. Stress at Bottom of Midspan       2311.61 |     20000.00 |
 Long. Stress at Top    of Saddles      11759.04 |     20000.00 |
 Long. Stress at Bottom of Saddles      -2343.80 |    -29943.00 |
 Long. Stress at Bottom of Saddles       2343.80 |     20000.00 |
 ----------------------------------------------------------------
 Tangential Shear in Shell               1950.42 |     16000.00 |
 Circ. Stress at Horn of Saddle         12514.52 |     25000.00 |
 Circ. Compressive Stress in Shell        494.89 |     20000.00 |
 ----------------------------------------------------------------
```

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( 1224.1/2 + 0 ) * 40/40
  = 1836.1 lbf
```

Saddle Reaction Force due to Wind Fl [Fwl]:
```
  = max( Fl, Sum of X Forces) * B / Ls
  = max( 462.44, 0 ) * 40/139
  = 133.1 lbf
```

Saddle Reaction Force due to Earthquake Fl [Fsl]:
```
  = max( Fl, Sum of X Forces ) * B / Ls
  = max( 26443, 0 ) * 40/139
  = 7609.5 lbf
```

Saddle Reaction Force due to Earthquake Ft [Fst]:
```
  = Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3( 26443/2 + 0 ) * 40/40
  = 39664.6 lbf
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
  = Saddle Load + max( Fwl, Fwt, Fsl, Fst )
  = 14841 + max( 133.08, 1836.1, 7609.5, 39665 )
  = 54506.0 lbf
```

Longitudinal Wind Force [Fl]:
```
  = WindScalar * WindPress( Platform Area + ( pi/4( OD * WindDiaMult )^2 ) )
  = 0.6 * 31.992( 0 + pi/4( 4.0427 * 1.37 )^2 )
  = 462.443 lbf
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	54994.52	lbf
Transverse Shear Load Saddle	13221.54	lbf
Longitudinal Shear Load Saddle	26443.08	lbf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:
= Baseplate Length
= 40.000 in

The Computed K values from Table 4.15.1:

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

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

Moment per Equation 4.15.1 [M1]:
= -Q*a [1 - (1- a/L + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
= -54506*58.638[1-(1-58.638/217.75+(22.441²-11.063²)/
(2*58.638*217.75))/(1+(4*11.063)/(3*217.75))]
= -80348.5 ft-lb

Moment per Equation 4.15.4 [M2]:
= Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/(3L))-4a/L
= 54506*217.75/4(1+2(22.441²-11.063²)/(217.75²))/(1+(4*11.063)/
(3*217.75))-4*58.638/217.75
= -31045.7 ft-lb

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:
= P * Rm/(2t) - M2/(pi*Rm²t)
= 150.78 * 22.441/(2*0.63) - -372548/(pi*22.441²*0.63)
= 3059.15 psi

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 150.78 * 22.441/(2 * 0.63) + -372548/(pi * 22.441² * 0.63)
= 2311.61 psi

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma✱3]:
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 150.78*22.441/(2*0.63)--964182/(0.1066*pi*22.441²*0.63)
= 11759.04 psi

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma✱4]:
= P * Rm/(2t) + M1/(K1✱ * pi * Rm² * t)
= 150.78*22.441/(2*0.63)+-964182/(0.1923*pi*22.441²*0.63)
= -2343.80 psi

Maximum Shear Force in the Saddle (4.15.3) [T]:
= Q(L-2a)/(L+(4*h2/3))
= 54506(217.75 - 2 * 58.638)/(217.75 +(4 * 11.063/3))
= 23554.2 lbf

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:
= K2 * T / (Rm * t)
= 1.1707 * 23554/(22.441 * 0.63)
= 1950.42 psi

Decay Length (4.15.20) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 22.441 * 0.63 )
  = 2.933 in
```

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:
```
  = -K5 * Q * k / ( t( b + X1 + X2 ) )
  = -0.7603 * 54506 * 0.1/( 0.63( 7.4252 + 2.9328 + 2.9328 ) )
  = -494.89 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:
```
  = -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -54506/(4 * 0.63(7.4252 + 2.9328 + 2.9328 )) -
     3 * 0.05285 * 54506/(2*0.63²)
  = -12514.52 psi
```

Effective reinforcing plate width (4.15.24) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 7.4252 + 1.56 * sqrt( 22.441 * 0.63 ), 2 * 58.638 )
  = 13.29 in
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	40.0000	in
Baseplate Thickness	Bpthk	1.2598	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	0.5510	in
Web Thickness	Webtk	0.5510	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	38000.0	psi
Height of Web at Center	Hw,c	17.0	in
Friction Coefficient	mu	0.000	

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

Inertia of Shell [ShellInertia]:
```
  = (( 1.56 * sqrt( R * t ) + WearPlateWidth )t³ )/12
  = (( 1.56 * sqrt( 22.126 * 0.63 ) + 9 )0.63³ )/12
  = 0.309 in**4
```

Resolved Inertia for the Shell [I,shell]:
```
  = ShellInertia + AShell( C1 - Y )²
  = 0.3089 + 9.3393( 8.0278 - 0.315 )²
  = 555.882 in**4
```

	B in	D in	Y in	A in^2	AY in^3	I + AD^2 in**4
Shell	14.8243	0.6300	0.3150	9.3393	2.9419	555.8818
Wearplate	9.0000	0.6300	0.9450	5.6700	5.3582	284.6299
Web	0.5510	15.3542	8.9371	8.4601	75.6091	173.2018
BasePlate	9.0000	1.2598	17.2441	11.3386	195.5232	964.5957
Totals	...	...	...	34.8080	279.4323	1978.3096

Distance to Centroid [C1]:
```
  = AY / A
  = 279.43/34.808
  = 8.028 in
```

Angle [beta]:
```
  = 180 - Saddle Angle/2
  = 180 - 120/2
  = 120.0
```

Saddle Splitting Coefficient [K1]:
```
  = ( 1 + cos(beta) - 0.5*sin(beta)² )/(pi - beta + sin(beta)cos(beta) )
  = ( 1 + cos(120 ) - 0.5*sin(120 )² )/(pi - 2.0944 + sin(120 )cos(120 ) )
  = 0.2035
```

Saddle Splitting Force [Fh]:
```
  = K1 * Q
  = 0.2035 * 54506
  = 11093.1494 lbf

 Tension Stress, St = ( Fh/As )       =        435.5600  psi
 Allowed Stress, Sa = 0.6 * Yield Str =      22800.0000  psi
```

Saddle Splitting Dimension [d]:
```
  = B - R * sin(theta/2)/(theta/2 in radians)
  = 40 - 22.126 * sin(120/2)/1.0472
  = 21.702 in

 Bending Moment, M  = Fh * d          =      20061.9219  ft-lb

 Bending Stress, Sb = ( M * C1 / I  ) =        976.9148  psi
 Allowed Stress, Sa = 2/3 * Yield Str =      25333.3340  psi
```

Minimum Thickness of Baseplate per Moss:
```
  = sqrt( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))
  = sqrt( 3(54506 + 488.53 )9/( 2 * 40 * 25333 ))
  = 0.856 in
```

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 - 120/2 )( 22.126 + 0.63 + 0.63 )
  = 40.506 in
```

Distance between Ribs [e]:
```
  = Web Length / ( Nribs - 1 )
  = 40.506/( 3 - 1 )
  = 20.253 in
```

Baseplate Pressure Area [Ap]:
```
  = e * Bpwid / 2
  = 20.253 * 9/2
  = 91.138 in^2
```

Bearing Pressure [Bp]:
```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 54506/( 40 * 9 )
  = 151.406 lbf/in^2
```

Axial Load [P]:
```
  = Ap * Bp
  = 91.138 * 151.41
  = 13798.773 lbf
```

Area of the Rib and Web [Ar]:
```
  = Rib Area + Web Area
  = 3.7877 + 5.5797
  = 9.367 in^2
```

Compressive Stress [Sc]:
```
  = P/Ar
  = 13799/9.3673
```

= 1473.072 psi

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	33.4385
Web	10.1264	0.5510	0.2755	5.5797	1.5372	12.7153
Totals	...	...	...	9.3673	16.6429	46.1538

Rib dimension [D]:
```
= Saddle Width - Web Thickness
= 7.4252 - 0.551
= 6.874 in
```

Distance to Centroid from Datum [ytot]:
```
= AY / A
= 16.643/9.3673
= 1.777 in
```

Distance to Centroid [C1]:
```
= max( ytot, Saddle Width - ytot )
= max( 1.7767, 7.4252 - 1.7767 )
= 5.649 in
```

Radius of Gyration [r]:
```
= sqrt( Total Inertia / Total Area )
= sqrt( 46.154/9.3673 )
= 2.220 in
```

Length of Outer Rib, step 1, [Lw]:
```
= 2 * sin( saddle bearing angle / 2 )( radius + shlthk + wpdthk )
= 2 * sin( 120/2 )( 22.126 + 0.63 + 0.63 )
= 40.506 in
```

Length of Outer Rib, step 2, [Bd]:
```
= Baseplate length - clearance
= 40 - 2
= 38.000 in
```

Length of Outer Rib, step 3, [Dd]:
```
= ( Lw - Bd )/2
= ( 40.506 - 38 )/2
= 1.253 in
```

Length of Outer Rib [L]:
= sqrt(Rl^2 + Dd^2)
= sqrt(27.076^2 + 1.2529^2)
= 27.076 in

Intermediate Term [Cc]:
```
= sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
= sqrt( 2 * pi² * 28999900/38000 )
= 122.736
```

Slenderness ratio [KL/r]:
```
= KL/r
= 1 * 27.076/2.2197
= 12.198
```

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

```
  = 26443/( 2 * 40 ) * 20.253 * 27.076/2
  = 7552.389 ft-lb
```

Compressive Allowable, KL/r < Cc(12.198 < 122.74) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.198 )²/(2 * 122.74² ))38000/
    ( 5/3+3*(12.198 )/(8* 122.74 )-( 12.198³)/(8*122.74³)
  = 22193 psi
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 1473.1/22193 +( 90629 * 5.6485/46.154 )/25333
  = 0.504
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	44.0158
Web	20.2529	0.5510	0.2755	11.1593	3.0744	10.1595
Totals	...	...	...	14.9470	18.1801	54.1753

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 18.18/14.947
  = 1.216 in
```

Distance to Centroid [C1]:
```
  = max( ytot, abs( Saddle Width - ytot ) )
  = max( 1.2163, abs( 7.4252 - 1.2163 ) )
  = 6.209 in
```

Length of Inner Rib [L]:
```
  = Saddle Height - Outside Radius - Bpthk
  = 40 - cos( 23.386/2 )( 1.2598 + 0 + 0 ) - 0
  = 15.354 in
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 54.175/14.947 )
  = 1.904 in
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 15.354/1.9038
  = 8.065
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 26443/( 2 * 40 )
  = 330.539 lbf/in
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 330.54 * 20.253 * 15.354
  = 102786.219 in.lbs
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 102786/8.7254
  = 11780.086 psi
```

Compressive Allowable, KL/r < Cc(8.065 < 122.74) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 8.065 )²/(2 * 122.74² ))38000/
    ( 5/3+3*(8.065 )/(8* 122.74 )-( 8.065³)/(8*122.74³)
  = 22420 psi
```

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

```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 1808/22420 +( 102786 * 6.2089/54.175 )/25333
  = 0.546
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-36	
Bolt Allowable Stress	Stba	21754.90	psi
Bolt Corrosion Allowance	Bca	0.0630	in
Distance from Bolts to Edge	Edgedis	4.0000	in
Nominal Bolt Diameter	Bnd	1.7500	in
Thread Series	Series	TEMA	
BasePlate Allowable Stress	S	20000.00	psi
Area Available in a Single Bolt	BltArea	1.6782	in^2
Saddle Load QO (Weight)	QO	15329.9	lbf
Saddle Load QL (Wind/Seismic contribution)	QL	7609.5	lbf
Maximum Transverse Force	Ft	13221.5	lbf
Maximum Longitudinal Force	Fl	26443.1	lbf
Saddle Bolted to Steel Foundation		No	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:

```
  = Fl / ( Bolt Area * Number of Bolts )
  = 26443/( 1.6782 * 2 )
  = 7878.3 psi.  Must be less than 13052.9 psi.
```

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:

```
  = Ft / ( Bolt Area * Number of Bolts )
  = 13222/( 1.6782 * 2 )
  = 3939.2 psi.  Must be less than 13052.9 psi.
```

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 / ( BoltShearAllowable * Nbolts )
  = 26443/(13053 * 2 )
  = 1.0129 in^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
  = B * Ft + Sum of X Moments
  = 3.3333 * 13222 + 0
  = 44071.80 ft-lb
```

Eccentricity (e):

```
  = Rmom / QO
  = 528862/15330
  = 34.50 in > Bplen/6 --> Uplift in Transverse direction
```

```
 f = Bplen / 2 - Edgedis
   = 40/2 - 4
   = 16.00 in
```

Modular Ratio Of Steel/Concrete (n1):
```
  = ES / EC
  = 29500000/3122018
  = 9.45

 K1 = 3 (e - 0.5 * Bplen)
    = 3(34.499 - 0.5*40 )
    = 43.50 in

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 9.449 * 1.6782/9 *(16 + 34.499 )
    = 533.86 in ²

 K3 = -K2 * (0.5 * Bplen + f)
    = -533.86 *(0.5 * 40 + 16 )
    = -19218.80 in ³
```

Iteratively Solving for the Effective Bearing Length:
```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + 43.496 * Y² + 533.86 * Y + -19219 = 0
 Y  = 14.20 in

 Num = (Bplen / 2 - Y / 3 - e)
     = (40/2 - 14.202/3 - 34.499 )
     = -19.23

 Denom = (Bplen / 2 - Y / 3 + f)
       = (40/2 - 14.202/3 + 16 )
       = 31.27
```

Total Bolt Tension Force [Tforce]:
```
  = - QO * Num / Denom
  = - 15330 * -19.233/31.266
  = 9429.85 lbf
```

Bolt Area Required due to Transverse Load [Bltareart]:
```
  = Tforce / (Stba * Nbt)
  = 9429.8/( 21755 * 1 )
  = 0.4335 in^2
```

Required Area of a Single Bolt [Bltarear]:
```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0, 1.0129, 0.4335 ]
  = 1.0129 in^2
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)
```
  = 2(QO + Tforce) / (Y * Bpwid)
  = 2(15330 + 9429.8 )/(14.202 * 9 )
  = 387.43 psig
```

Distance from Baseplate Edge to the Web [ADIST]:
```
  = (Bplen - Weblngth) / 2
  = (40 - 38 )/2
  = 1.0000 in
```

Overturning Moment due To Bolt Tension [Mt]:
```
  = Tforce * Adist
  = 9429.8 * 1
  = 785.82 ft-lb
```

Equivalent Bearing Pressure (f1):
```
  = fc * (Y - Adist) / Y
  = 387.43 *(14.202 - 1 )/14.202
  = 360.15 psig
```

Overturning Moment due to Bearing Pressure [Mc]:
```
  = (Adist² * Bpwid / 6) * (f1 + 2 * fc)
  = (0.08333² * 0.75/6) *(51861 + 2 * 55790 )
  = 141.88 ft-lb
```

Baseplate Required Thickness [Treq]:
```
  = sqrt(6 * max(Mt,Mc) / (Bpwid * Sba))
  = sqrt(6 * max(9429.8,1702.5 )/(9 * 30000 ))
  = 0.4578 in
```

MDMT Calculations for: Fixed Saddle, Saddle to Wearplate Junction, Curve: D

Govrn. thk, tg = 0.63, tr = 0.3125, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.4961, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve D             -50 F
```

ASME VIII Division 2 Horizontal Vessel Analysis, Left Saddle:

Horizontal Vessel Stress Calculations : Test Case

Note:
Wear Pad Width (9.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

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

```
  = min( b + 1.56*sqrt( Rm * t ), 2a )
  = min( 7.4252 + 1.56*sqrt( 22.441 * 0.63 ), 2 * 20.354 )
  = 13.2908 in
```

Input and Calculated Values:

```
 Vessel Mean Radius                              Rm       22.44  in
 Shell Thickness used in this Case                t       0.630  in
 Stiffened Vessel Length per 4.15.6               L      217.75  in
 Distance from Saddle to Vessel tangent     a1 or a       20.35  in

 Saddle Width                               b1 or b        7.43  in
 Saddle Bearing Angle                delta or theta      120.00  degrees

 Shell Allowable Stress used in Calculation          34200.00  psi
 Head Allowable Stress used in Calculation           34200.00  psi
 Circumferential Efficiency in Plane of Saddle           1.00
 Circumferential Efficiency at Mid-Span                  1.00

 Distance from Saddle Base to Centerline          B       40.00  in
 Coefficient of Friction                         mu        0.40

 Saddle Force Q, Test Case, no Ext. Forces          33601.30  lbf

 Pressure used in Analysis                        P     364.992  psig

 Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                             psi |          psi |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan       5312.64 |     34200.00 |
 Long. Stress at Bottom of Midspan       7688.61 |     34200.00 |
 Long. Stress at Top    of Saddles       6736.59 |     34200.00 |
 Long. Stress at Bottom of Saddles       6369.84 |     34200.00 |
 ----------------------------------------------------------------
 Tangential Shear in Shell               2262.22 |     20254.00 |
 Circ. Stress at Horn of Saddle          6778.57 |     51300.00 |
 Circ. Compressive Stress in Shell        305.09 |     34200.00 |
 ----------------------------------------------------------------
```

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( 612.04/2 + 0 ) * 40/40
  = 918.1 lbf
```

Saddle Reaction Force due to Wind Fl [Fwl]:

```
  = max( Fl, Sum of X Forces) * B / Ls
  = max( 231.22, 0 ) * 40/139
  = 66.5 lbf
```

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

```
  = Saddle Load + max( Fwl, Fwt, Fsl, Fst )
  = 32683 + max( 66.539, 918.06, 0, 0 )
```

= 33601.3 lbf

Longitudinal Wind Force [Fl]:
= WindScalar * WindPress(Platform Area + (pi/4(OD * WindDiaMult)^2))
= 0.6 * 31.992(0 + pi/4(4.0427 * 1.37)^2)
= 462.443 lbf

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	34089.83	lbf
Transverse Shear Load Saddle	306.02	lbf
Longitudinal Shear Load Saddle	231.22	lbf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:
= Baseplate Length
= 40.000 in

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 = 0.0455	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	

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

Moment per Equation 4.15.1 [M1]:
= -Q*a [1 - (1- a/L + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
= -33601*20.354[1-(1-20.354/217.75+(22.441²-0²)/
(2*20.354*217.75))/(1+(4*0)/(3*217.75))]
= -2089.5 ft-lb

Moment per Equation 4.15.4 [M2]:
= Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/(3L))-4a/L
= 33601*217.75/4(1+2(22.441²-0²)/(217.75²))/(1+(4*0)/
(3*217.75))-4*20.354/217.75
= 98674.4 ft-lb

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:
= P * Rm/(2t) - M2/(pi*Rm²t)
= 364.99 * 22.441/(2*0.63) - 1184092/(pi*22.441²*0.63)
= 5312.64 psi

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 364.99 * 22.441/(2 * 0.63) + 1184092/(pi * 22.441² * 0.63)
= 7688.61 psi

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma✱3]:
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 364.99*22.441/(2*0.63)--25074/(0.1066*pi*22.441²*0.63)
= 6736.59 psi

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma✱4]:
= P * Rm/(2t) + M1/(K1✱ * pi * Rm² * t)
= 364.99*22.441/(2*0.63)+-25074/(0.1923*pi*22.441²*0.63)
= 6369.84 psi

Maximum Shear Force in the Saddle (4.15.3) [T]:
= Q(L-2a)/(L+(4*h2/3))
= 33601(217.75 - 2 * 20.354)/(217.75 +(4 * 0/3))
= 27319.5 lbf

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 27320/( 22.441 * 0.63 )
  = 2262.22 psi
```

Decay Length (4.15.20) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 22.441 * 0.63 )
  = 2.933 in
```

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:
```
  = -K5 * Q * k / ( t( b + X1 + X2 ) )
  = -0.7603 * 33601 * 0.1/( 0.63( 7.4252 + 2.9328 + 2.9328 ) )
  = -305.09 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:
```
  = -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -33601/(4 * 0.63(7.4252 + 2.9328 + 2.9328 )) -
     3 * 0.04548 * 33601/(2*0.63²)
  = -6778.57 psi
```

Effective reinforcing plate width (4.15.24) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 7.4252 + 1.56 * sqrt( 22.441 * 0.63 ), 2 * 20.354 )
  = 13.29 in
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	40.0000	in
Baseplate Thickness	Bpthk	1.2598	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	0.5510	in
Web Thickness	Webtk	0.5510	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	33270.0	psi
Height of Web at Center	Hw,c	17.0	in
Friction Coefficient	mu	0.400	

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

Inertia of Shell [ShellInertia]:

$= ((1.56 * sqrt(R * t) + WearPlateWidth)t^3)/12$

$= ((1.56 * sqrt(22.126 * 0.63) + 9)0.63^3)/12$

$= 0.309$ in**4

Resolved Inertia for the Shell [I,shell]:

$= ShellInertia + AShell(C1 - Y)^2$

$= 0.3089 + 9.3393(8.0278 - 0.315)^2$

$= 555.882$ in**4

	B in	D in	Y in	A in^2	AY in^3	I + AD^2 in**4
Shell	14.8243	0.6300	0.3150	9.3393	2.9419	555.8818
Wearplate	9.0000	0.6300	0.9450	5.6700	5.3582	284.6299
Web	0.5510	15.3542	8.9371	8.4601	75.6091	173.2018
BasePlate	9.0000	1.2598	17.2441	11.3386	195.5232	964.5957
Totals	...	...	...	34.8080	279.4323	1978.3096

Distance to Centroid [C1]:
```
  = AY / A
  = 279.43/34.808
  = 8.028 in
```

Angle [beta]:
 = 180 - Saddle Angle/2
 = 180 - 120/2
 = 120.0

Saddle Splitting Coefficient [K1]:
 = (1 + cos(beta) - 0.5*sin(beta)²)/(pi - beta + sin(beta)cos(beta))
 = (1 + cos(120) - 0.5*sin(120)²)/(pi - 2.0944 + sin(120)cos(120))
 = 0.2035

Saddle Splitting Force [Fh]:
 = K1 * Q
 = 0.2035 * 33601
 = 6838.5933 lbf

```
 Tension Stress, St = ( Fh/As )        =        268.5096  psi
 Allowed Stress, Sa = 0.6 * Yield Str =      19962.0000  psi
```

Saddle Splitting Dimension [d]:
 = B - R * sin(theta/2)/(theta/2 in radians)
 = 40 - 22.126 * sin(120/2)/1.0472
 = 21.702 in

```
 Bending Moment, M  = Fh * d           =      12367.5713  ft-lb

 Bending Stress, Sb = ( M * C1 / I  ) =        602.2386  psi
 Allowed Stress, Sa = 2/3 * Yield Str =      22180.0000  psi
```

Minimum Thickness of Baseplate per Moss:
 = sqrt(3(Q + Saddle_Wt)BasePlateWidth / (2 * BasePlateLength * AllStress))
 = sqrt(3(33601 + 488.53)9/(2 * 40 * 22180))
 = 0.720 in

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 - 120/2)(22.126 + 0.63 + 0.63)
 = 40.506 in

Distance between Ribs [e]:
 = Web Length / (Nribs - 1)
 = 40.506/(3 - 1)
 = 20.253 in

Baseplate Pressure Area [Ap]:
 = e * Bpwid / 2
 = 20.253 * 9/2
 = 91.138 in^2

Bearing Pressure [Bp]:
 = Q / (BasePlateLength * BasePlateWidth)
 = 33601/(40 * 9)
 = 93.337 lbf/in^2

Axial Load [P]:
 = Ap * Bp
 = 91.138 * 93.337
 = 8506.528 lbf

Area of the Rib and Web [Ar]:
 = Rib Area + Web Area
 = 3.7877 + 5.5797

= 9.367 in^2

Compressive Stress [Sc]:
= P/Ar
= 8506.5/9.3673
= 908.104 psi

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	33.4385
Web	10.1264	0.5510	0.2755	5.5797	1.5372	12.7153
Totals	...	...	...	9.3673	16.6429	46.1538

Rib dimension [D]:
= Saddle Width - Web Thickness
= 7.4252 - 0.551
= 6.874 in

Distance to Centroid from Datum [ytot]:
= AY / A
= 16.643/9.3673
= 1.777 in

Distance to Centroid [C1]:
= max(ytot, Saddle Width - ytot)
= max(1.7767, 7.4252 - 1.7767)
= 5.649 in

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(46.154/9.3673)
= 2.220 in

Length of Outer Rib, step 1, [Lw]:
= 2 * sin(saddle bearing angle / 2)(radius + shlthk + wpdthk)
= 2 * sin(120/2)(22.126 + 0.63 + 0.63)
= 40.506 in

Length of Outer Rib, step 2, [Bd]:
= Baseplate length - clearance
= 40 - 2
= 38.000 in

Length of Outer Rib, step 3, [Dd]:
= (Lw - Bd)/2
= (40.506 - 38)/2
= 1.253 in

Length of Outer Rib [L]:
= sqrt(Rl^2 + Dd^2)
= sqrt(27.076^2 + 1.2529^2)
= 27.076 in

Intermediate Term [Cc]:
= sqrt(2 * pi² * Elastic Modulus / Yield Stress)
= sqrt(2 * pi² * 28999900/33270)
= 131.171

Slenderness ratio [KL/r]:
= KL/r

```
  = 1 * 27.076/2.2197
  = 12.198
```

Bending Moment [Rm]:

```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 231.22/( 2 * 40 ) * 20.253 * 27.076/2
  = 66.039 ft-lb
```

Compressive Allowable, KL/r < Cc(12.198 < 131.17) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.198 )²/(2 * 131.17² ))33270/
    ( 5/3+3*(12.198 )/(8* 131.17 )-( 12.198³)/(8*131.17³)
  = 19469 psi
```

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

```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 908.1/19469 +( 792.47 * 5.6485/46.154 )/22180
  = 0.051
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	44.0158
Web	20.2529	0.5510	0.2755	11.1593	3.0744	10.1595
Totals	...	...	...	14.9470	18.1801	54.1753

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 18.18/14.947
  = 1.216 in
```

Distance to Centroid [C1]:

```
  = max( ytot, abs( Saddle Width - ytot ) )
  = max( 1.2163, abs( 7.4252 - 1.2163 ) )
  = 6.209 in
```

Length of Inner Rib [L]:

```
  = Saddle Height - Outside Radius - Bpthk
  = 40 - cos( 23.386/2 )( 1.2598 + 0 + 0 ) - 0
  = 15.354 in
```

Radius of Gyration [r]:

```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 54.175/14.947 )
  = 1.904 in
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 15.354/1.9038
  = 8.065
```

Unit Force [Force,u]:

```
  = Fl / ( 2 * Baseplate Length )
  = 231.22/( 2 * 40 )
  = 2.890 lbf/in
```

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

```
  = Unit Force * e * L
  = 2.8903 * 20.253 * 15.354
  = 898.775 in.lbs
```

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

```
  = Bending Moment / Section Modulus
  = 898.78/8.7254
  = 103.007 psi
```

Compressive Allowable, KL/r < Cc(8.065 < 131.17) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 8.065 )²/(2 * 131.17² ))33270/
    ( 5/3+3*(8.065 )/(8* 131.17 )-( 8.065³)/(8*131.17³)
  = 19653 psi
```

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

```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 1114.6/19653 +( 898.78 * 6.2089/54.175 )/22180
  = 0.061
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-36	
Bolt Allowable Stress	Stba	21754.90	psi
Bolt Corrosion Allowance	Bca	0.0630	in
Distance from Bolts to Edge	Edgedis	4.0000	in
Nominal Bolt Diameter	Bnd	1.7500	in
Thread Series	Series	TEMA	
BasePlate Allowable Stress	S	20000.00	psi
Area Available in a Single Bolt	BltArea	1.6782	in^2
Saddle Load QO (Weight)	QO	33171.8	lbf
Saddle Load QL (Wind/Seismic contribution)	QL	66.5	lbf
Maximum Transverse Force	Ft	306.0	lbf
Maximum Longitudinal Force	Fl	231.2	lbf
Saddle Bolted to Steel Foundation		No	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:

```
  = Fl / ( Bolt Area * Number of Bolts )
  = 231.22/( 1.6782 * 2 )
  = 68.9 psi.  Must be less than 13052.9 psi.
```

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:

```
  = Ft / ( Bolt Area * Number of Bolts )
  = 306.02/( 1.6782 * 2 )
  = 91.2 psi.  Must be less than 13052.9 psi.
```

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 / ( BoltShearAllowable * Nbolts )
  = 231.22/(13053 * 2 )
  = 0.0089 in^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
  = B * Ft + Sum of X Moments
  = 3.3333 * 306.02 + 0
  = 1020.06 ft-lb
```

Eccentricity (e):

```
  = Rmom / QO
  = 12241/33172
```

```
  = 0.37 in < 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, 0.008857, 0 ]
  = 0.0089 in^2
```

ASME VIII Division 2 Horizontal Vessel Analysis, Right Saddle:

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

Note:
Wear Pad Width (9.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

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

```
  = min( b + 1.56*sqrt( Rm * t ), 2a )
  = min( 7.4252 + 1.56*sqrt( 22.441 * 0.63 ), 2 * 58.638 )
  = 13.2908 in
```

Input and Calculated Values:

```
 Vessel Mean Radius                              Rm       22.44  in
 Shell Thickness used in this Case                t       0.630  in
 Stiffened Vessel Length per 4.15.6               L      217.75  in
 Distance from Saddle to Vessel tangent     a1 or a       58.64  in

 Saddle Width                               b1 or b        7.43  in
 Saddle Bearing Angle                delta or theta      120.00  degrees

 Inside Depth of Head                      Hi or h2       11.06  in

 Shell Allowable Stress used in Calculation            34200.00  psi
 Head Allowable Stress used in Calculation             34200.00  psi
 Circumferential Efficiency in Plane of Saddle             1.00
 Circumferential Efficiency at Mid-Span                    1.00

 Distance from Saddle Base to Centerline          B       40.00  in
 Coefficient of Friction                         mu        0.00

 Saddle Force Q, Test Case, no Ext. Forces             15810.55  lbf

 Pressure used in Analysis                        P     364.992  psig

 Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                             psi |          psi |
 ---------------------------------------------------------------
 Long. Stress at Top    of Midspan       6609.05 |     34200.00 |
 Long. Stress at Bottom of Midspan       6392.20 |     34200.00 |
 Long. Stress at Top    of Saddles       9132.62 |     34200.00 |
 Long. Stress at Bottom of Saddles       5041.81 |     34200.00 |
 ---------------------------------------------------------------
 Tangential Shear in Shell                565.76 |     20254.00 |
 Circ. Stress at Horn of Saddle          3630.09 |     51300.00 |
 Circ. Compressive Stress in Shell        143.55 |     34200.00 |
 ---------------------------------------------------------------
```

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( 612.04/2 + 0 ) * 40/40
  = 918.1 lbf
```

Saddle Reaction Force due to Wind Fl [Fwl]:

```
  = max( Fl, Sum of X Forces) * B / Ls
  = max( 231.22, 0 ) * 40/139
  = 66.5 lbf
```

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

```
  = Saddle Load + max( Fwl, Fwt, Fsl, Fst )
  = 14892 + max( 66.539, 918.06, 0, 0 )
  = 15810.5 lbf
```

Longitudinal Wind Force [Fl]:

$$= WindScalar * WindPress(Platform Area + (pi/4(OD * WindDiaMult)^2))$$
$$= 0.6 * 31.992(0 + pi/4(4.0427 * 1.37)^2)$$

```
  = 462.443 lbf
```

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	16299.08	lbf
Transverse Shear Load Saddle	306.02	lbf
Longitudinal Shear Load Saddle	231.22	lbf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:

```
  = Baseplate Length
  = 40.000 in
```

The Computed K values from Table 4.15.1:

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

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

Moment per Equation 4.15.1 [M1]:

```
  = -Q*a [1 - (1- a/L + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -15811*58.638[1-(1-58.638/217.75+(22.441²-11.063²)/
    (2*58.638*217.75))/(1+(4*11.063)/(3*217.75))]
  = -23306.7 ft-lb
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 15811*217.75/4(1+2(22.441²-11.063²)/(217.75²))/(1+(4*11.063)/
    (3*217.75))-4*58.638/217.75
  = -9005.4 ft-lb
```

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 364.99 * 22.441/(2*0.63 ) - -108065/(pi*22.441²*0.63 )
  = 6609.05 psi
```

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 364.99 * 22.441/(2 * 0.63 ) + -108065/(pi * 22.441² * 0.63 )
  = 6392.20 psi
```

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma✱3]:

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 364.99*22.441/(2*0.63)--279680/(0.1066*pi*22.441²*0.63)
```

= 9132.62 psi

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma✱4]:
= P * Rm/(2t) + M1/(K1✱ * pi * Rm² * t)
= 364.99*22.441/(2*0.63)+-279680/(0.1923*pi*22.441²*0.63)
= 5041.81 psi

Maximum Shear Force in the Saddle (4.15.3) [T]:
= Q(L-2a)/(L+(4*h2/3))
= 15811(217.75 - 2 * 58.638)/(217.75 +(4 * 11.063/3))
= 6832.4 lbf

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:
= K2 * T / (Rm * t)
= 1.1707 * 6832.4/(22.441 * 0.63)
= 565.76 psi

Decay Length (4.15.20) [x1,x2]:
= 0.78 * sqrt(Rm * t)
= 0.78 * sqrt(22.441 * 0.63)
= 2.933 in

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:
= -K5 * Q * k / (t(b + X1 + X2))
= -0.7603 * 15811 * 0.1/(0.63(7.4252 + 2.9328 + 2.9328))
= -143.55 psi

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:
= -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
= -15811/(4 * 0.63(7.4252 + 2.9328 + 2.9328)) -
3 * 0.05285 * 15811/(2*0.63²)
= -3630.09 psi

Effective reinforcing plate width (4.15.24) [B1]:
= min(b + 1.56 * sqrt(Rm * t), 2a)
= min(7.4252 + 1.56 * sqrt(22.441 * 0.63), 2 * 58.638)
= 13.29 in

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	40.0000	in
Baseplate Thickness	Bpthk	1.2598	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	0.5510	in
Web Thickness	Webtk	0.5510	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	38000.0	psi
Height of Web at Center	Hw,c	17.0	in
Friction Coefficient	mu	0.000	

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

Inertia of Shell [ShellInertia]:
= ((1.56 * sqrt(R * t) + WearPlateWidth)t^3)/12
= ((1.56 * sqrt(22.126 * 0.63) + 9)0.63^3)/12
= 0.309 in**4

Resolved Inertia for the Shell [I,shell]:
= ShellInertia + AShell(C1 - Y $)^2$
= 0.3089 + 9.3393(8.0278 - 0.315 $)^2$
= 555.882 in**4

B	D	Y	A	AY	I + AD^2

	in	in	in	in^2	in^3	in**4
Shell	14.8243	0.6300	0.3150	9.3393	2.9419	555.8818
Wearplate	9.0000	0.6300	0.9450	5.6700	5.3582	284.6299
Web	0.5510	15.3542	8.9371	8.4601	75.6091	173.2018
BasePlate	9.0000	1.2598	17.2441	11.3386	195.5232	964.5957
Totals	...	...	...	34.8080	279.4323	1978.3096

Distance to Centroid [C1]:
```
  = AY / A
  = 279.43/34.808
  = 8.028 in
```

Angle [beta]:
```
  = 180 - Saddle Angle/2
  = 180 - 120/2
  = 120.0
```

Saddle Splitting Coefficient [K1]:
```
  = ( 1 + cos(beta) - 0.5*sin(beta)² )/(pi - beta + sin(beta)cos(beta) )
  = ( 1 + cos(120 ) - 0.5*sin(120 )² )/(pi - 2.0944 + sin(120 )cos(120 ) )
  = 0.2035
```

Saddle Splitting Force [Fh]:
```
  = K1 * Q
  = 0.2035 * 15811
  = 3217.7896 lbf

 Tension Stress, St = ( Fh/As )       =        126.3429  psi
 Allowed Stress, Sa = 0.6 * Yield Str =      22800.0000  psi
```

Saddle Splitting Dimension [d]:
```
  = B - R * sin(theta/2)/(theta/2 in radians)
  = 40 - 22.126 * sin(120/2)/1.0472
  = 21.702 in

 Bending Moment, M  = Fh * d          =       5819.3613  ft-lb

 Bending Stress, Sb = ( M * C1 / I  ) =        283.3737  psi
 Allowed Stress, Sa = 2/3 * Yield Str =      25333.3340  psi
```

Minimum Thickness of Baseplate per Moss:
```
  = sqrt( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))
  = sqrt( 3(15811 + 488.53 )9/( 2 * 40 * 25333 ))
  = 0.466 in
```

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 - 120/2 )( 22.126 + 0.63 + 0.63 )
  = 40.506 in
```

Distance between Ribs [e]:
```
  = Web Length / ( Nribs - 1 )
  = 40.506/( 3 - 1 )
  = 20.253 in
```

Baseplate Pressure Area [Ap]:
```
  = e * Bpwid / 2
  = 20.253 * 9/2
  = 91.138 in^2
```

Bearing Pressure [Bp]:

```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 15811/( 40 * 9 )
  = 43.918 lbf/in^2
```

Axial Load [P]:

```
  = Ap * Bp
  = 91.138 * 43.918
  = 4002.609 lbf
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 3.7877 + 5.5797
  = 9.367 in^2
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 4002.6/9.3673
  = 427.294 psi
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	33.4385
Web	10.1264	0.5510	0.2755	5.5797	1.5372	12.7153
Totals	...	...	...	9.3673	16.6429	46.1538

Rib dimension [D]:

```
  = Saddle Width - Web Thickness
  = 7.4252 - 0.551
  = 6.874 in
```

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 16.643/9.3673
  = 1.777 in
```

Distance to Centroid [C1]:

```
  = max( ytot, Saddle Width - ytot )
  = max( 1.7767, 7.4252 - 1.7767 )
  = 5.649 in
```

Radius of Gyration [r]:

```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 46.154/9.3673 )
  = 2.220 in
```

Length of Outer Rib, step 1, [Lw]:

```
  = 2 * sin( saddle bearing angle / 2 )( radius + shlthk + wpdthk )
  = 2 * sin( 120/2 )( 22.126 + 0.63 + 0.63 )
  = 40.506 in
```

Length of Outer Rib, step 2, [Bd]:

```
  = Baseplate length - clearance
  = 40 - 2
  = 38.000 in
```

Length of Outer Rib, step 3, [Dd]:

```
  = ( Lw - Bd )/2
  = ( 40.506 - 38 )/2
  = 1.253 in
```

Length of Outer Rib [L]:
= sqrt($Rl^2 + Dd^2$)
= sqrt($27.076^2 + 1.2529^2$)
= 27.076 in

Intermediate Term [Cc]:
= sqrt(2 * pi² * Elastic Modulus / Yield Stress)
= sqrt(2 * pi² * 28999900/38000)
= 122.736

Slenderness ratio [KL/r]:
= KL/r
= 1 * 27.076/2.2197
= 12.198

Bending Moment [Rm]:
= Fl /(2 * Bplen) * e * L / 2
= 231.22/(2 * 40) * 20.253 * 27.076/2
= 66.039 ft-lb

Compressive Allowable, KL/r < Cc(12.198 < 122.74) per AISC E2-1 [Sca]:
= (1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= (1-(12.198)²/(2 * 122.74²))38000/
(5/3+3*(12.198)/(8* 122.74)-(12.198³)/(8*122.74³)
= 22193 psi

AISC Unity Check of Outside Ribs (must be <= 1)
= Sc/Sca + (Rm * C1 / I)/Sba
= 427.29/22193 +(792.47 * 5.6485/46.154)/25333
= 0.023

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	44.0158
Web	20.2529	0.5510	0.2755	11.1593	3.0744	10.1595
Totals	...	...	...	14.9470	18.1801	54.1753

Distance to Centroid from Datum [ytot]:
= AY / A
= 18.18/14.947
= 1.216 in

Distance to Centroid [C1]:
= max(ytot, abs(Saddle Width - ytot))
= max(1.2163, abs(7.4252 - 1.2163))
= 6.209 in

Length of Inner Rib [L]:
= Saddle Height - Outside Radius - Bpthk
= 40 - cos(23.386/2)(1.2598 + 0 + 0) - 0
= 15.354 in

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(54.175/14.947)
= 1.904 in

Slenderness ratio [KL/r]:
= KL/r
= 1 * 15.354/1.9038
= 8.065

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 231.22/( 2 * 40 )
  = 2.890 lbf/in
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 2.8903 * 20.253 * 15.354
  = 898.775 in.lbs
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 898.78/8.7254
  = 103.007 psi
```

Compressive Allowable, KL/r < Cc(8.065 < 122.74) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 8.065 )²/(2 * 122.74² ))38000/
    ( 5/3+3*(8.065 )/(8* 122.74 )-( 8.065³)/(8*122.74³)
  = 22420 psi
```

AISC Unity Check of Inside Ribs (must be <= 1)
```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 524.46/22420 +( 898.78 * 6.2089/54.175 )/25333
  = 0.027
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-36	
Bolt Allowable Stress	Stba	21754.90	psi
Bolt Corrosion Allowance	Bca	0.0630	in
Distance from Bolts to Edge	Edgedis	4.0000	in
Nominal Bolt Diameter	Bnd	1.7500	in
Thread Series	Series	TEMA	
BasePlate Allowable Stress	S	20000.00	psi
Area Available in a Single Bolt	BltArea	1.6782	in^2
Saddle Load QO (Weight)	QO	15381.0	lbf
Saddle Load QL (Wind/Seismic contribution)	QL	66.5	lbf
Maximum Transverse Force	Ft	306.0	lbf
Maximum Longitudinal Force	Fl	231.2	lbf
Saddle Bolted to Steel Foundation		No	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:
```
  = Fl / ( Bolt Area * Number of Bolts )
  = 231.22/( 1.6782 * 2 )
  = 68.9 psi.  Must be less than 13052.9 psi.
```

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:
```
  = Ft / ( Bolt Area * Number of Bolts )
  = 306.02/( 1.6782 * 2 )
  = 91.2 psi.  Must be less than 13052.9 psi.
```

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 / ( BoltShearAllowable * Nbolts )
  = 231.22/(13053 * 2 )
  = 0.0089 in^2
```


Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 3.3333 * 306.02 + 0
  = 1020.06 ft-lb
```

Eccentricity (e):
```
  = Rmom / QO
  = 12241/15381
  = 0.80 in < 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, 0.008857, 0 ]
  = 0.0089 in^2
```

Input, Nozzle Desc: T2 From: 30

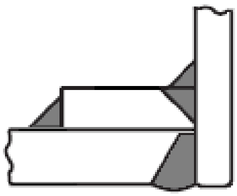
```
Pressure for Reinforcement Calculations        P     280.199  psig
Temperature for Internal Pressure           Temp         300  F
Design External Pressure                    Pext       15.00  psig
Temperature for External Pressure         Tempex         300  F
Maximum Allowable Pressure New & Cold                 377.46  psig

Parent Material [Normalized]                         SA-516 70
Parent Allowable Stress at Temperature        Sv    20000.00  psi
Parent Allowable Stress At Ambient           Sva    20000.00  psi

Inside Diameter of Cylindrical Shell           D     44.2520  in
Design Length of Section                       L     33.4646  in
Shell Finished (Minimum) Thickness             t      0.6300  in
Shell Internal Corrosion Allowance             c      0.0000  in
Shell External Corrosion Allowance            co      0.0000  in

Distance from Cylinder/Cone Centerline        L1      9.0000  in

Distance from Bottom/Left Tangent                      28.96  in

User Entered Minimum Design Metal Temperature          32.00  F
```

Type of Element Connected to the Parent : Nozzle

```
Material                                               SA-106 B
Material UNS Number                                      K03006
Material Specification/Type                          Smls. pipe
Allowable Stress at Temperature               Sn    17100.00  psi
Allowable Stress At Ambient                  Sna    17100.00  psi

Diameter Basis (for tr calc only)                    Outside
Layout Angle                                           23.30  deg
Diameter                                             10.0000  in.

Size and Thickness Basis                             Nominal
Nominal Thickness                                         80

Flange Type                                 Weld Neck Flange

Corrosion Allowance                          can      0.0000  in
Joint Efficiency of Shell Seam at Nozzle      E1        1.00
Joint Efficiency of Nozzle Neck               En        1.00

Outside Projection                            ho     11.4795  in
Weld leg size between Nozzle and Pad/Shell    Wo      0.3940  in
Groove weld depth between Nozzle and Vessel Wgnv      0.6299  in
Inside Projection                              h      0.0000  in
Weld leg size, Inside Element to Shell        Wi      0.0000  in

Pad Material    [Normalized]                         SA-516 70
Pad Allowable Stress at Temperature           Sp    20000.00  psi
Pad Allowable Stress At Ambient              Spa    20000.00  psi
Diameter of Pad along vessel surface          Dp     17.7165  in
Thickness of Pad                              te      0.6299  in
Weld leg size between Pad and Shell           Wp      0.4724  in
Groove weld depth between Pad and Nozzle    Wgpn      0.6299  in
Reinforcing Pad Width                                 3.4832  in

Flange Class                                             300
Flange Grade                                          GR 1.1
```

The Pressure Design option was MAWP + static head (to the nozzle).

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



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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: T2

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
 Actual Outside Diameter Used in Calculation          10.750  in.
 Actual Thickness Used in Calculation                  0.594  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)
  = 280.2*22.126/(20000*1-0.6*280.2)
  = 0.3126 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 377.46*22.126/(20000*1-0.6*377.46)
  = 0.4224 in
```

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)
  = 280.2*5.375/(17100*1+0.4*280.2)
  = 0.0875 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Mapnc]
```
  = P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = 377.46*5.375/(17100*1+0.4*377.46)
  = 0.1176 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0355 in

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl    21.2135  in
 Parallel to Vessel Wall, opening length              d    10.6067  in
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp     1.5750  in
```

UG-40, Limits of Reinforcement : [Mapnc]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl    21.2135  in
 Parallel to Vessel Wall, opening length              d    10.6067  in
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp     1.5750  in
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 17100/20000 )
```

= 0.855

Weld Strength Reduction Factor [fr2]:
= min(1, Sn/Sv)
= min(1, 17100/20000)
= 0.855

Weld Strength Reduction Factor [fr4]:
= min(1, Sp/Sv)
= min(1, 20000/20000)
= 1.000

Weld Strength Reduction Factor [fr3]:
= min(fr2, fr4)
= min(0.855, 1)
= 0.855

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

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	3.370	0.690	4.553
Area in Shell	A1	3.312	5.238	2.167
Area in Nozzle Wall	A2	1.382	1.524	1.300
Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.356	0.356	0.356
Area in Element	A5	4.388	4.388	4.388
TOTAL AREA AVAILABLE	Atot	9.438	11.506	8.210

The MAP(nc) Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 64.36 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:	11.9375	0.6299	in
Based on given Pad Diameter:	17.7165	0.1250	in
Based on Shell or Nozzle Thickness:	13.1250	0.6250	in

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (10.607*0.4224*1+2*0.594*0.4224*1*(1-0.855))
= 4.553 in^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)
= 10.607(1 * 0.63 - 1 * 0.4224) - 2 * 0.594
(1 * 0.63 - 1 * 0.4224) *(1 - 0.855)
= 2.167 in^2

Area Available in Nozzle Wall Projecting Outward [A2]:
= (2 * Tlwp) * (tn - trn) * fr2/sin(alpha3)
= (2 * 1.575) *(0.594 - 0.1176) * 0.855/sin(80.834)
= 1.300 in^2

See ASME VIII-1 2011(a) Appendix L, L-7.7.7(b) for more information.

Area Available in Welds [A41 + A42 + A43]:
= Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
= 0.394² * 0.855 +(0)² * 0.855 + 0.4724² * 1

```
  = 0.356 in^2
```

Area Available in Element [A5]:

```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 18.891 - 11.925 ) * 0.6299 * 1
  = 4.388 in^2
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, min(Curve:C, Curve:B)

Govrn. thk, tg = 0.5197, tr = 0.0875, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.1684, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              -4 F
```

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

Govrn. thk, tg = 0.5197, tr = 0.0875, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.1684, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve C             -35 F
```

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

Govrn. thk, tg = 0.5197, tr = 0.0875, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.1684, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve D             -55 F
```

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

Govrn. thk, tg = 0.6299, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.4962, Temp. Reduction = 0 F
Attachment governing, Attachment stress = Shell stress per Code

```
 Min Metal Temp. w/o impact per UCS-66, Curve D             -50 F
```

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

Govrn. thk, tg = 0.5197, tr = 0.0875, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.1684, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve C             -35 F

 Gov. MDMT of the Nozzle                                :    -4 F
 Gov. MDMT of the Reinforcement Pad                     :   -50 F
 Gov. MDMT of the nozzle to shell joint welded assembly :    -4 F
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
 Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)     -20 F
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -20 F
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :

```
 Design Pressure/Ambient Rating = 280.20/740.00 = 0.379
```

Note: The MDMT was not reduced based on lower stress per user request.

Weld Size Calculations, Description: T2

```
 Intermediate Calc. for nozzle/shell Welds    Tmin      0.5940  in
 Intermediate Calc. for pad/shell Welds     TminPad     0.6299  in
```

Results Per UW-16.1:

```
                      Required Thickness     Actual Thickness
 Nozzle Weld          0.2500 = Min per Code 0.2786 = 0.7 * Wo in
 Pad Weld             0.3150 = 0.5*TminPad  0.3340 = 0.7 * Wp in
```

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,(4.5526 - 2.1666 + 2 * 0.594 * 0.855 *
    (1 * 0.63 - 0.4224 ) )20000 )
  = 51939.41 lbf
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.2996 + 4.3883 + 0.3559 - 0 * 0.855 ) * 20000
  = 120878.27 lbf
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.2996 + 0 + 0.1327 +( 0.6399 ) ) * 20000
  = 41445.70 lbf
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.2996 + 0 + 0.3559 + 4.3883 +( 0.6399 ) ) * 20000
  = 133676.59 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 11.925 * 0.394 * 0.49 * 17100
  = 61837. lbf
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 17.716 * 0.4724 * 0.49 * 20000
  = 128846. lbf
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 5.6328 ) *( 0.594 - 0 ) * 0.7 * 17100
  = 125822. lbf
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  = (3.1416/2 ) * 11.925 * 0.6299 * 0.74 * 20000
  = 174626. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * Wgnvi * 0.74 * Sng
  = ( 3.1416/2.0 ) * 11.925 *( 0.6299 - 0 ) * 0.74 * 20000
  = 174626. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:

```
  = ( SPEW + SNW ) = ( 128846 + 125822 ) = 254668 lbf
```

Failure Path [Path 2-2]:
  = (Sonw + Tpgw + Tngw + Sinw)
  = (61837 + 174626 + 174626 + 0) = 411089 lbf

Failure Path [Path 3-3]:
  = (Spew + Tngw + Sinw)
  = (128846 + 174626 + 0) = 303472 lbf

Summary of Failure Path Calculations:

```
 Path 1-1 = 254667  lbf, must exceed W = 51939 lbf    or W1 = 120878 lbf
 Path 2-2 = 411089  lbf, must exceed W = 51939 lbf    or W2 = 41445 lbf
 Path 3-3 = 303472  lbf, must exceed W = 51939 lbf    or W3 = 133676 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:
 Converged Maximum Allowable Pressure in the Operating case: 280.14 psig

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

 Nozzle is O.K. for the External Pressure: 15 psig

 Approximate Maximum Allowable Pressure New & Cold: 526.56 psig

Note : Checking Nozzle in plane parallel to the vessel axis.

Reinforcement CALCULATION, Description: T2

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
 Actual Outside Diameter Used in Calculation          10.750  in.
 Actual Thickness Used in Calculation                  0.594  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)
  = 280.2*22.126/(20000*1-0.6*280.2)
  = 0.3126 in

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 377.46*22.126/(20000*1-0.6*377.46)
  = 0.4224 in

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)
  = 280.2*5.375/(17100*1+0.4*280.2)
  = 0.0875 in

Reqd thk per UG-37(a) of Nozzle Wall, trn [Mapnc]
  = P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = 377.46*5.375/(17100*1+0.4*377.46)
  = 0.1176 in

Required Nozzle thickness under External Pressure per UG-28 : 0.0355 in

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

```
 Parallel to Vessel Wall (Diameter Limit)            Dl     19.1240  in
 Parallel to Vessel Wall, opening length              d      9.5620  in
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp      1.5750  in
```

UG-40, Limits of Reinforcement : [Mapnc]

```
 Parallel to Vessel Wall (Diameter Limit)            Dl     19.1240  in
 Parallel to Vessel Wall, opening length              d      9.5620  in
```

Normal to Vessel Wall (Thickness Limit), pad side Tlwp 1.5750 in

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

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	3.043	0.623	4.111
Area in Shell	A1	2.980	4.714	1.950
Area in Nozzle Wall	A2	1.364	1.504	1.283
Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.356	0.356	0.356
Area in Element	A5	4.388	4.388	4.388
TOTAL AREA AVAILABLE	Atot	9.089	10.962	7.977

The MAP(nc) 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:	11.6250	0.6299	in
Based on given Pad Diameter:	17.7165	0.1250	in
Based on Shell or Nozzle Thickness:	11.6250	0.6250	in

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (9.562*0.4224*1+2*0.594*0.4224*1*(1-0.855))
  = 4.111 in^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 )
  = 9.562( 1 * 0.63 - 1 * 0.4224 ) - 2 * 0.594
    ( 1 * 0.63 - 1 * 0.4224 ) *( 1 - 0.855 )
  = 1.950 in^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:
```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 1.575 ) *( 0.594 - 0.1176 ) * 0.855
  = 1.283 in^2
```

Area Available in Welds [A41 + A42 + A43]:
```
  = Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
  = 0.394² * 0.855 +(0 )² * 0.855 + 0.4724² * 1
  = 0.356 in^2
```

Area Available in Element [A5]:
```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 17.716 - 10.75 ) * 0.6299 * 1
  = 4.388 in^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 0.1176 in
 Wall Thickness per UG16(b),                       tr16b = 0.0625 in
 Wall Thickness, shell/head, internal pressure      trb1 = 0.3126 in
 Wall Thickness                  tb1 = max(trb1, tr16b) = 0.3126 in
 Wall Thickness, shell/head, external pressure      trb2 = 0.0166 in
 Wall Thickness                  tb2 = max(trb2, tr16b) = 0.0625 in
 Wall Thickness per table UG-45                      tb3 = 0.3190 in
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.319, max( 0.3126, 0.0625 ) ]
  = 0.3126 in
```

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

```
  = max( ta, tb )
  = max( 0.1176, 0.3126 )
  = 0.3126 in
```

Available Nozzle Neck Thickness = 0.875 * 0.594 = 0.520 in --> OK

UG-45 Minimum Nozzle Neck Thickness Requirement: [MAPnc]

```
 Wall Thickness for Internal/External pressures      ta = 0.1176 in
 Wall Thickness per UG16(b),                       tr16b = 0.0625 in
 Wall Thickness, shell/head, internal pressure     trb1 = 0.4224 in
 Wall Thickness                  tb1 = max(trb1, tr16b) = 0.4224 in
 Wall Thickness, shell/head, external pressure     trb2 = 0.0166 in
 Wall Thickness                  tb2 = max(trb2, tr16b) = 0.0625 in
 Wall Thickness per table UG-45                      tb3 = 0.3190 in
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.319, max( 0.4224, 0.0625 ) ]
  = 0.3190 in
```

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

```
  = max( ta, tb )
  = max( 0.1176, 0.319 )
  = 0.3190 in
```

Available Nozzle Neck Thickness = 0.875 * 0.594 = 0.520 in --> 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   :    4334.8,  Allowable :  17100.0 psi  Passed
 Expansion   :       0.0,  Allowable :  38415.2 psi  Passed
 Occasional  :    1061.7,  Allowable :  22743.0 psi  Passed
 Shear       :    2336.6,  Allowable :  11970.0 psi  Passed
```

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

Weld Size Calculations, Description: T2

```
 Intermediate Calc. for nozzle/shell Welds    Tmin       0.5940  in
 Intermediate Calc. for pad/shell Welds    TminPad       0.6299  in
```

Results Per UW-16.1:

```
                       Required Thickness     Actual Thickness
 Nozzle Weld          0.2500 = Min per Code 0.2786 = 0.7 * Wo in
 Pad Weld             0.3150 = 0.5*TminPad  0.3340 = 0.7 * Wp in
```

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,(4.1114 - 1.9497 + 2 * 0.594 * 0.855 *
    (1 * 0.63 - 0.4224 ) )20000 )
  = 47452.79 lbf
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
```

```
  = ( 1.283 + 4.3883 + 0.3559 - 0 * 0.855 ) * 20000
  = 120546.36 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.283 + 0 + 0.1327 +( 0.6399 ) ) * 20000
  = 41113.79 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.283 + 0 + 0.3559 + 4.3883 +( 0.6399 ) ) * 20000
  = 133344.69 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 10.75 * 0.394 * 0.49 * 17100
  = 55746. lbf
```

Shear, Pad Element Weld [Spew]:
```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 17.716 * 0.4724 * 0.49 * 20000
  = 128846. lbf
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 5.078 ) *( 0.594 - 0 ) * 0.7 * 17100
  = 113429. lbf
```

Tension, Pad Groove Weld [Tpgw]:
```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  = (3.1416/2 ) * 10.75 * 0.6299 * 0.74 * 20000
  = 157426. lbf
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * Wgnvi * 0.74 * Sng
  = ( 3.1416/2.0 ) * 10.75 *( 0.6299 - 0 ) * 0.74 * 20000
  = 157426. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:
```
  = ( SPEW + SNW ) = ( 128846 + 113429 ) = 242275 lbf
```

Failure Path [Path 2-2]:
```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 55746 + 157426 + 157426 + 0 ) = 370598 lbf
```

Failure Path [Path 3-3]:
```
  = ( Spew + Tngw + Sinw )
  = ( 128846 + 157426 + 0 ) = 286272 lbf
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 242274  lbf, must exceed W = 47452 lbf    or W1 = 120546 lbf
 Path 2-2 = 370598  lbf, must exceed W = 47452 lbf    or W2 = 41113 lbf
 Path 3-3 = 286272  lbf, must exceed W = 47452 lbf    or W3 = 133344 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Maximum Allowable Pressure in the Operating case: 280.14 psig
```

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

Nozzle is O.K. for the External Pressure: 15 psig

Approximate Maximum Allowable Pressure New & Cold: 537.97 psig

The Drop for this Nozzle is : 3.3927 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 15.5599 in

Warning:
The equations for nozzle local stress analysis pertain to radial nozzles only and this nozzle is not specified as radial. Please check the specific analysis code for all assumptions and limitations.

Input Echo, WRC297 Item 1, Description: T2 :

Diameter Basis for Cylindrical Shell		ID	
Shell Corrosion Allowance		0.0000	in
Shell Diameter		44.252	in
Shell Thickness		0.6300	in
Shell Stress Concentration Factor		1.000	
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	20000.00	psi
Vessel Hot S.I. Allowable	Smh	20000.00	psi

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

Diameter Basis for Nozzle		OD	
Nozzle Corrosion Allowance		0.0000	in
Nozzle Diameter		10.750	in
Nozzle Thickness		0.5940	in
Nozzle Stress Concentration Factor		1.000	
Nozzle Material		SA-106 B	
Nozzle Cold S.I. Allowable	SNmc	17100.00	psi
Nozzle Hot S.I. Allowable	SNmh	17100.00	psi

Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not time-dependent for Material: SA-106 B

Diameter of Reinforcing Pad	17.716	in
Thickness of Reinforcing Pad	0.6299	in

Note:
External Forces and Moments in WRC 107/537 Convention:
These loads are assumed to be SUStained loads.

Design Internal Pressure	Dp	280.20	psig
Radial Load	P	-2580.00	lbf
Circumferential Shear	Vc	3239.99	lbf
Longitudinal Shear	Vl	3239.99	lbf
Circumferential Moment	Mc	8020.03	ft-lb
Longitudinal Moment	Ml	10180.00	ft-lb
Torsional Moment	Mt	12960.00	ft-lb

Include Axial Pressure Thrust	No
Include Pressure Stress Indices per Div. 2	No
Local Loads applied at end of Nozzle/Attachment	No

Stress Computations at the Edge of the Nozzle:

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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 10.75 + 2 * 1.65 * sqrt( 22.756( 0.63 - 0.0 ) )
  = 23.245 in
```

WRC 297 Curve Access Parameters:

```
 Vessel Mean Diameter      (D) =     45.512 in
 Nozzle Outside Diameter   (d) =     10.750 in
 Vessel Thickness used     (T) =      1.260 in
 Nozzle Thickness used     (t) =      0.594 in
 T / t                         =      2.121
 d / t                         =     18.098

Lambda = [(d/D) * sqrt(D/T)]  = 1.420

 Nr/P    =      0.094
 Mr/P    =      0.102
 M0/P    =      0.064
 N0/P    =      0.156
 MrD/Mc  =      0.202
 NrDL/Mc =      0.149
 M0d/Mc  =      0.150
 N0DL/Mc =      0.120
 MrD/Ml  =      0.148
 NrDL/Ml =      0.108
 M0D/Ml  =      0.107
 N0DL/Ml =      0.236
```

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stresses Normal to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Outplane Membrane (P)	254	254	254	254
Outplane Bending (P)	623	-623	623	-623
Outplane Membrane (Mc)	0	0	0	0
Outplane Bending (Mc)	0	0	0	0
Outplane Membrane (ML)	-1691	-1691	1691	1691
Outplane Bending (ML)	-4592	4592	4592	-4592
Normal Pressure Stress	4784	5064	4784	5064
Outplane Stress Summary	-622	7596	11944	1794

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stresses parallel to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Inplane Membrane (P)	152	152	152	152
Inplane Bending (P)	993	-993	993	-993
Inplane Membrane (Mc)	0	0	0	0
Inplane Bending (Mc)	0	0	0	0
Inplane Membrane (ML)	-773	-773	773	773
Inplane Bending (ML)	-6365	6365	6365	-6365
Inplane Pressure Stress	2392	2392	2392	2392
Inplane Stress Summary	-3601	7143	10675	-4041

Vessel Stresses (psi):

LONGITUDINAL PLANE (Shear stress normal to	Au Top	Al Top	Bu Bottom	Bl Bottom

```
 longitudinal plane)      Outside   Inside  Outside   Inside
 ---------------------------------------------------------------
 Outplane  Shear  (Vc)        152      152     -152     -152
 Outplane  Shear  (Vl)          0        0        0        0
 Outplane  Shear  (Mt)        679      679      679      679
 ---------------------- -------- -------- -------- --------
 Shear Stress Summary         831      831      527      527
```

Vessel Stresses (psi):

```
 LONGITUDINAL PLANE            Au       Al       Bu       Bl
 (Stress Intensities          Top      Top   Bottom   Bottom
                          Outside   Inside  Outside   Inside
 ---------------------------------------------------------------
 Two * Max Shear Stress      3817     8230    12134     5929
```

Vessel Stresses (psi):

```
 CIRCUMFERENTIAL PLANE         Cu       Cl       Du       Dl
 (Stresses Normal to         Left     Left    Right    Right
 circumferential plane)   Outside   Inside  Outside   Inside
 ---------------------------------------------------------------
 Outplane Membrane (P )       254      254      254      254
 Outplane Bending  (P )       623     -623      623     -623
 Outplane Membrane (Mc)      -675     -675      675      675
 Outplane Bending  (Mc)     -5066     5066     5066    -5066
 Outplane Membrane (ML)         0        0        0        0
 Outplane Bending  (ML)         0        0        0        0
 Normal Pressure Stress      2392     2392     2392     2392
 ---------------------- -------- -------- -------- --------
 Outplane Stress Summary    -2472     6414     9010    -2368
```

Vessel Stresses (psi):

```
 CIRCUMFERENTIAL PLANE         Cu       Cl       Du       Dl
 (Stresses parallel to       Left     Left    Right    Right
 circumferential plane)   Outside   Inside  Outside   Inside
 ---------------------------------------------------------------
 Inplane Membrane (P )        152      152      152      152
 Inplane Bending  (P )        993     -993      993     -993
 Inplane Membrane (Mc)       -838     -838      838      838
 Inplane Bending  (Mc)      -6838     6838     6838    -6838
 Inplane Membrane (ML)          0        0        0        0
 Inplane Bending  (ML)          0        0        0        0
 Inplane Pressure Stress     4784     5064     4784     5064
 ---------------------- -------- -------- -------- --------
 Inplane Stress Summary     -1747    10223    13605    -1777
```

Vessel Stresses (psi):

```
 CIRCUMFERENTIAL PLANE         Cu       Cl       Du       Dl
 (Shear stress normal to     Left     Left    Right    Right
 circumferential plane)   Outside   Inside  Outside   Inside
 ---------------------------------------------------------------
 Outplane  Shear  (Vc)          0        0        0        0
 Outplane  Shear  (Vl)       -152     -152      152      152
 Torsional Shear  (Mt)        679      679      679      679
 ---------------------- -------- -------- -------- --------
 Shear Stress Summary         527      527      831      831
```

Vessel Stresses (psi):

```
 CIRCUMFERENTIAL PLANE         Cu       Cl       Du       Dl
 (Stress Intensities         Left     Left    Right    Right
                          Outside   Inside  Outside   Inside
 ---------------------------------------------------------------
 Two * Max Shear Stress      2749    10294    13750     2954
```

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Stresses in the hoop direction)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Hoop Membrane (P)	254	254	254	254
Hoop Bending (P)	0	0	0	0
Hoop Membrane (Mc)	0	0	0	0
Hoop Bending (Mc)	0	0	0	0
Hoop Membrane (ML)	-1691	-1691	1691	1691
Hoop Bending (ML)	0	0	0	0
Hoop Pressure Stress	2548	2884	2548	2884
Hoop Stress Summary	1111	1447	4493	4829

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Stresses Normal to pipe cross-section)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Axial Membrane (P)	136	136	136	136
Axial Bending (P)	2408	-2408	2408	-2408
Axial Membrane (Mc)	0	0	0	0
Axial Bending (Mc)	0	0	0	0
Axial Membrane (ML)	-2677	-2677	2677	2677
Axial Bending (ML)	-18204	18204	18204	-18204
Axial Pressure Stress	1274	1274	1274	1274
Axial Stress Summary	-17063	14529	24699	-16525

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Shear stress)	Au Outside	Al Inside	Bu Outside	Bl Inside
Shear due to (Vc)	323	323	-323	-323
Shear due to (Vl)	0	0	0	0
Shear due to Torsion	1442	1442	1442	1442
Shear Stress Summary	1765	1765	1119	1119

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Stress Intensities	Au Outside	Al Inside	Bu Outside	Bl Inside
Two * Max Shear Stress	18513	14762	24760	21470

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses in the hoop direction)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Hoop Membrane (P)	254	254	254	254
Hoop Bending (P)	0	0	0	0
Hoop Membrane (Mc)	-675	-675	675	675
Hoop Bending (Mc)	0	0	0	0
Hoop Membrane (ML)	0	0	0	0
Hoop Bending (ML)	0	0	0	0
Hoop Pressure Stress	2548	2884	2548	2884
Hoop Stress Summary	2127	2463	3477	3813

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses Normal to pipe cross-section)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside

Axial Membrane (P)	136	136	136	136
Axial Bending (P)	2408	-2408	2408	-2408
Axial Membrane (Mc)	-2109	-2109	2109	2109
Axial Bending (Mc)	-19445	19445	19445	-19445
Axial Membrane (ML)	0	0	0	0
Axial Bending (ML)	0	0	0	0
Axial Pressure Stress	1274	1274	1274	1274
Axial Stress Summary	-17736	16338	25372	-18334

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Shear stress)	Cu Outside	Cl Inside	Du Outside	Dl Inside
Shear due to (Vc)	0	0	0	0
Shear due to (Vl)	-323	-323	323	323
Shear due to Torsion	1442	1442	1442	1442
Shear Stress Summary	1119	1119	1765	1765

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Stress Intensities	Cu Outside	Cl Inside	Du Outside	Dl Inside
Two * Max Shear Stress	19988	16427	25513	22426

Stress Computations at the Edge of the Reinforcing Pad:

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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 10.75 + 2 * 1.65 * sqrt( 22.441( 0.63 - 0.0 ) )
  = 23.158 in
```

WRC 297 Curve Access Parameters:

```
 Vessel Mean Diameter      (D) =     44.882 in
 Nozzle Outside Diameter   (d) =     17.716 in
 Vessel Thickness used     (T) =      0.630 in
 Nozzle Thickness used     (t) =      4.077 in
 T / t                         =      0.155
 d / t                         =     10.000
```

Lambda = [(d/D) * sqrt(D/T)] = 3.332

Note: Re-pad thickness is added to nozzle thickness to simulate the Re-pad.

```
 Nr/P    =      0.056
 Mr/P    =      0.098
 M0/P    =      0.029
 N0/P    =      0.050
 MrD/Mc  =      0.262
 NrDL/Mc =      0.099
 M0d/Mc  =      0.079
 N0DL/Mc =      0.075
 MrD/Ml  =      0.075
 NrDL/Ml =      0.065
 M0D/Ml  =      0.022
 N0DL/Ml =      0.059
```

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stresses Normal to	Au Top	Al Top	Bu Bottom	Bl Bottom

longitudinal plane)	Outside	Inside	Outside	Inside
Outplane Membrane (P)	322	322	322	322
Outplane Bending (P)	1125	-1125	1125	-1125
Outplane Membrane (Mc)	0	0	0	0
Outplane Bending (Mc)	0	0	0	0
Outplane Membrane (ML)	-1018	-1018	1018	1018
Outplane Bending (ML)	-2291	2291	2291	-2291
Normal Pressure Stress	9702	9982	9702	9982
Outplane Stress Summary	7840	10452	14458	7906

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stresses parallel to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Inplane Membrane (P)	367	367	367	367
Inplane Bending (P)	3811	-3811	3811	-3811
Inplane Membrane (Mc)	0	0	0	0
Inplane Bending (Mc)	0	0	0	0
Inplane Membrane (ML)	-1133	-1133	1133	1133
Inplane Bending (ML)	-7791	7791	7791	-7791
Inplane Pressure Stress	4851	4851	4851	4851
Inplane Stress Summary	105	8065	17953	-5251

Vessel Stresses (psi):

LONGITUDINAL PLANE (Shear stress normal to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Outplane Shear (Vc)	184	184	-184	-184
Outplane Shear (Vl)	0	0	0	0
Outplane Shear (Mt)	500	500	500	500
Shear Stress Summary	684	684	316	316

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stress Intensities	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Two * Max Shear Stress	7900	10634	17981	13172

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses Normal to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Outplane Membrane (P)	322	322	322	322
Outplane Bending (P)	1125	-1125	1125	-1125
Outplane Membrane (Mc)	-1024	-1024	1024	1024
Outplane Bending (Mc)	-6455	6455	6455	-6455
Outplane Membrane (ML)	0	0	0	0
Outplane Bending (ML)	0	0	0	0
Normal Pressure Stress	4851	4851	4851	4851
Outplane Stress Summary	-1181	9479	13777	-1383

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses parallel to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside

Inplane Membrane (P)	367	367	367	367
Inplane Bending (P)	3811	-3811	3811	-3811
Inplane Membrane (Mc)	-1348	-1348	1348	1348
Inplane Bending (Mc)	-21535	21535	21535	-21535
Inplane Membrane (ML)	0	0	0	0
Inplane Bending (ML)	0	0	0	0
Inplane Pressure Stress	9702	9982	9702	9982
Inplane Stress Summary	-9003	26725	36763	-13649

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Shear stress normal to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Outplane Shear (Vc)	0	0	0	0
Outplane Shear (Vl)	-184	-184	184	184
Torsional Shear (Mt)	500	500	500	500
Shear Stress Summary	316	316	684	684

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stress Intensities	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Two * Max Shear Stress	9015	26730	36783	13687

WRC 297 Stress Summations per ASME Sec. VIII Div. 2:

Vessel Stress Summation at Vessel-Nozzle Junction (psi):

Type of Stress Int. Location	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	4784	5064	4784	5064	4784	5064	4784	5064
Circ. Pl (SUS)	-1437	-1437	1945	1945	-686	-686	990	990
Circ. Q (SUS)	-3969	3969	5215	-5215	-5845	5845	7831	-7831
Long. Pm (SUS)	2392	2392	2392	2392	2392	2392	2392	2392
Long. Pl (SUS)	-621	-621	925	925	-421	-421	929	929
Long. Q (SUS)	-5372	5372	7358	-7358	-4443	4443	5689	-5689
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	152	152	-152	-152	-152	-152	152	152
Shear Q (SUS)	679	679	679	679	679	679	679	679
Pm (SUS)	4784	5064	4784	5064	4784	5064	4784	5064
Pm+Pl (SUS)	3361	3639	6735	7015	4108	4387	5783	6062
Pm+Pl+Q (Total)	3817	8230	12134	5929	2749	10294	13750	2954

Vessel Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	5064	20000	Passed
Pm+Pl (SUS)	7015	30000	Passed
Pm+Pl+Q (TOTAL)	13750	60000	Passed

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

WRC 297 Stress Summations per ASME Sec. VIII Div. 2:

Vessel Stress Summation at Reinforcing Pad Edge (psi):

Type of Stress Int. Location	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	9702	9982	9702	9982	9702	9982	9702	9982
Circ. Pl (SUS)	-696	-696	1340	1340	-981	-981	1715	1715
Circ. Q (SUS)	-1166	1166	3416	-3416	-17724	17724	25346	-25346
Long. Pm (SUS)	4851	4851	4851	4851	4851	4851	4851	4851
Long. Pl (SUS)	-766	-766	1500	1500	-702	-702	1346	1346
Long. Q (SUS)	-3980	3980	11602	-11602	-5330	5330	7580	-7580
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	184	184	-184	-184	-184	-184	184	184
Shear Q (SUS)	500	500	500	500	500	500	500	500
Pm (SUS)	9702	9982	9702	9982	9702	9982	9702	9982
Pm+Pl (SUS)	9012	9292	11049	11328	8728	9007	11423	11703
Pm+Pl+Q (Total)	7900	10634	17981	13172	9015	26730	36783	13687

Vessel Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	9982	20000	Passed
Pm+Pl (SUS)	11703	30000	Passed
Pm+Pl+Q (TOTAL)	36783	60000	Passed

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

WRC 297 Stress Summations per ASME Sec. VIII Div. 2:

Nozzle Stress Summation at Vessel-Nozzle Junction (psi):

Type of Stress Int. Location	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	2548	2884	2548	2884	2548	2884	2548	2884
Circ. Pl (SUS)	-1437	-1437	1945	1945	-421	-421	929	929
Circ. Q (SUS)	0	0	0	0	0	0	0	0
Long. Pm (SUS)	1274	1274	1274	1274	1274	1274	1274	1274
Long. Pl (SUS)	-2541	-2541	2813	2813	-1973	-1973	2245	2245
Long. Q (SUS)	-15796	15796	20612	-20612	-17037	17037	21853	-21853
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	323	323	-323	-323	-323	-323	323	323
Shear Q (SUS)	1442	1442	1442	1442	1442	1442	1442	1442
Pm (SUS)	2548	2884	2548	2884	2548	2884	2548	2884
Pm+Pl (SUS)	2464	2789	4671	4949	2898	3227	3821	4020

```
 -----------------------------------------------------------------------
 Pm+Pl+Q (Total)|  18513  14762  24760  21470  19988  16427  25513  22426|
```

Nozzle Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	2884	17100	Passed
Pm+Pl (SUS)	4949	25650	Passed
Pm+Pl+Q (TOTAL)	25513	51300	Passed

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

Input, Nozzle Desc: T1 From: 30

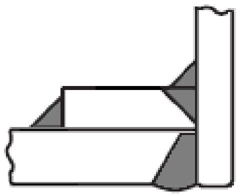
```
Pressure for Reinforcement Calculations        P     281.738  psig
Temperature for Internal Pressure           Temp         300  F
Design External Pressure                    Pext       15.00  psig
Temperature for External Pressure         Tempex         300  F
Maximum Allowable Pressure New & Cold                 377.46  psig

Parent Material [Normalized]                          SA-516 70
Parent Allowable Stress at Temperature        Sv    20000.00  psi
Parent Allowable Stress At Ambient           Sva    20000.00  psi

Inside Diameter of Cylindrical Shell           D     44.2520  in
Design Length of Section                       L     33.4646  in
Shell Finished (Minimum) Thickness             t      0.6300  in
Shell Internal Corrosion Allowance             c      0.0000  in
Shell External Corrosion Allowance            co      0.0000  in

Distance from Cylinder/Cone Centerline        L1      9.0000  in

Distance from Bottom/Left Tangent                      28.96  in

User Entered Minimum Design Metal Temperature          32.00  F
```

Type of Element Connected to the Parent : Nozzle

```
Material                                             SA-106 B
Material UNS Number                                    K03006
Material Specification/Type                        Smls. pipe
Allowable Stress at Temperature               Sn    17100.00  psi
Allowable Stress At Ambient                  Sna    17100.00  psi

Diameter Basis (for tr calc only)                    Outside
Layout Angle                                          156.70  deg
Diameter                                             10.0000  in.

Size and Thickness Basis                             Nominal
Nominal Thickness                                         80

Flange Type                                 Weld Neck Flange

Corrosion Allowance                          can      0.0000  in
Joint Efficiency of Shell Seam at Nozzle      E1        1.00
Joint Efficiency of Nozzle Neck               En        1.00

Outside Projection                            ho     11.4795  in
Weld leg size between Nozzle and Pad/Shell    Wo      0.3940  in
Groove weld depth between Nozzle and Vessel Wgnv      0.6300  in
Inside Projection                              h      0.0000  in
Weld leg size, Inside Element to Shell        Wi      0.0000  in

Pad Material    [Normalized]                          SA-516 70
Pad Allowable Stress at Temperature           Sp    20000.00  psi
Pad Allowable Stress At Ambient              Spa    20000.00  psi
Diameter of Pad along vessel surface          Dp     17.7170  in
Thickness of Pad                              te      0.6299  in
Weld leg size between Pad and Shell           Wp      0.4724  in
Groove weld depth between Pad and Nozzle    Wgpn      0.6299  in
Reinforcing Pad Width                                 3.4835  in

Flange Class                                             300
Flange Grade                                          GR 1.1
```

The Pressure Design option was MAWP + static head (to the nozzle).

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



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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: T1

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
 Actual Outside Diameter Used in Calculation          10.750  in.
 Actual Thickness Used in Calculation                  0.594  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)
  = 281.74*22.126/(20000*1-0.6*281.74)
  = 0.3143 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 377.46*22.126/(20000*1-0.6*377.46)
  = 0.4224 in
```

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)
  = 281.74*5.375/(17100*1+0.4*281.74)
  = 0.0880 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Mapnc]
```
  = P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = 377.46*5.375/(17100*1+0.4*377.46)
  = 0.1176 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0355 in

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl    21.2135  in
 Parallel to Vessel Wall, opening length              d    10.6067  in
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp     1.5750  in
```

UG-40, Limits of Reinforcement : [Mapnc]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl    21.2135  in
 Parallel to Vessel Wall, opening length              d    10.6067  in
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp     1.5750  in
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 17100/20000 )
```

```
  = 0.855
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 17100/20000 )
  = 0.855
```

Weld Strength Reduction Factor [fr4]:

```
  = min( 1, Sp/Sv )
  = min( 1, 20000/20000 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 0.855, 1 )
  = 0.855
```

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

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	3.388	0.690	4.553
Area in Shell	A1	3.294	5.238	2.167
Area in Nozzle Wall	A2	1.380	1.524	1.300
Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.356	0.356	0.356
Area in Element	A5	4.389	4.389	4.389
TOTAL AREA AVAILABLE	Atot	9.419	11.506	8.211

The MAP(nc) Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 64.36 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:	11.9375	0.6299	in
Based on given Pad Diameter:	17.7170	0.1250	in
Based on Shell or Nozzle Thickness:	13.1250	0.6250	in

Area Required [A]:

```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (10.607*0.4224*1+2*0.594*0.4224*1*(1-0.855))
  = 4.553 in^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 )
  = 10.607( 1 * 0.63 - 1 * 0.4224 ) - 2 * 0.594
    ( 1 * 0.63 - 1 * 0.4224 ) *( 1 - 0.855 )
  = 2.167 in^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2/sin( alpha3 )
  = ( 2 * 1.575 ) *( 0.594 - 0.1176 ) * 0.855/sin( 80.834 )
  = 1.300 in^2
```

See ASME VIII-1 2011(a) Appendix L, L-7.7.7(b) for more information.

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

```
  = Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
  = 0.394² * 0.855 +(0 )² * 0.855 + 0.4724² * 1
```

```
  = 0.356 in^2
```

Area Available in Element [A5]:

```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 18.892 - 11.925 ) * 0.6299 * 1
  = 4.389 in^2
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, min(Curve:C, Curve:B)

Govrn. thk, tg = 0.5197, tr = 0.08798, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.1693, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve B            -4 F
```

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

Govrn. thk, tg = 0.5197, tr = 0.08798, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.1693, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve C           -35 F
```

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

Govrn. thk, tg = 0.5197, tr = 0.08798, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.1693, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve D           -55 F
```

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

Govrn. thk, tg = 0.6299, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.499, Temp. Reduction = 0 F
Attachment governing, Attachment stress = Shell stress per Code

```
 Min Metal Temp. w/o impact per UCS-66, Curve D           -50 F
```

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

Govrn. thk, tg = 0.5197, tr = 0.08798, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.1693, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve C           -35 F

 Gov. MDMT of the Nozzle                                :    -4 F
 Gov. MDMT of the Reinforcement Pad                     :   -50 F
 Gov. MDMT of the nozzle to shell joint welded assembly :    -4 F
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
 Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)     -20 F
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -20 F
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :

```
 Design Pressure/Ambient Rating = 281.74/740.00 = 0.381
```

Note: The MDMT was not reduced based on lower stress per user request.

Weld Size Calculations, Description: T1

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.5940  in
 Intermediate Calc. for pad/shell Welds    TminPad     0.6299  in
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
 Nozzle Weld          0.2500 = Min per Code 0.2786 = 0.7 * Wo in
 Pad Weld             0.3150 = 0.5*TminPad  0.3340 = 0.7 * Wp in
```

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,(4.5526 - 2.1666 + 2 * 0.594 * 0.855 *
    (1 * 0.63 - 0.4224 ) )20000 )
  = 51939.41 lbf
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.2996 + 4.3887 + 0.3559 - 0 * 0.855 ) * 20000
  = 120884.56 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.2996 + 0 + 0.1327 +( 0.6399 ) ) * 20000
  = 41445.70 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.2996 + 0 + 0.3559 + 4.3887 +( 0.6399 ) ) * 20000
  = 133682.88 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 11.925 * 0.394 * 0.49 * 17100
  = 61837. lbf
```

Shear, Pad Element Weld [Spew]:
```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 17.717 * 0.4724 * 0.49 * 20000
  = 128850. lbf
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 5.6328 ) *( 0.594 - 0 ) * 0.7 * 17100
  = 125822. lbf
```

Tension, Pad Groove Weld [Tpgw]:
```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  = (3.1416/2 ) * 11.925 * 0.6299 * 0.74 * 20000
  = 174626. lbf
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 11.925 *( 0.63 - 0 ) * 0.74 * 20000
  = 174648. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:
```
  = ( SPEW + SNW ) = ( 128850 + 125822 ) = 254672 lbf
```

Failure Path [Path 2-2]:
```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 61837 + 174626 + 174648 + 0 ) = 411111 lbf
```

Failure Path [Path 3-3]:
```
  = ( Spew + Tngw + Sinw )
  = ( 128850 + 174648 + 0 ) = 303498 lbf
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 254671  lbf, must exceed W = 51939 lbf    or W1 = 120884 lbf
 Path 2-2 = 411111  lbf, must exceed W = 51939 lbf    or W2 = 41445 lbf
 Path 3-3 = 303497  lbf, must exceed W = 51939 lbf    or W3 = 133682 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Maximum Allowable Pressure in the Operating case: 280.14 psig
```

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

```
 Nozzle is O.K. for the External Pressure: 15 psig

 Approximate Maximum Allowable Pressure New & Cold: 526.57 psig
```

Note : Checking Nozzle in plane parallel to the vessel axis.

Reinforcement CALCULATION, Description: T1

ASME Code, Section VIII, Div. 1, 2021, UG-37 to UG-45

```
 Actual Outside Diameter Used in Calculation          10.750  in.
 Actual Thickness Used in Calculation                  0.594  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)
  = 281.74*22.126/(20000*1-0.6*281.74)
  = 0.3143 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 377.46*22.126/(20000*1-0.6*377.46)
  = 0.4224 in
```

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)
  = 281.74*5.375/(17100*1+0.4*281.74)
  = 0.0880 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Mapnc]
```
  = P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = 377.46*5.375/(17100*1+0.4*377.46)
  = 0.1176 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0355 in

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl     19.1240  in
 Parallel to Vessel Wall, opening length              d      9.5620  in
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp      1.5750  in
```

UG-40, Limits of Reinforcement : [Mapnc]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl     19.1240  in
 Parallel to Vessel Wall, opening length              d      9.5620  in
```

```
Normal to Vessel Wall (Thickness Limit), pad side Tlwp     1.5750  in
```

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

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	3.060	0.623	4.111
Area in Shell	A1	2.964	4.714	1.950
Area in Nozzle Wall	A2	1.363	1.504	1.283
Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.356	0.356	0.356
Area in Element	A5	4.389	4.389	4.389
TOTAL AREA AVAILABLE	Atot	9.071	10.963	7.977

The MAP(nc) 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:	11.6250	0.6299	in
Based on given Pad Diameter:	17.7170	0.1250	in
Based on Shell or Nozzle Thickness:	11.6250	0.6250	in

Area Required [A]:

```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (9.562*0.4224*1+2*0.594*0.4224*1*(1-0.855))
  = 4.111 in^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 )
  = 9.562( 1 * 0.63 - 1 * 0.4224 ) - 2 * 0.594
    ( 1 * 0.63 - 1 * 0.4224 ) *( 1 - 0.855 )
  = 1.950 in^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 1.575 ) *( 0.594 - 0.1176 ) * 0.855
  = 1.283 in^2
```

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

```
  = Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
  = 0.394² * 0.855 +(0 )² * 0.855 + 0.4724² * 1
  = 0.356 in^2
```

Area Available in Element [A5]:

```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 17.717 - 10.75 ) * 0.6299 * 1
  = 4.389 in^2
```

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

```
Wall Thickness for Internal/External pressures       ta = 0.1176 in
Wall Thickness per UG16(b),                        tr16b = 0.0625 in
Wall Thickness, shell/head, internal pressure      trb1 = 0.3143 in
Wall Thickness                 tb1 = max(trb1, tr16b) = 0.3143 in
Wall Thickness, shell/head, external pressure      trb2 = 0.0166 in
Wall Thickness                 tb2 = max(trb2, tr16b) = 0.0625 in
Wall Thickness per table UG-45                       tb3 = 0.3190 in
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.319, max( 0.3143, 0.0625 ) ]
  = 0.3143 in
```

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

```
  = max( ta, tb )
  = max( 0.1176, 0.3143 )
  = 0.3143 in
```

Available Nozzle Neck Thickness = 0.875 * 0.594 = 0.520 in --> OK

UG-45 Minimum Nozzle Neck Thickness Requirement: [MAPnc]

```
 Wall Thickness for Internal/External pressures      ta = 0.1176 in
 Wall Thickness per UG16(b),                       tr16b = 0.0625 in
 Wall Thickness, shell/head, internal pressure     trb1 = 0.4224 in
 Wall Thickness                 tb1 = max(trb1, tr16b) = 0.4224 in
 Wall Thickness, shell/head, external pressure     trb2 = 0.0166 in
 Wall Thickness                 tb2 = max(trb2, tr16b) = 0.0625 in
 Wall Thickness per table UG-45                     tb3 = 0.3190 in
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.319, max( 0.4224, 0.0625 ) ]
  = 0.3190 in
```

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

```
  = max( ta, tb )
  = max( 0.1176, 0.319 )
  = 0.3190 in
```

Available Nozzle Neck Thickness = 0.875 * 0.594 = 0.520 in --> 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   :   4340.6,  Allowable :  17100.0 psi  Passed
 Expansion   :      0.0,  Allowable :  38409.4 psi  Passed
 Occasional  :   1067.5,  Allowable :  22743.0 psi  Passed
 Shear       :   2336.6,  Allowable :  11970.0 psi  Passed
```

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

Weld Size Calculations, Description: T1

```
 Intermediate Calc. for nozzle/shell Welds   Tmin       0.5940  in
 Intermediate Calc. for pad/shell Welds    TminPad      0.6299  in
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
 Nozzle Weld          0.2500 = Min per Code 0.2786 = 0.7 * Wo in
 Pad Weld             0.3150 = 0.5*TminPad  0.3340 = 0.7 * Wp in
```

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,(4.1114 - 1.9497 + 2 * 0.594 * 0.855 *
    (1 * 0.63 - 0.4224 ) )20000 )
  = 47452.79 lbf
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
```

```
  = ( 1.283 + 4.3887 + 0.3559 - 0 * 0.855 ) * 20000
  = 120552.66 lbf
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.283 + 0 + 0.1327 +( 0.6399 ) ) * 20000
  = 41113.79 lbf
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.283 + 0 + 0.3559 + 4.3887 +( 0.6399 ) ) * 20000
  = 133350.98 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 10.75 * 0.394 * 0.49 * 17100
  = 55746. lbf
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 17.717 * 0.4724 * 0.49 * 20000
  = 128850. lbf
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 5.078 ) *( 0.594 - 0 ) * 0.7 * 17100
  = 113429. lbf
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  = (3.1416/2 ) * 10.75 * 0.6299 * 0.74 * 20000
  = 157426. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 10.75 *( 0.63 - 0 ) * 0.74 * 20000
  = 157446. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:

```
  = ( SPEW + SNW ) = ( 128850 + 113429 ) = 242279 lbf
```

Failure Path [Path 2-2]:

```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 55746 + 157426 + 157446 + 0 ) = 370618 lbf
```

Failure Path [Path 3-3]:

```
  = ( Spew + Tngw + Sinw )
  = ( 128850 + 157446 + 0 ) = 286295 lbf
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 242278  lbf, must exceed W = 47452 lbf    or W1 = 120552 lbf
 Path 2-2 = 370617  lbf, must exceed W = 47452 lbf    or W2 = 41113 lbf
 Path 3-3 = 286295  lbf, must exceed W = 47452 lbf    or W3 = 133350 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Maximum Allowable Pressure in the Operating case: 280.14 psig
```

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

```
 Nozzle is O.K. for the External Pressure: 15 psig

 Approximate Maximum Allowable Pressure New & Cold: 537.98 psig
```

The Drop for this Nozzle is : 3.3927 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 15.5599 in

Warning:
The equations for nozzle local stress analysis pertain to radial nozzles only and this nozzle is not specified as radial. Please check the specific analysis code for all assumptions and limitations.

Input Echo, WRC297 Item 1, Description: T1 :

```
 Diameter Basis for Cylindrical Shell                     ID
 Shell Corrosion Allowance                            0.0000  in
 Shell Diameter                                       44.252  in
 Shell Thickness                                      0.6300  in
 Shell Stress Concentration Factor                     1.000
 Vessel Material                                   SA-516 70
 Vessel Cold S.I. Allowable                 Smc     20000.00  psi
 Vessel Hot  S.I. Allowable                 Smh     20000.00  psi
```

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

```
 Diameter Basis for Nozzle                                OD
 Nozzle Corrosion Allowance                           0.0000  in
 Nozzle Diameter                                      10.750  in
 Nozzle Thickness                                     0.5940  in
 Nozzle Stress Concentration Factor                    1.000
 Nozzle Material                                    SA-106 B
 Nozzle Cold S.I. Allowable                SNmc     17100.00  psi
 Nozzle Hot  S.I. Allowable                SNmh     17100.00  psi
```

Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not time-dependent for Material: SA-106 B

```
 Diameter of Reinforcing Pad                          17.717  in
 Thickness of Reinforcing Pad                         0.6299  in
```

Note:
External Forces and Moments in WRC 107/537 Convention:
These loads are assumed to be SUStained loads.

```
 Design Internal Pressure                    Dp       281.74  psig
 Radial Load                                  P     -2580.00  lbf
 Circumferential Shear                       Vc      3239.99  lbf
 Longitudinal Shear                          Vl      3239.99  lbf
 Circumferential Moment                      Mc      8020.03  ft-lb
 Longitudinal Moment                         Ml     10180.00  ft-lb
 Torsional Moment                            Mt     12960.00  ft-lb

 Include Axial Pressure Thrust                                No
 Include Pressure Stress Indices per Div. 2                   No
 Local Loads applied at end of Nozzle/Attachment              No
```

Stress Computations at the Edge of the Nozzle:

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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 10.75 + 2 * 1.65 * sqrt( 22.756( 0.63 - 0.0 ) )
  = 23.245 in
```

WRC 297 Curve Access Parameters:

```
 Vessel Mean Diameter      (D) =     45.512 in
 Nozzle Outside Diameter   (d) =     10.750 in
 Vessel Thickness used     (T) =      1.260 in
 Nozzle Thickness used     (t) =      0.594 in
 T / t                         =      2.121
 d / t                         =     18.098

Lambda = [(d/D) * sqrt(D/T)]  = 1.420

 Nr/P    =      0.094
 Mr/P    =      0.102
 M0/P    =      0.064
 N0/P    =      0.156
 MrD/Mc  =      0.202
 NrDL/Mc =      0.149
 M0d/Mc  =      0.150
 N0DL/Mc =      0.120
 MrD/Ml  =      0.148
 NrDL/Ml =      0.108
 M0D/Ml  =      0.107
 N0DL/Ml =      0.236
```

Vessel Stresses (psi):

```
 LONGITUDINAL PLANE              Au       Al       Bu       Bl
 (Stresses Normal to            Top      Top   Bottom   Bottom
 longitudinal plane)        Outside   Inside  Outside   Inside
 -----------------------------------------------------------
 Outplane Membrane (P )         254      254      254      254
 Outplane Bending  (P )         623     -623      623     -623
 Outplane Membrane (Mc)           0        0        0        0
 Outplane Bending  (Mc)           0        0        0        0
 Outplane Membrane (ML)       -1691    -1691     1691     1691
 Outplane Bending  (ML)       -4592     4592     4592    -4592
 Normal Pressure Stress        4810     5092     4810     5092
 ---------------------- -------- -------- -------- --------
 Outplane Stress Summary       -596     7624    11970     1822
```

Vessel Stresses (psi):

```
 LONGITUDINAL PLANE              Au       Al       Bu       Bl
 (Stresses parallel to          Top      Top   Bottom   Bottom
 longitudinal plane)        Outside   Inside  Outside   Inside
 -----------------------------------------------------------
 Inplane Membrane (P )          152      152      152      152
 Inplane Bending  (P )          993     -993      993     -993
 Inplane Membrane (Mc)            0        0        0        0
 Inplane Bending  (Mc)            0        0        0        0
 Inplane Membrane (ML)         -773     -773      773      773
 Inplane Bending  (ML)        -6365     6365     6365    -6365
 Inplane Pressure Stress       2405     2405     2405     2405
 ---------------------- -------- -------- -------- --------
 Inplane Stress Summary       -3588     7156    10688    -4028
```

Vessel Stresses (psi):

```
 LONGITUDINAL PLANE              Au       Al       Bu       Bl
 (Shear stress normal to        Top      Top   Bottom   Bottom
```

longitudinal plane)	Outside	Inside	Outside	Inside
Outplane Shear (Vc)	152	152	-152	-152
Outplane Shear (Vl)	0	0	0	0
Outplane Shear (Mt)	679	679	679	679
Shear Stress Summary	831	831	527	527

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stress Intensities	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Two * Max Shear Stress	3803	8253	12158	5944

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses Normal to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Outplane Membrane (P)	254	254	254	254
Outplane Bending (P)	623	-623	623	-623
Outplane Membrane (Mc)	-675	-675	675	675
Outplane Bending (Mc)	-5066	5066	5066	-5066
Outplane Membrane (ML)	0	0	0	0
Outplane Bending (ML)	0	0	0	0
Normal Pressure Stress	2405	2405	2405	2405
Outplane Stress Summary	-2459	6427	9023	-2355

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses parallel to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Inplane Membrane (P)	152	152	152	152
Inplane Bending (P)	993	-993	993	-993
Inplane Membrane (Mc)	-838	-838	838	838
Inplane Bending (Mc)	-6838	6838	6838	-6838
Inplane Membrane (ML)	0	0	0	0
Inplane Bending (ML)	0	0	0	0
Inplane Pressure Stress	4810	5092	4810	5092
Inplane Stress Summary	-1721	10251	13631	-1749

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Shear stress normal to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Outplane Shear (Vc)	0	0	0	0
Outplane Shear (Vl)	-152	-152	152	152
Torsional Shear (Mt)	679	679	679	679
Shear Stress Summary	527	527	831	831

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stress Intensities	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Two * Max Shear Stress	2733	10322	13776	2936

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Stresses in the hoop direction)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Hoop Membrane (P)	254	254	254	254
Hoop Bending (P)	0	0	0	0
Hoop Membrane (Mc)	0	0	0	0
Hoop Bending (Mc)	0	0	0	0
Hoop Membrane (ML)	-1691	-1691	1691	1691
Hoop Bending (ML)	0	0	0	0
Hoop Pressure Stress	2562	2900	2562	2900
Hoop Stress Summary	1125	1463	4507	4845

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Stresses Normal to pipe cross-section)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Axial Membrane (P)	136	136	136	136
Axial Bending (P)	2408	-2408	2408	-2408
Axial Membrane (Mc)	0	0	0	0
Axial Bending (Mc)	0	0	0	0
Axial Membrane (ML)	-2677	-2677	2677	2677
Axial Bending (ML)	-18204	18204	18204	-18204
Axial Pressure Stress	1281	1281	1281	1281
Axial Stress Summary	-17056	14536	24706	-16518

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Shear stress)	Au Outside	Al Inside	Bu Outside	Bl Inside
Shear due to (Vc)	323	323	-323	-323
Shear due to (Vl)	0	0	0	0
Shear due to Torsion	1442	1442	1442	1442
Shear Stress Summary	1765	1765	1119	1119

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Stress Intensities	Au Outside	Al Inside	Bu Outside	Bl Inside
Two * Max Shear Stress	18520	14770	24767	21479

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses in the hoop direction)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Hoop Membrane (P)	254	254	254	254
Hoop Bending (P)	0	0	0	0
Hoop Membrane (Mc)	-675	-675	675	675
Hoop Bending (Mc)	0	0	0	0
Hoop Membrane (ML)	0	0	0	0
Hoop Bending (ML)	0	0	0	0
Hoop Pressure Stress	2562	2900	2562	2900
Hoop Stress Summary	2141	2479	3491	3829

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses Normal to pipe cross-section)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside

Axial Membrane (P)	136	136	136	136
Axial Bending (P)	2408	-2408	2408	-2408
Axial Membrane (Mc)	-2109	-2109	2109	2109
Axial Bending (Mc)	-19445	19445	19445	-19445
Axial Membrane (ML)	0	0	0	0
Axial Bending (ML)	0	0	0	0
Axial Pressure Stress	1281	1281	1281	1281
Axial Stress Summary	-17729	16345	25379	-18327

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Shear stress)	Cu Outside	Cl Inside	Du Outside	Dl Inside
Shear due to (Vc)	0	0	0	0
Shear due to (Vl)	-323	-323	323	323
Shear due to Torsion	1442	1442	1442	1442
Shear Stress Summary	1119	1119	1765	1765

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Stress Intensities	Cu Outside	Cl Inside	Du Outside	Dl Inside
Two * Max Shear Stress	19995	16434	25520	22435

Stress Computations at the Edge of the Reinforcing Pad:

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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 10.75 + 2 * 1.65 * sqrt( 22.441( 0.63 - 0.0 ) )
  = 23.158 in
```

WRC 297 Curve Access Parameters:

```
 Vessel Mean Diameter      (D) =     44.882 in
 Nozzle Outside Diameter   (d) =     17.717 in
 Vessel Thickness used     (T) =      0.630 in
 Nozzle Thickness used     (t) =      4.077 in
 T / t                         =      0.155
 d / t                         =     10.000

Lambda = [(d/D) * sqrt(D/T)]  = 3.332
```

Note: Re-pad thickness is added to nozzle thickness to simulate the Re-pad.

```
 Nr/P     =      0.056
 Mr/P     =      0.098
 M0/P     =      0.029
 N0/P     =      0.050
 MrD/Mc   =      0.262
 NrDL/Mc  =      0.099
 M0d/Mc   =      0.079
 N0DL/Mc  =      0.075
 MrD/Ml   =      0.075
 NrDL/Ml  =      0.065
 M0D/Ml   =      0.022
 N0DL/Ml  =      0.059
```

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stresses Normal to	Au Top	Al Top	Bu Bottom	Bl Bottom

```
 longitudinal plane)      Outside   Inside  Outside   Inside
 ---------------------------------------------------------
 Outplane Membrane (P )       322      322      322      322
 Outplane Bending  (P )      1125    -1125     1125    -1125
 Outplane Membrane (Mc)         0        0        0        0
 Outplane Bending  (Mc)         0        0        0        0
 Outplane Membrane (ML)     -1018    -1018     1018     1018
 Outplane Bending  (ML)     -2291     2291     2291    -2291
 Normal Pressure Stress      9755    10037     9755    10037
 ---------------------- -------- -------- -------- --------
 Outplane Stress Summary     7893    10507    14511     7961
```

Vessel Stresses (psi):

```
 LONGITUDINAL PLANE             Au       Al       Bu       Bl
 (Stresses parallel to         Top      Top   Bottom   Bottom
 longitudinal plane)       Outside   Inside  Outside   Inside
 ---------------------------------------------------------
 Inplane Membrane (P )        367      367      367      367
 Inplane Bending  (P )       3811    -3811     3811    -3811
 Inplane Membrane (Mc)          0        0        0        0
 Inplane Bending  (Mc)          0        0        0        0
 Inplane Membrane (ML)      -1133    -1133     1133     1133
 Inplane Bending  (ML)      -7790     7790     7790    -7790
 Inplane Pressure Stress     4877     4877     4877     4877
 ---------------------- -------- -------- -------- --------
 Inplane Stress Summary       132     8090    17978    -5224
```

Vessel Stresses (psi):

```
 LONGITUDINAL PLANE             Au       Al       Bu       Bl
 (Shear stress normal to       Top      Top   Bottom   Bottom
 longitudinal plane)       Outside   Inside  Outside   Inside
 ---------------------------------------------------------
 Outplane  Shear  (Vc)        184      184     -184     -184
 Outplane  Shear  (Vl)          0        0        0        0
 Outplane  Shear  (Mt)        500      500      500      500
 ---------------------- -------- -------- -------- --------
 Shear Stress Summary         684      684      316      316
```

Vessel Stresses (psi):

```
 LONGITUDINAL PLANE             Au       Al       Bu       Bl
 (Stress Intensities           Top      Top   Bottom   Bottom
                           Outside   Inside  Outside   Inside
 ---------------------------------------------------------
 Two * Max Shear Stress      7952    10687    18006    13200
```

Vessel Stresses (psi):

```
 CIRCUMFERENTIAL PLANE          Cu       Cl       Du       Dl
 (Stresses Normal to          Left     Left    Right    Right
 circumferential plane)    Outside   Inside  Outside   Inside
 ---------------------------------------------------------
 Outplane Membrane (P )       322      322      322      322
 Outplane Bending  (P )      1125    -1125     1125    -1125
 Outplane Membrane (Mc)     -1024    -1024     1024     1024
 Outplane Bending  (Mc)     -6455     6455     6455    -6455
 Outplane Membrane (ML)         0        0        0        0
 Outplane Bending  (ML)         0        0        0        0
 Normal Pressure Stress      4877     4877     4877     4877
 ---------------------- -------- -------- -------- --------
 Outplane Stress Summary    -1155     9505    13803    -1357
```

Vessel Stresses (psi):

```
 CIRCUMFERENTIAL PLANE          Cu       Cl       Du       Dl
 (Stresses parallel to        Left     Left    Right    Right
 circumferential plane)    Outside   Inside  Outside   Inside
```

Inplane Membrane (P)	367	367	367	367
Inplane Bending (P)	3811	-3811	3811	-3811
Inplane Membrane (Mc)	-1348	-1348	1348	1348
Inplane Bending (Mc)	-21534	21534	21534	-21534
Inplane Membrane (ML)	0	0	0	0
Inplane Bending (ML)	0	0	0	0
Inplane Pressure Stress	9755	10037	9755	10037
Inplane Stress Summary	-8949	26779	36815	-13593

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Shear stress normal to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Outplane Shear (Vc)	0	0	0	0
Outplane Shear (Vl)	-184	-184	184	184
Torsional Shear (Mt)	500	500	500	500
Shear Stress Summary	316	316	684	684

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stress Intensities	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Two * Max Shear Stress	8961	26784	36835	13631

WRC 297 Stress Summations per ASME Sec. VIII Div. 2:

Vessel Stress Summation at Vessel-Nozzle Junction (psi):

Type of Stress Int. Location	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	4810	5092	4810	5092	4810	5092	4810	5092
Circ. Pl (SUS)	-1437	-1437	1945	1945	-686	-686	990	990
Circ. Q (SUS)	-3969	3969	5215	-5215	-5845	5845	7831	-7831
Long. Pm (SUS)	2405	2405	2405	2405	2405	2405	2405	2405
Long. Pl (SUS)	-621	-621	925	925	-421	-421	929	929
Long. Q (SUS)	-5372	5372	7358	-7358	-4443	4443	5689	-5689
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	152	152	-152	-152	-152	-152	152	152
Shear Q (SUS)	679	679	679	679	679	679	679	679
Pm (SUS)	4810	5092	4810	5092	4810	5092	4810	5092
Pm+Pl (SUS)	3387	3667	6761	7043	4134	4415	5809	6090
Pm+Pl+Q (Total)	3803	8253	12158	5944	2733	10322	13776	2936

Vessel Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	5092	20000	Passed
Pm+Pl (SUS)	7043	30000	Passed
Pm+Pl+Q (TOTAL)	13776	60000	Passed

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

WRC 297 Stress Summations per ASME Sec. VIII Div. 2:

Vessel Stress Summation at Reinforcing Pad Edge (psi):

Type of Stress Int. Location	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	9755	10037	9755	10037	9755	10037	9755	10037
Circ. Pl (SUS)	-696	-696	1340	1340	-981	-981	1715	1715
Circ. Q (SUS)	-1166	1166	3416	-3416	-17723	17723	25345	-25345
Long. Pm (SUS)	4877	4877	4877	4877	4877	4877	4877	4877
Long. Pl (SUS)	-766	-766	1500	1500	-702	-702	1346	1346
Long. Q (SUS)	-3979	3979	11601	-11601	-5330	5330	7580	-7580
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	184	184	-184	-184	-184	-184	184	184
Shear Q (SUS)	500	500	500	500	500	500	500	500
Pm (SUS)	9755	10037	9755	10037	9755	10037	9755	10037
Pm+Pl (SUS)	9065	9347	11102	11383	8781	9062	11476	11758
Pm+Pl+Q (Total)	7952	10687	18006	13200	8961	26784	36835	13631

Vessel Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	10037	20000	Passed
Pm+Pl (SUS)	11758	30000	Passed
Pm+Pl+Q (TOTAL)	36835	60000	Passed

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

WRC 297 Stress Summations per ASME Sec. VIII Div. 2:

Nozzle Stress Summation at Vessel-Nozzle Junction (psi):

Type of Stress Int. Location	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	2562	2900	2562	2900	2562	2900	2562	2900
Circ. Pl (SUS)	-1437	-1437	1945	1945	-421	-421	929	929
Circ. Q (SUS)	0	0	0	0	0	0	0	0
Long. Pm (SUS)	1281	1281	1281	1281	1281	1281	1281	1281
Long. Pl (SUS)	-2541	-2541	2813	2813	-1973	-1973	2245	2245
Long. Q (SUS)	-15796	15796	20612	-20612	-17037	17037	21853	-21853
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	323	323	-323	-323	-323	-323	323	323
Shear Q (SUS)	1442	1442	1442	1442	1442	1442	1442	1442
Pm (SUS)	2562	2900	2562	2900	2562	2900	2562	2900
Pm+Pl (SUS)	2470	2798	4683	4964	2905	3236	3831	4034


```
 ------------------------------------------------------------------
 Pm+Pl+Q (Total)|  18520  14770  24767  21479  19995  16434  25520  22435|
```

Nozzle Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	2900	17100	Passed
Pm+Pl (SUS)	4964	25650	Passed
Pm+Pl+Q (TOTAL)	25520	51300	Passed

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

Input, Nozzle Desc: V1 From: 30

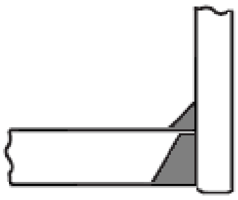
Pressure for Reinforcement Calculations	P	280.213	psig
Temperature for Internal Pressure	Temp	300	F
Design External Pressure	Pext	15.00	psig
Temperature for External Pressure	Tempex	300	F
Maximum Allowable Pressure New & Cold		377.46	psig
Parent Material [Normalized]		SA-516 70	
Parent Allowable Stress at Temperature	Sv	20000.00	psi
Parent Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Cylindrical Shell	D	44.2520	in
Design Length of Section	L	33.4646	in
Shell Finished (Minimum) Thickness	t	0.6300	in
Shell Internal Corrosion Allowance	c	0.0000	in
Shell External Corrosion Allowance	co	0.0000	in
Distance from Cylinder/Cone Centerline	L1	9.8430	in
Distance from Bottom/Left Tangent		28.96	in
User Entered Minimum Design Metal Temperature		32.00	F

Type of Element Connected to the Parent : Nozzle

Material [Normalized]		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	20000.00	psi
Allowable Stress At Ambient	Sna	20000.00	psi
Diameter Basis (for tr calc only)		Inside	
Layout Angle		-25.63	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	0.6540	in
Flange Type		Long Weld Neck	
Corrosion Allowance	can	0.0000	in
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	10.1731	in
Weld leg size between Nozzle and Pad/Shell	Wo	0.3940	in
Groove weld depth between Nozzle and Vessel	Wgnv	0.6300	in
Inside Projection	h	0.0000	in
Weld leg size, Inside Element to Shell	Wi	0.0000	in
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was MAWP + static head (to the nozzle).

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



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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: V1

ASME Code, Section VIII, Div. 1, 2021, 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)
  = 280.21*22.126/(20000*1-0.6*280.21)
  = 0.3126 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 377.46*22.126/(20000*1-0.6*377.46)
  = 0.4224 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1(exp([280.21/(20000*1]-1)
  = 0.0141 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Mapnc]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1(exp([377.46/(20000*1]-1)
  = 0.0191 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0170 in

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl     4.7976  in
Parallel to Vessel Wall                        Rn+tn+t     2.3988  in
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     1.5750  in
```

UG-40, Limits of Reinforcement : [Mapnc]
```
Parallel to Vessel Wall (Diameter Limit)            Dl     4.7976  in
Parallel to Vessel Wall                        Rn+tn+t     2.3988  in
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     1.5750  in
```

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

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	0.349	0.143	0.471
Area in Shell	A1	1.216	1.289	1.076
Area in Nozzle Wall	A2	2.188	2.178	2.171

Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.155	0.155	0.155
Area in Element	A5	0.000	0.000	0.000
TOTAL AREA AVAILABLE	Atot	3.559	3.622	3.401

The MAP(nc) Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 63.77 Degs.

The area available without a pad is Sufficient.

Area Required [A]:
= (d * tr*F + 2 * tn * tr*F * (1-fr1)) UG-37(c)
= (2.2296*0.4224*0.5+2*0.654*0.4224*0.5*(1-1))
= 0.471 in^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)
= 2.568(1 * 0.63 - 0.5 * 0.4224) - 2 * 0.654
(1 * 0.63 - 0.5 * 0.4224) *(1 - 1)
= 1.076 in^2

Area Available in Nozzle Projecting Outward [A2]:
= (2 * tlnp)(tn - trn)fr2/sin(alpha3)
= (2 * 1.575)(0.654 - 0.01905)1/sin(67.133)
= 2.171 in^2

See ASME VIII-1 2011(a) Appendix L, L-7.7.7(b) for more information.

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo^2 * fr2 + (Wi-can/0.707)^2 * fr2
= 0.394^2 * 1 +(0)^2 * 1
= 0.155 in^2

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 0.63, tr = 0.3126, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.4962, Temp. Reduction = 0 F

Min Metal Temp. w/o impact per UCS-66, Curve B 7 F

Gov. MDMT of the nozzle to shell joint welded assembly : 7 F

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c) -20 F
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b) -20 F

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 280.21/740.00 = 0.379

Note: The MDMT was not reduced based on lower stress per user request.

Weld Size Calculations, Description: V1

Intermediate Calc. for nozzle/shell Welds Tmin 0.6300 in

Results Per UW-16.1:

Required Thickness Actual Thickness

```
 Nozzle Weld          0.2500 = Min per Code 0.2786 = 0.7 * Wo in
```

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,(0.4708 - 1.0755 + 2 * 0.654 * 1 *
    (1 * 0.63 - 0.2112 ) )20000 )
  = max( 0, -1137.35) lbf
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 2.1707 + 0 + 0.1552 - 0 * 1 ) * 20000
  = 46518.49 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 2.1707 + 0 + 0.1552 +( 0.824 ) ) * 20000
  = 62999.29 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 2.1707 + 0 + 0.1552 + 0 +( 0.824 ) ) * 20000
  = 62999.29 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 3.6877 * 0.394 * 0.49 * 20000
  = 22367. lbf
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 1.4793 ) *( 0.654 - 0 ) * 0.7 * 20000
  = 42552. lbf
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 3.6877 *( 0.63 - 0 ) * 0.74 * 20000
  = 54011. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:
```
  = ( SONW + SNW ) = ( 22367 + 42552 ) = 64918 lbf
```

Failure Path [Path 2-2]:
```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 22367 + 0 + 54011 + 0 ) = 76377 lbf
```

Failure Path [Path 3-3]:
```
  = ( Sonw + Tngw + Sinw )
  = ( 22367 + 54011 + 0 ) = 76377 lbf
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 64918   lbf, must exceed W = 0 lbf        or W1 = 46518 lbf
 Path 2-2 = 76377   lbf, must exceed W = 0 lbf        or W2 = 62999 lbf
 Path 3-3 = 76377   lbf, must exceed W = 0 lbf        or W3 = 62999 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Maximum Allowable Pressure in the Operating case: 280.14 psig

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

Nozzle is O.K. for the External Pressure: 15 psig

Approximate Maximum Allowable Pressure New & Cold: 559.9 psig

Note: The M.A.P.(NC) of this junction was limited by the parent Shell/Head.

Note : Checking Nozzle in plane parallel to the vessel axis.

Reinforcement CALCULATION, Description: V1

ASME Code, Section VIII, Div. 1, 2021, 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)
  = 280.21*22.126/(20000*1-0.6*280.21)
  = 0.3126 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 377.46*22.126/(20000*1-0.6*377.46)
  = 0.4224 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1(exp([280.21/(20000*1]-1)
  = 0.0141 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Mapnc]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1(exp([377.46/(20000*1]-1)
  = 0.0191 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0170 in

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl     4.5680  in
Parallel to Vessel Wall                        Rn+tn+t     2.2840  in
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     1.5750  in
```

UG-40, Limits of Reinforcement : [Mapnc]
```
Parallel to Vessel Wall (Diameter Limit)            Dl     4.5680  in
Parallel to Vessel Wall                        Rn+tn+t     2.2840  in
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     1.5750  in
```

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

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	0.625	0.128	0.845
Area in Shell	A1	0.815	1.289	0.533
Area in Nozzle Wall	A2	2.016	2.007	2.000
Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.155	0.155	0.155
Area in Element	A5	0.000	0.000	0.000

```
 TOTAL AREA AVAILABLE      Atot |      2.986|      3.451|      2.689|
```

The MAP(nc) 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)
  = (2*0.4224*1+2*0.654*0.4224*1*(1-1))
  = 0.845 in^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 )
  = 2.568( 1 * 0.63 - 1 * 0.4224 ) - 2 * 0.654
    ( 1 * 0.63 - 1 * 0.4224 ) *( 1 - 1 )
  = 0.533 in^2
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 1.575 )( 0.654 - 0.01905 )1
  = 2.000 in^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 0.394² * 1 +( 0 )² * 1
  = 0.155 in^2
```

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

```
 Wall Thickness for Internal/External pressures      ta = 0.0191 in
 Wall Thickness per UG16(b),                       tr16b = 0.0625 in
 Wall Thickness, shell/head, internal pressure     trb1 = 0.3126 in
 Wall Thickness                  tb1 = max(trb1, tr16b) = 0.3126 in
 Wall Thickness, shell/head, external pressure     trb2 = 0.0166 in
 Wall Thickness                  tb2 = max(trb2, tr16b) = 0.0625 in
 Wall Thickness per table UG-45                     tb3 = 0.1890 in
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.189, max( 0.3126, 0.0625 ) ]
  = 0.1890 in
```

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

```
  = max( ta, tb )
  = max( 0.01905, 0.189 )
  = 0.1890 in
```

Available Nozzle Neck Thickness = 0.6540 in --> OK

UG-45 Minimum Nozzle Neck Thickness Requirement: [MAPnc]

```
 Wall Thickness for Internal/External pressures      ta = 0.0191 in
 Wall Thickness per UG16(b),                       tr16b = 0.0625 in
 Wall Thickness, shell/head, internal pressure     trb1 = 0.4224 in
 Wall Thickness                  tb1 = max(trb1, tr16b) = 0.4224 in
 Wall Thickness, shell/head, external pressure     trb2 = 0.0166 in
 Wall Thickness                  tb2 = max(trb2, tr16b) = 0.0625 in
 Wall Thickness per table UG-45                     tb3 = 0.1890 in
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.189, max( 0.4224, 0.0625 ) ]
```

```
  = 0.1890 in
```

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

```
  = max( ta, tb )
  = max( 0.01905, 0.189 )
  = 0.1890 in
```

Available Nozzle Neck Thickness = 0.6540 in --> OK

Weld Size Calculations, Description: V1

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.6300  in
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
 Nozzle Weld         0.2500 = Min per Code 0.2786 = 0.7 * Wo in
```

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,(0.8447 - 0.5332 + 2 * 0.654 * 1 *
    (1 * 0.63 - 0.4224 ) )20000 )
  = 11662.07 lbf
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 2 + 0 + 0.1552 - 0 * 1 ) * 20000
  = 43106.44 lbf
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 2 + 0 + 0.1552 +( 0.824 ) ) * 20000
  = 59587.24 lbf
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 2  + 0 + 0.1552 + 0 +( 0.824 ) ) * 20000
  = 59587.24 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 3.308 * 0.394 * 0.49 * 20000
  = 20064. lbf
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 1.327 ) *( 0.654 - 0 ) * 0.7 * 20000
  = 38170. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 3.308 *( 0.63 - 0 ) * 0.74 * 20000
  = 48449. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:

```
  = ( SONW + SNW ) = ( 20064 + 38170 ) = 58234 lbf
```

Failure Path [Path 2-2]:

```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 20064 + 0 + 48449 + 0 ) = 68513 lbf
```

Failure Path [Path 3-3]:

```
  = ( Sonw + Tngw + Sinw )
  = ( 20064 + 48449 + 0 ) = 68513 lbf
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 58233   lbf, must exceed W = 11662 lbf    or W1 = 43106 lbf
 Path 2-2 = 68512   lbf, must exceed W = 11662 lbf    or W2 = 59587 lbf
 Path 3-3 = 68512   lbf, must exceed W = 11662 lbf    or W3 = 59587 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Maximum Allowable Pressure in the Operating case: 280.14 psig
```

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

```
 Nozzle is O.K. for the External Pressure: 15 psig

 Approximate Maximum Allowable Pressure New & Cold: 559.9 psig
```

Note: The M.A.P.(NC) of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 0.9116 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 11.7857 in

Input, Nozzle Desc: D1 From: 30

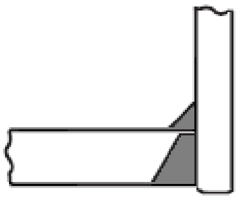
Pressure for Reinforcement Calculations	P	281.724	psig
Temperature for Internal Pressure	Temp	300	F
Design External Pressure	Pext	15.00	psig
Temperature for External Pressure	Tempex	300	F
Maximum Allowable Pressure New & Cold		377.46	psig
Parent Material [Normalized]		SA-516 70	
Parent Allowable Stress at Temperature	Sv	20000.00	psi
Parent Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Cylindrical Shell	D	44.2520	in
Design Length of Section	L	33.4646	in
Shell Finished (Minimum) Thickness	t	0.6300	in
Shell Internal Corrosion Allowance	c	0.0000	in
Shell External Corrosion Allowance	co	0.0000	in
Distance from Cylinder/Cone Centerline	L1	9.8425	in
Distance from Bottom/Left Tangent		28.96	in
User Entered Minimum Design Metal Temperature		32.00	F

Type of Element Connected to the Parent : Nozzle

Material [Normalized]		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	20000.00	psi
Allowable Stress At Ambient	Sna	20000.00	psi
Diameter Basis (for tr calc only)		Inside	
Layout Angle		205.63	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	0.6540	in
Flange Type		Long Weld Neck	
Corrosion Allowance	can	0.0000	in
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	10.1730	in
Weld leg size between Nozzle and Pad/Shell	Wo	0.3950	in
Groove weld depth between Nozzle and Vessel	Wgnv	0.6300	in
Inside Projection	h	0.0000	in
Weld leg size, Inside Element to Shell	Wi	0.0000	in
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was MAWP + static head (to the nozzle).

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



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

Note : Checking Nozzle 90 degrees to the Longitudinal axis.

Reinforcement CALCULATION, Description: D1

ASME Code, Section VIII, Div. 1, 2021, 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)
  = 281.72*22.126/(20000*1-0.6*281.72)
  = 0.3143 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 377.46*22.126/(20000*1-0.6*377.46)
  = 0.4224 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1(exp([281.72/(20000*1]-1)
  = 0.0142 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Mapnc]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1(exp([377.46/(20000*1]-1)
  = 0.0191 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0170 in

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl     4.7975  in
Parallel to Vessel Wall                        Rn+tn+t     2.3988  in
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     1.5750  in
```

UG-40, Limits of Reinforcement : [Mapnc]
```
Parallel to Vessel Wall (Diameter Limit)            Dl     4.7975  in
Parallel to Vessel Wall                        Rn+tn+t     2.3988  in
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     1.5750  in
```

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

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	0.350	0.143	0.471
Area in Shell	A1	1.214	1.289	1.076
Area in Nozzle Wall	A2	2.187	2.178	2.171

Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.156	0.156	0.156
Area in Element	A5	0.000	0.000	0.000
TOTAL AREA AVAILABLE	Atot	3.558	3.623	3.402

The MAP(nc) Case Governs the Analysis.

```
 Nozzle Angle Used in Area Calculations                    63.77  Degs.
```

The area available without a pad is Sufficient.

Area Required [A]:
```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (2.2295*0.4224*0.5+2*0.654*0.4224*0.5*(1-1))
  = 0.471 in^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 )
  = 2.568( 1 * 0.63 - 0.5 * 0.4224 ) - 2 * 0.654
    ( 1 * 0.63 - 0.5 * 0.4224 ) *( 1 - 1 )
  = 1.076 in^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2/sin( alpha3 )
  = ( 2 * 1.575 )( 0.654 - 0.01905 )1/sin( 67.134 )
  = 2.171 in^2
```

See ASME VIII-1 2011(a) Appendix L, L-7.7.7(b) for more information.

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 0.395² * 1 +( 0 )² * 1
  = 0.156 in^2
```

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 0.63, tr = 0.3143, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.4989, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              7 F

 Gov. MDMT of the nozzle to shell joint welded assembly :    7 F
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
 Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)     -20 F
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -20 F
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
```
 Design Pressure/Ambient Rating = 281.72/740.00 = 0.381
```

Note: The MDMT was not reduced based on lower stress per user request.

Weld Size Calculations, Description: D1

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.6300   in
```

Results Per UW-16.1:
```
                       Required Thickness    Actual Thickness
```

```
 Nozzle Weld          0.2500 = Min per Code 0.2793 = 0.7 * Wo in
```

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,(0.4708 - 1.0755 + 2 * 0.654 * 1 *
    (1 * 0.63 - 0.2112 ) )20000 )
  = max( 0, -1137.45) lbf
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 2.1707 + 0 + 0.156 - 0 * 1 ) * 20000
  = 46533.86 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 2.1707 + 0 + 0.156 +( 0.824 ) ) * 20000
  = 63014.66 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 2.1707 + 0 + 0.156 + 0 +( 0.824 ) ) * 20000
  = 63014.66 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 3.6877 * 0.395 * 0.49 * 20000
  = 22423. lbf
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 1.4793 ) *( 0.654 - 0 ) * 0.7 * 20000
  = 42551. lbf
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 3.6877 *( 0.63 - 0 ) * 0.74 * 20000
  = 54010. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:
```
  = ( SONW + SNW ) = ( 22423 + 42551 ) = 64974 lbf
```

Failure Path [Path 2-2]:
```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 22423 + 0 + 54010 + 0 ) = 76433 lbf
```

Failure Path [Path 3-3]:
```
  = ( Sonw + Tngw + Sinw )
  = ( 22423 + 54010 + 0 ) = 76433 lbf
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 64974   lbf, must exceed W = 0 lbf        or W1 = 46533 lbf
 Path 2-2 = 76433   lbf, must exceed W = 0 lbf        or W2 = 63014 lbf
 Path 3-3 = 76433   lbf, must exceed W = 0 lbf        or W3 = 63014 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Maximum Allowable Pressure in the Operating case: 280.14 psig

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

Nozzle is O.K. for the External Pressure: 15 psig

Approximate Maximum Allowable Pressure New & Cold: 559.9 psig

Note: The M.A.P.(NC) of this junction was limited by the parent Shell/Head.

Note : Checking Nozzle in plane parallel to the vessel axis.

Reinforcement CALCULATION, Description: D1

ASME Code, Section VIII, Div. 1, 2021, 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)
  = 281.72*22.126/(20000*1-0.6*281.72)
  = 0.3143 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]

```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 377.46*22.126/(20000*1-0.6*377.46)
  = 0.4224 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Int. Press]

```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1(exp([281.72/(20000*1]-1)
  = 0.0142 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Mapnc]

```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1(exp([377.46/(20000*1]-1)
  = 0.0191 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0170 in

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl     4.5680  in
Parallel to Vessel Wall                         Rn+tn+t     2.2840  in
Normal to Vessel Wall (Thickness Limit), no pad    Tlnp     1.5750  in
```

UG-40, Limits of Reinforcement : [Mapnc]

```
Parallel to Vessel Wall (Diameter Limit)            Dl     4.5680  in
Parallel to Vessel Wall                         Rn+tn+t     2.2840  in
Normal to Vessel Wall (Thickness Limit), no pad    Tlnp     1.5750  in
```

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

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	0.629	0.128	0.845
Area in Shell	A1	0.811	1.289	0.533
Area in Nozzle Wall	A2	2.015	2.007	2.000
Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.156	0.156	0.156
Area in Element	A5	0.000	0.000	0.000

```
 TOTAL AREA AVAILABLE      Atot |      2.982|      3.452|      2.689|
```

The MAP(nc) 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)
  = (2*0.4224*1+2*0.654*0.4224*1*(1-1))
  = 0.845 in^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 )
  = 2.568( 1 * 0.63 - 1 * 0.4224 ) - 2 * 0.654
    ( 1 * 0.63 - 1 * 0.4224 ) *( 1 - 1 )
  = 0.533 in^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 1.575 )( 0.654 - 0.01905 )1
  = 2.000 in^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 0.395² * 1 +( 0 )² * 1
  = 0.156 in^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 0.0191 in
 Wall Thickness per UG16(b),                       tr16b = 0.0625 in
 Wall Thickness, shell/head, internal pressure      trb1 = 0.3143 in
 Wall Thickness                  tb1 = max(trb1, tr16b) = 0.3143 in
 Wall Thickness, shell/head, external pressure      trb2 = 0.0166 in
 Wall Thickness                  tb2 = max(trb2, tr16b) = 0.0625 in
 Wall Thickness per table UG-45                      tb3 = 0.1890 in
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.189, max( 0.3143, 0.0625 ) ]
  = 0.1890 in
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 0.01905, 0.189 )
  = 0.1890 in
```

Available Nozzle Neck Thickness = 0.6540 in --> OK

UG-45 Minimum Nozzle Neck Thickness Requirement: [MAPnc]
```
 Wall Thickness for Internal/External pressures      ta = 0.0191 in
 Wall Thickness per UG16(b),                       tr16b = 0.0625 in
 Wall Thickness, shell/head, internal pressure      trb1 = 0.4224 in
 Wall Thickness                  tb1 = max(trb1, tr16b) = 0.4224 in
 Wall Thickness, shell/head, external pressure      trb2 = 0.0166 in
 Wall Thickness                  tb2 = max(trb2, tr16b) = 0.0625 in
 Wall Thickness per table UG-45                      tb3 = 0.1890 in
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.189, max( 0.4224, 0.0625 ) ]
```

```
  = 0.1890 in
```

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

```
  = max( ta, tb )
  = max( 0.01905, 0.189 )
  = 0.1890 in
```

Available Nozzle Neck Thickness = 0.6540 in --> OK

Weld Size Calculations, Description: D1

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.6300  in
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
 Nozzle Weld          0.2500 = Min per Code 0.2793 = 0.7 * Wo in
```

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,(0.8447 - 0.5332 + 2 * 0.654 * 1 *
    (1 * 0.63 - 0.4224 ) )20000 )
  = 11662.07 lbf
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 2 + 0 + 0.156 - 0 * 1 ) * 20000
  = 43122.22 lbf
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 2 + 0 + 0.156 +( 0.824 ) ) * 20000
  = 59603.02 lbf
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 2  + 0 + 0.156 + 0 +( 0.824 ) ) * 20000
  = 59603.02 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 3.308 * 0.395 * 0.49 * 20000
  = 20114. lbf
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 1.327 ) *( 0.654 - 0 ) * 0.7 * 20000
  = 38170. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 3.308 *( 0.63 - 0 ) * 0.74 * 20000
  = 48449. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:

```
  = ( SONW + SNW ) = ( 20114 + 38170 ) = 58285 lbf
```

Failure Path [Path 2-2]:

```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 20114 + 0 + 48449 + 0 ) = 68564 lbf
```

Failure Path [Path 3-3]:

```
  = ( Sonw + Tngw + Sinw )
  = ( 20114 + 48449 + 0 ) = 68564 lbf
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 58284   lbf, must exceed W = 11662 lbf    or W1 = 43122 lbf
 Path 2-2 = 68563   lbf, must exceed W = 11662 lbf    or W2 = 59603 lbf
 Path 3-3 = 68563   lbf, must exceed W = 11662 lbf    or W3 = 59603 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Maximum Allowable Pressure in the Operating case: 280.14 psig
```

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

```
 Nozzle is O.K. for the External Pressure: 15 psig

 Approximate Maximum Allowable Pressure New & Cold: 559.9 psig
```

Note: The M.A.P.(NC) of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 0.9115 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 11.7856 in

Input, Nozzle Desc: Aux1   **Parent: T1**

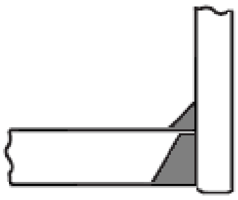
Pressure for Reinforcement Calculations	P	281.957	psig
Temperature for Internal Pressure	Temp	300	F
Design External Pressure	Pext	15.00	psig
Temperature for External Pressure	Tempex	300	F
Maximum Allowable Pressure New & Cold		377.46	psig
Parent Material		SA-106 B	
Parent Allowable Stress at Temperature	Sv	17100.00	psi
Parent Allowable Stress At Ambient	Sva	17100.00	psi
Inside Diameter of Cylindrical Shell	D	9.5620	in
Design Length of Section	L	11.4795	in
Shell Finished (Minimum) Thickness	t	0.5940	in
Shell Internal Corrosion Allowance	c	0.0000	in
Shell External Corrosion Allowance	co	0.0000	in
User Entered Minimum Design Metal Temperature		32.00	F

Type of Element Connected to the Parent : Nozzle

Material [Normalized]		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	20000.00	psi
Allowable Stress At Ambient	Sna	20000.00	psi
Diameter Basis (for tr calc only)		Inside	
Layout Angle		90.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	0.6540	in
Flange Type		Long Weld Neck	
Corrosion Allowance	can	0.0000	in
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	9.5870	in
Weld leg size between Nozzle and Pad/Shell	Wo	0.3940	in
Groove weld depth between Nozzle and Vessel	Wgnv	0.5940	in
Inside Projection	h	0.0000	in
Weld leg size, Inside Element to Shell	Wi	0.0000	in
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was MAWP + static head (to the nozzle).

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



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

Reinforcement CALCULATION, Description: Aux1

ASME Code, Section VIII, Div. 1, 2021, 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)
  = 281.96*4.781/(17100*1-0.6*281.96)
  = 0.0796 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 377.46*4.781/(17100*1-0.6*377.46)
  = 0.1069 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1(exp([281.96/(20000*1]-1)
  = 0.0142 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Mapnc]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1(exp([377.46/(20000*1]-1)
  = 0.0191 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0166 in

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl     4.4960  in
 Parallel to Vessel Wall                        Rn+tn+t     2.2480  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     1.4850  in
```

UG-40, Limits of Reinforcement : [Mapnc]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl     4.4960  in
 Parallel to Vessel Wall                        Rn+tn+t     2.2480  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     1.4850  in
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 20000/17100 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 20000/17100 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

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

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	0.159	0.036	0.214
Area in Shell	A1	1.284	1.394	1.216
Area in Nozzle Wall	A2	1.900	1.893	1.886
Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.155	0.155	0.155
Area in Element	A5	0.000	0.000	0.000
TOTAL AREA AVAILABLE	Atot	3.339	3.442	3.257

The MAP(nc) 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)
  = (2*0.1069*1+2*0.654*0.1069*1*(1-1))
  = 0.214 in^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 )
  = 2.496( 1 * 0.594 - 1 * 0.1069 ) - 2 * 0.654
    ( 1 * 0.594 - 1 * 0.1069 ) *( 1 - 1 )
  = 1.216 in^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 1.485 )( 0.654 - 0.01905 )1
  = 1.886 in^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 0.394² * 1 +( 0 )² * 1
  = 0.155 in^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures       ta = 0.0191 in
 Wall Thickness per UG16(b),                        tr16b = 0.0625 in
 Wall Thickness, shell/head, internal pressure      trb1 = 0.0796 in
 Wall Thickness                  tb1 = max(trb1, tr16b) = 0.0796 in
 Wall Thickness                  tb2 = max(trb2, tr16b) = 0.0625 in
 Wall Thickness per table UG-45                      tb3 = 0.1890 in
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.189, max( 0.07962, 0.0625 ) ]
  = 0.0796 in
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 0.01905, 0.07962 )
  = 0.0796 in
```

Available Nozzle Neck Thickness = 0.6540 in --> OK

UG-45 Minimum Nozzle Neck Thickness Requirement: [MAPnc]

```
Wall Thickness for Internal/External pressures      ta = 0.0191 in
Wall Thickness per UG16(b),                       tr16b = 0.0625 in
Wall Thickness, shell/head, internal pressure     trb1 = 0.1069 in
Wall Thickness                 tb1 = max(trb1, tr16b) = 0.1069 in
Wall Thickness                 tb2 = max(trb2, tr16b) = 0.0625 in
Wall Thickness per table UG-45                     tb3 = 0.1890 in
```

Determine Nozzle Thickness candidate [tb]:

```
= min[ tb3, max( tb1,tb2) ]
= min[ 0.189, max( 0.1069, 0.0625 ) ]
= 0.1069 in
```

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

```
= max( ta, tb )
= max( 0.01905, 0.1069 )
= 0.1069 in
```

Available Nozzle Neck Thickness = 0.6540 in --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 0.594, tr = 0.07962, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.134, Temp. Reduction = 0 F

```
Min Metal Temp. w/o impact per UCS-66, Curve B              3 F

Gov. MDMT of the nozzle to shell joint welded assembly :    3 F
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)     -20 F
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -20 F
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 281.96/740.00 = 0.381

Note: The MDMT was not reduced based on lower stress per user request.

Weld Size Calculations, Description: Aux1

```
Intermediate Calc. for nozzle/shell Welds   Tmin      0.5940  in
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	0.2500 = Min per Code	0.2786 = 0.7 * Wo in

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,(0.2139 - 1.2157 + 2 * 0.654 * 1 *
  (1 * 0.594 - 0.1069 ) )17100 )
= max( 0, -6236.64) lbf
```

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

Weld Load [W1]:

```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
```

```
  = ( 1.8858 + 0 + 0.1552 - 0 * 1 ) * 17100
  = 34901.63 lbf
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.8858 + 0 + 0.1552 +( 0.777 ) ) * 17100
  = 48187.51 lbf
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.8858 + 0 + 0.1552 + 0 +( 0.777 ) ) * 17100
  = 48187.51 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 3.308 * 0.394 * 0.49 * 17100
  = 17154. lbf
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 1.327 ) *( 0.654 - 0 ) * 0.7 * 20000
  = 38170. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 3.308 *( 0.594 - 0 ) * 0.74 * 20000
  = 45681. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:

```
  = ( SONW + SNW ) = ( 17154 + 38170 ) = 55325 lbf
```

Failure Path [Path 2-2]:

```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 17154 + 0 + 45681 + 0 ) = 62835 lbf
```

Failure Path [Path 3-3]:

```
  = ( Sonw + Tngw + Sinw )
  = ( 17154 + 45681 + 0 ) = 62835 lbf
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 55324   lbf, must exceed W = 0 lbf        or W1 = 34901 lbf
 Path 2-2 = 62835   lbf, must exceed W = 0 lbf        or W2 = 48187 lbf
 Path 3-3 = 62835   lbf, must exceed W = 0 lbf        or W3 = 48187 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Maximum Allowable Pressure in the Operating case: 1977.1 psig
```

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

```
 Nozzle is O.K. for the External Pressure: 15 psig

 Approximate Maximum Allowable Pressure New & Cold: 1977.1 psig
```

Note: The M.A.P.(NC) of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 0.2952 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 10.4762 in

Input, Nozzle Desc: Aux2 Parent: T2

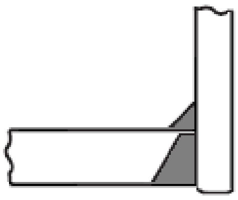
Pressure for Reinforcement Calculations	P	280.418	psig
Temperature for Internal Pressure	Temp	300	F
Design External Pressure	Pext	15.00	psig
Temperature for External Pressure	Tempex	300	F
Maximum Allowable Pressure New & Cold		377.46	psig
Parent Material		SA-106 B	
Parent Allowable Stress at Temperature	Sv	17100.00	psi
Parent Allowable Stress At Ambient	Sva	17100.00	psi
Inside Diameter of Cylindrical Shell	D	9.5620	in
Design Length of Section	L	11.4795	in
Shell Finished (Minimum) Thickness	t	0.5940	in
Shell Internal Corrosion Allowance	c	0.0000	in
Shell External Corrosion Allowance	co	0.0000	in
User Entered Minimum Design Metal Temperature		32.00	F

Type of Element Connected to the Parent : Nozzle

Material [Normalized]		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	20000.00	psi
Allowable Stress At Ambient	Sna	20000.00	psi
Diameter Basis (for tr calc only)		Inside	
Layout Angle		90.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	0.6540	in
Flange Type		Long Weld Neck	
Corrosion Allowance	can	0.0000	in
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	9.5870	in
Weld leg size between Nozzle and Pad/Shell	Wo	0.3940	in
Groove weld depth between Nozzle and Vessel	Wgnv	0.5940	in
Inside Projection	h	0.0000	in
Weld leg size, Inside Element to Shell	Wi	0.0000	in
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was MAWP + static head (to the nozzle).

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



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

Reinforcement CALCULATION, Description: Aux2

ASME Code, Section VIII, Div. 1, 2021, 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)
  = 280.42*4.781/(17100*1-0.6*280.42)
  = 0.0792 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 377.46*4.781/(17100*1-0.6*377.46)
  = 0.1069 in
```

Reqd thk per App. 1 of Nozzle Wall, trn   [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1(exp([280.42/(20000*1]-1)
  = 0.0141 in
```

Reqd thk per App. 1 of Nozzle Wall, trn   [Mapnc]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1(exp([377.46/(20000*1]-1)
  = 0.0191 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0166 in

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl     4.4960  in
 Parallel to Vessel Wall                       Rn+tn+t     2.2480  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     1.4850  in
```

UG-40, Limits of Reinforcement : [Mapnc]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl     4.4960  in
 Parallel to Vessel Wall                       Rn+tn+t     2.2480  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     1.4850  in
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 20000/17100 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 20000/17100 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
 = min(fr2, fr4)
 = min(1, 1)
 = 1.000

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

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	0.158	0.036	0.214
Area in Shell	A1	1.285	1.394	1.216
Area in Nozzle Wall	A2	1.900	1.893	1.886
Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.155	0.155	0.155
Area in Element	A5	0.000	0.000	0.000
TOTAL AREA AVAILABLE	Atot	3.341	3.442	3.257

The MAP(nc) 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)
 = (2*0.1069*1+2*0.654*0.1069*1*(1-1))
 = 0.214 in^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)
 = 2.496(1 * 0.594 - 1 * 0.1069) - 2 * 0.654
 (1 * 0.594 - 1 * 0.1069) *(1 - 1)
 = 1.216 in^2

Area Available in Nozzle Projecting Outward [A2]:
 = (2 * tlnp)(tn - trn)fr2
 = (2 * 1.485)(0.654 - 0.01905)1
 = 1.886 in^2

Area Available in Inward Weld + Outward Weld [A41 + A43]:
 = Wo² * fr2 + (Wi-can/0.707)² * fr2
 = 0.394² * 1 +(0)² * 1
 = 0.155 in^2

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

Wall Thickness for Internal/External pressures ta = 0.0191 in
Wall Thickness per UG16(b), tr16b = 0.0625 in
Wall Thickness, shell/head, internal pressure trb1 = 0.0792 in
Wall Thickness tb1 = max(trb1, tr16b) = 0.0792 in
Wall Thickness tb2 = max(trb2, tr16b) = 0.0625 in
Wall Thickness per table UG-45 tb3 = 0.1890 in

Determine Nozzle Thickness candidate [tb]:
 = min[tb3, max(tb1,tb2)]
 = min[0.189, max(0.07918, 0.0625)]
 = 0.0792 in

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
 = max(ta, tb)
 = max(0.01905, 0.07918)
 = 0.0792 in

Available Nozzle Neck Thickness = 0.6540 in --> OK

UG-45 Minimum Nozzle Neck Thickness Requirement: [MAPnc]

```
Wall Thickness for Internal/External pressures       ta = 0.0191 in
Wall Thickness per UG16(b),                        tr16b = 0.0625 in
Wall Thickness, shell/head, internal pressure       trb1 = 0.1069 in
Wall Thickness                  tb1 = max(trb1, tr16b) = 0.1069 in
Wall Thickness                  tb2 = max(trb2, tr16b) = 0.0625 in
Wall Thickness per table UG-45                       tb3 = 0.1890 in
```

Determine Nozzle Thickness candidate [tb]:

```
= min[ tb3, max( tb1,tb2) ]
= min[ 0.189, max( 0.1069, 0.0625 ) ]
= 0.1069 in
```

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

```
= max( ta, tb )
= max( 0.01905, 0.1069 )
= 0.1069 in
```

Available Nozzle Neck Thickness = 0.6540 in --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 0.594, tr = 0.07918, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.1333, Temp. Reduction = 0 F

```
Min Metal Temp. w/o impact per UCS-66, Curve B              3 F

Gov. MDMT of the nozzle to shell joint welded assembly :    3 F
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)     -20 F
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -20 F
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :

```
Design Pressure/Ambient Rating = 280.42/740.00 = 0.379
```

Note: The MDMT was not reduced based on lower stress per user request.

Weld Size Calculations, Description: Aux2

```
Intermediate Calc. for nozzle/shell Welds   Tmin      0.5940   in
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	0.2500 = Min per Code	0.2786 = 0.7 * Wo in

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,(0.2139 - 1.2157 + 2 * 0.654 * 1 *
  (1 * 0.594 - 0.1069 ) )17100 )
= max( 0, -6236.64) lbf
```

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

Weld Load [W1]:

```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
```

```
  = ( 1.8858 + 0 + 0.1552 - 0 * 1 ) * 17100
  = 34901.63 lbf
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.8858 + 0 + 0.1552 +( 0.777 ) ) * 17100
  = 48187.51 lbf
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.8858 + 0 + 0.1552 + 0 +( 0.777 ) ) * 17100
  = 48187.51 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 3.308 * 0.394 * 0.49 * 17100
  = 17154. lbf
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 1.327 ) *( 0.654 - 0 ) * 0.7 * 20000
  = 38170. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 3.308 *( 0.594 - 0 ) * 0.74 * 20000
  = 45681. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:

```
  = ( SONW + SNW ) = ( 17154 + 38170 ) = 55325 lbf
```

Failure Path [Path 2-2]:

```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 17154 + 0 + 45681 + 0 ) = 62835 lbf
```

Failure Path [Path 3-3]:

```
  = ( Sonw + Tngw + Sinw )
  = ( 17154 + 45681 + 0 ) = 62835 lbf
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 55324   lbf, must exceed W = 0 lbf        or W1 = 34901 lbf
 Path 2-2 = 62835   lbf, must exceed W = 0 lbf        or W2 = 48187 lbf
 Path 3-3 = 62835   lbf, must exceed W = 0 lbf        or W3 = 48187 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Maximum Allowable Pressure in the Operating case: 1977.1 psig
```

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

```
 Nozzle is O.K. for the External Pressure: 15 psig

 Approximate Maximum Allowable Pressure New & Cold: 1977.1 psig
```

Note: The M.A.P.(NC) of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 0.2952 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 10.4762 in

Input, Nozzle Desc: S1 From: 60

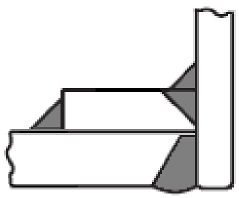
Pressure for Reinforcement Calculations	P	280.140	psig
Temperature for Internal Pressure	Temp	330	F
Design External Pressure	Pext	15.00	psig
Temperature for External Pressure	Tempex	300	F
Maximum Allowable Pressure New & Cold		377.46	psig
Parent Material [Normalized]		SA-516 70	
Parent Allowable Stress at Temperature	Sv	20000.00	psi
Parent Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Cylindrical Shell	D	44.2520	in
Design Length of Section	L	214.3491	in
Shell Finished (Minimum) Thickness	t	0.6300	in
Shell Internal Corrosion Allowance	c	0.0000	in
Shell External Corrosion Allowance	co	0.0000	in
Distance from Bottom/Left Tangent		77.82	in
User Entered Minimum Design Metal Temperature		32.00	F

Type of Element Connected to the Parent : Nozzle

Material [Normalized]		SA-516 70	
Material UNS Number		K02700	
Material Specification/Type		Plate	
Allowable Stress at Temperature	Sn	20000.00	psi
Allowable Stress At Ambient	Sna	20000.00	psi
Diameter Basis (for tr calc only)		Outside	
Layout Angle		0.00	deg
Diameter		12.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	0.5512	in
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	0.0000	in
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	10.1241	in
Weld leg size between Nozzle and Pad/Shell	Wo	0.3940	in
Groove weld depth between Nozzle and Vessel	Wgnv	0.6300	in
Inside Projection	h	0.0000	in
Weld leg size, Inside Element to Shell	Wi	0.0000	in
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	20000.00	psi
Pad Allowable Stress At Ambient	Spa	20000.00	psi
Diameter of Pad along vessel surface	Dp	19.6850	in
Thickness of Pad	te	0.6299	in
Weld leg size between Pad and Shell	Wp	0.4724	in
Groove weld depth between Pad and Nozzle	Wgpn	0.6299	in
Reinforcing Pad Width		3.8425	in
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was MAWP + static head (to the nozzle).

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, 2021, UG-37 to UG-45

```
 Actual Outside Diameter Used in Calculation           12.000  in.
 Actual Thickness Used in Calculation                   0.551  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)
  = 280.14*22.126/(20000*1-0.6*280.14)
  = 0.3125 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 377.46*22.126/(20000*1-0.6*377.46)
  = 0.4224 in
```

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)
  = 280.14*6/(20000*1+0.4*280.14)
  = 0.0836 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Mapnc]
```
  = P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = 377.46*6/(20000*1+0.4*377.46)
  = 0.1124 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0357 in

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)             Dl    21.7953  in
 Parallel to Vessel Wall, opening length               d    10.8976  in
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp      1.5750  in
```

UG-40, Limits of Reinforcement : [Mapnc]
```
 Parallel to Vessel Wall (Diameter Limit)             Dl    21.7953  in
 Parallel to Vessel Wall, opening length               d    10.8976  in
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp      1.5750  in
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 20000/20000 )
  = 1.000
```

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

```
  = min( 1, 20000/20000 )
  = 1.000
```

Weld Strength Reduction Factor [fr4]:

```
  = min( 1, Sp/Sv )
  = min( 1, 20000/20000 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

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

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	3.406	1.522	4.603
Area in Shell	A1	3.460	3.821	2.263
Area in Nozzle Wall	A2	1.473	1.624	1.382
Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.378	0.378	0.378
Area in Element	A5	4.841	4.841	4.841
TOTAL AREA AVAILABLE	Atot	10.152	10.664	8.864

The MAP(nc) 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:	12.9375	0.6299	in
Based on given Pad Diameter:	19.6850	0.1250	in
Based on Shell or Nozzle Thickness:	13.0625	0.5625	in

Area Required [A]:

```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (10.898*0.4224*1+2*0.5512*0.4224*1*(1-1))
  = 4.603 in^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 )
  = 10.898( 1 * 0.63 - 1 * 0.4224 ) - 2 * 0.5512
    ( 1 * 0.63 - 1 * 0.4224 ) *( 1 - 1 )
  = 2.263 in^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 1.575 ) *( 0.5512 - 0.1124 ) * 1
  = 1.382 in^2
```

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

```
  = Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
  = 0.394² * 1 +(0 )² * 1 + 0.4724² * 1
  = 0.378 in^2
```

Area Available in Element [A5]:

```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 19.685 - 12 ) * 0.6299 * 1
  = 4.841 in^2
```

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

```
Wall Thickness for Internal/External pressures      ta = 0.1124 in
Wall Thickness per UG16(b),                       tr16b = 0.0625 in
Wall Thickness, shell/head, internal pressure     trb1 = 0.3125 in
Wall Thickness                 tb1 = max(trb1, tr16b) = 0.3125 in
Wall Thickness, shell/head, external pressure     trb2 = 0.0166 in
Wall Thickness                 tb2 = max(trb2, tr16b) = 0.0625 in
Wall Thickness per table UG-45                     tb3 = 0.3280 in
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.328, max( 0.3125, 0.0625 ) ]
  = 0.3125 in
```

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

```
  = max( ta, tb )
  = max( 0.1124, 0.3125 )
  = 0.3125 in
```

Available Nozzle Neck Thickness = 0.5512 in --> OK

UG-45 Minimum Nozzle Neck Thickness Requirement: [MAPnc]

```
Wall Thickness for Internal/External pressures      ta = 0.1124 in
Wall Thickness per UG16(b),                       tr16b = 0.0625 in
Wall Thickness, shell/head, internal pressure     trb1 = 0.4224 in
Wall Thickness                 tb1 = max(trb1, tr16b) = 0.4224 in
Wall Thickness, shell/head, external pressure     trb2 = 0.0166 in
Wall Thickness                 tb2 = max(trb2, tr16b) = 0.0625 in
Wall Thickness per table UG-45                     tb3 = 0.3280 in
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.328, max( 0.4224, 0.0625 ) ]
  = 0.3280 in
```

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

```
  = max( ta, tb )
  = max( 0.1124, 0.328 )
  = 0.3280 in
```

Available Nozzle Neck Thickness = 0.5512 in --> 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   :   5195.1,  Allowable :  20000.0 psi  Passed
Expansion   :      0.0,  Allowable :  44804.9 psi  Passed
Occasional  :   1318.0,  Allowable :  26600.0 psi  Passed
Shear       :   2702.0,  Allowable :  14000.0 psi  Passed
```

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, min(Curve:D, Curve:B)

Govrn. thk, tg = 0.5512, tr = 0.08357, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.1516, Temp. Reduction = 0 F

```
Min Metal Temp. w/o impact per UCS-66, Curve B            -1 F
```

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

Govrn. thk, tg = 0.5512, tr = 0.08357, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.1516, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve D             -55 F
```

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

Govrn. thk, tg = 0.5512, tr = 0.08357, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.1516, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve D             -55 F
```

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

Govrn. thk, tg = 0.6299, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.4961, Temp. Reduction = 0 F
Attachment governing, Attachment stress = Shell stress per Code

```
 Min Metal Temp. w/o impact per UCS-66, Curve D             -50 F
```

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

Govrn. thk, tg = 0.5512, tr = 0.08357, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.1516, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve D             -55 F

 Gov. MDMT of the Nozzle                                :    -1 F
 Gov. MDMT of the Reinforcement Pad                     :   -50 F
 Gov. MDMT of the nozzle to shell joint welded assembly :    -1 F
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
 Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)     -20 F
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -20 F
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
 Design Pressure/Ambient Rating = 280.14/740.00 = 0.379

Note: The MDMT was not reduced based on lower stress per user request.

<u>Weld Size Calculations, Description: S1</u>

```
 Intermediate Calc. for nozzle/shell Welds    Tmin      0.5512  in
 Intermediate Calc. for pad/shell Welds    TminPad      0.6299  in
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
 Nozzle Weld          0.2500 = Min per Code 0.2786 = 0.7 * Wo in
 Pad Weld             0.3150 = 0.5*TminPad  0.3340 = 0.7 * Wp in
```

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,(4.6028 - 2.2628 + 2 * 0.5512 * 1 *
    (1 * 0.63 - 0.4224 ) )20000 )
  = 51377.95 lbf
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
```

```
  = ( 1.3822 + 4.8409 + 0.3784 - 0 * 1 ) * 20000
  = 132031.50 lbf
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.3822 + 0 + 0.1552 +( 0.6945 ) ) * 20000
  = 44638.41 lbf
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.3822 + 0 + 0.3784 + 4.8409 +( 0.6945 ) ) * 20000
  = 145921.27 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 12 * 0.394 * 0.49 * 20000
  = 72782. lbf
```

Shear, Pad Element Weld [Spew]:

```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 19.685 * 0.4724 * 0.49 * 20000
  = 143162. lbf
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 5.7244 ) *( 0.5512 - 0 ) * 0.7 * 20000
  = 138772. lbf
```

Tension, Pad Groove Weld [Tpgw]:

```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  = (3.1416/2 ) * 12 * 0.6299 * 0.74 * 20000
  = 175731. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 12 *( 0.63 - 0 ) * 0.74 * 20000
  = 175753. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:

```
  = ( SPEW + SNW ) = ( 143162 + 138772 ) = 281935 lbf
```

Failure Path [Path 2-2]:

```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 72782 + 175731 + 175753 + 0 ) = 424266 lbf
```

Failure Path [Path 3-3]:

```
  = ( Spew + Tngw + Sinw )
  = ( 143162 + 175753 + 0 ) = 318916 lbf
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 281934  lbf, must exceed W = 51377 lbf    or W1 = 132031 lbf
 Path 2-2 = 424266  lbf, must exceed W = 51377 lbf    or W2 = 44638 lbf
 Path 3-3 = 318915  lbf, must exceed W = 51377 lbf    or W3 = 145921 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Maximum Allowable Pressure in the Operating case: 280.14 psig
```

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

Nozzle is O.K. for the External Pressure: 15 psig

Approximate Maximum Allowable Pressure New & Cold: 545.72 psig

The Drop for this Nozzle is : 0.8291 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 11.5832 in

Percent Elongation Calculations:
% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 4.814 %

Input Echo, WRC297 Item 1, Description: S1 :

Diameter Basis for Cylindrical Shell		ID	
Shell Corrosion Allowance		0.0000	in
Shell Diameter		44.252	in
Shell Thickness		0.6300	in
Shell Stress Concentration Factor		1.000	
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	20000.00	psi
Vessel Hot S.I. Allowable	Smh	20000.00	psi

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

Diameter Basis for Nozzle		OD	
Nozzle Corrosion Allowance		0.0000	in
Nozzle Diameter		12.000	in
Nozzle Thickness		0.5512	in
Nozzle Stress Concentration Factor		1.000	
Nozzle Material		SA-516 70	
Nozzle Cold S.I. Allowable	SNmc	20000.00	psi
Nozzle Hot S.I. Allowable	SNmh	20000.00	psi

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

Diameter of Reinforcing Pad	19.685	in
Thickness of Reinforcing Pad	0.6299	in

Note:
External Forces and Moments in WRC 107/537 Convention:
These loads are assumed to be SUStained loads.

Design Internal Pressure	Dp	280.14	psig
Radial Load	P	-3060.01	lbf
Circumferential Shear	Vc	3839.99	lbf
Longitudinal Shear	Vl	3839.99	lbf
Circumferential Moment	Mc	11280.00	ft-lb
Longitudinal Moment	Ml	14320.00	ft-lb
Torsional Moment	Mt	18220.00	ft-lb

Include Axial Pressure Thrust	No
Include Pressure Stress Indices per Div. 2	No
Local Loads applied at end of Nozzle/Attachment	No

Stress Computations at the Edge of the Nozzle:

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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 12.0 + 2 * 1.65 * sqrt( 22.756( 0.63 - 0.0 ) )
  = 24.495 in
```

WRC 297 Curve Access Parameters:

```
 Vessel Mean Diameter      (D) =     45.512 in
 Nozzle Outside Diameter   (d) =     12.000 in
 Vessel Thickness used     (T) =      1.260 in
 Nozzle Thickness used     (t) =      0.551 in
 T / t                         =      2.286
 d / t                         =     21.771

Lambda = [(d/D) * sqrt(D/T)]  = 1.585

 Nr/P    =      0.080
 Mr/P    =      0.088
 M0/P    =      0.061
 N0/P    =      0.165
 MrD/Mc  =      0.191
 NrDL/Mc =      0.131
 M0d/Mc  =      0.152
 N0DL/Mc =      0.149
 MrD/Ml  =      0.134
 NrDL/Ml =      0.090
 M0D/Ml  =      0.104
 N0DL/Ml =      0.271
```

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stresses Normal to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Outplane Membrane (P)	318	318	318	318
Outplane Bending (P)	708	-708	708	-708
Outplane Membrane (Mc)	0	0	0	0
Outplane Bending (Mc)	0	0	0	0
Outplane Membrane (ML)	-2446	-2446	2446	2446
Outplane Bending (ML)	-5605	5605	5605	-5605
Normal Pressure Stress	4783	5063	4783	5063
Outplane Stress Summary	-2242	7832	13860	1514

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stresses parallel to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Inplane Membrane (P)	153	153	153	153
Inplane Bending (P)	1023	-1023	1023	-1023
Inplane Membrane (Mc)	0	0	0	0
Inplane Bending (Mc)	0	0	0	0
Inplane Membrane (ML)	-810	-810	810	810
Inplane Bending (ML)	-7237	7237	7237	-7237
Inplane Pressure Stress	2391	2391	2391	2391
Inplane Stress Summary	-4480	7948	11614	-4906

Vessel Stresses (psi):

LONGITUDINAL PLANE (Shear stress normal to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside

Outplane Shear (Vc)	161	161	-161	-161
Outplane Shear (Vl)	0	0	0	0
Outplane Shear (Mt)	767	767	767	767
Shear Stress Summary	928	928	606	606

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stress Intensities	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Two * Max Shear Stress	4814	8819	14013	6533

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses Normal to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Outplane Membrane (P)	318	318	318	318
Outplane Bending (P)	708	-708	708	-708
Outplane Membrane (Mc)	-1057	-1057	1057	1057
Outplane Bending (Mc)	-6476	6476	6476	-6476
Outplane Membrane (ML)	0	0	0	0
Outplane Bending (ML)	0	0	0	0
Normal Pressure Stress	2391	2391	2391	2391
Outplane Stress Summary	-4116	7420	10950	-3418

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses parallel to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Inplane Membrane (P)	153	153	153	153
Inplane Bending (P)	1023	-1023	1023	-1023
Inplane Membrane (Mc)	-929	-929	929	929
Inplane Bending (Mc)	-8152	8152	8152	-8152
Inplane Membrane (ML)	0	0	0	0
Inplane Bending (ML)	0	0	0	0
Inplane Pressure Stress	4783	5063	4783	5063
Inplane Stress Summary	-3122	11416	15040	-3030

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Shear stress normal to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Outplane Shear (Vc)	0	0	0	0
Outplane Shear (Vl)	-161	-161	161	161
Torsional Shear (Mt)	767	767	767	767
Shear Stress Summary	606	606	928	928

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stress Intensities	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Two * Max Shear Stress	4402	11505	15240	4172

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Stresses in the	Au Top	Al Top	Bu Bottom	Bl Bottom

hoop direction)	Outside	Inside	Outside	Inside
Hoop Membrane (P)	318	318	318	318
Hoop Bending (P)	0	0	0	0
Hoop Membrane (Mc)	0	0	0	0
Hoop Bending (Mc)	0	0	0	0
Hoop Membrane (ML)	-2446	-2446	2446	2446
Hoop Bending (ML)	0	0	0	0
Hoop Pressure Stress	3163	3499	3163	3499
Hoop Stress Summary	1035	1371	5927	6263

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Stresses Normal to pipe cross-section)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Axial Membrane (P)	154	154	154	154
Axial Bending (P)	2943	-2943	2943	-2943
Axial Membrane (Mc)	0	0	0	0
Axial Bending (Mc)	0	0	0	0
Axial Membrane (ML)	-3166	-3166	3166	3166
Axial Bending (ML)	-25113	25113	25113	-25113
Axial Pressure Stress	1581	1581	1581	1581
Axial Stress Summary	-23601	20739	32957	-23155

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Shear stress)	Au Outside	Al Inside	Bu Outside	Bl Inside
Shear due to (Vc)	369	369	-369	-369
Shear due to (Vl)	0	0	0	0
Shear due to Torsion	1753	1753	1753	1753
Shear Stress Summary	2122	2122	1384	1384

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Stress Intensities	Au Outside	Al Inside	Bu Outside	Bl Inside
Two * Max Shear Stress	24998	20968	33027	29547

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses in the hoop direction)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Hoop Membrane (P)	318	318	318	318
Hoop Bending (P)	0	0	0	0
Hoop Membrane (Mc)	-1057	-1057	1057	1057
Hoop Bending (Mc)	0	0	0	0
Hoop Membrane (ML)	0	0	0	0
Hoop Bending (ML)	0	0	0	0
Hoop Pressure Stress	3163	3499	3163	3499
Hoop Stress Summary	2424	2760	4538	4874

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses Normal to pipe cross-section)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Axial Membrane (P)	154	154	154	154

```
 Axial Bending  (P )        2943    -2943     2943    -2943
 Axial Membrane (Mc)       -2494    -2494     2494     2494
 Axial Bending  (Mc)      -28026    28026    28026   -28026
 Axial Membrane (ML)           0        0        0        0
 Axial Bending  (ML)           0        0        0        0
 Axial Pressure Stress      1581     1581     1581     1581
 ---------------------- -------- -------- -------- --------
 Axial Stress Summary     -25842    24324    35198   -26740
```

Nozzle Stresses (psi):

```
 CIRCUMFERENTIAL PLANE        Cu       Cl       Du       Dl
 (Shear stress)          Outside   Inside  Outside   Inside
 -----------------------------------------------------------
 Shear due to (Vc)             0        0        0        0
 Shear due to (Vl)          -369     -369      369      369
 Shear due to Torsion       1753     1753     1753     1753
 ---------------------- -------- -------- -------- --------
 Shear Stress Summary       1384     1384     2122     2122
```

Nozzle Stresses (psi):

```
 CIRCUMFERENTIAL PLANE        Cu       Cl       Du       Dl
 (Stress Intensities     Outside   Inside  Outside   Inside
 -----------------------------------------------------------
 Two * Max Shear Stress    28401    24412    35344    31897
```

Stress Computations at the Edge of the Reinforcing Pad:

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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 12.0 + 2 * 1.65 * sqrt( 22.441( 0.63 - 0.0 ) )
  = 24.408 in
```

WRC 297 Curve Access Parameters:

```
 Vessel Mean Diameter      (D) =     44.882 in
 Nozzle Outside Diameter   (d) =     19.685 in
 Vessel Thickness used     (T) =      0.630 in
 Nozzle Thickness used     (t) =      4.394 in
 T / t                         =      0.143
 d / t                         =     10.000

Lambda = [(d/D) * sqrt(D/T)]  = 3.702
```

Note: Re-pad thickness is added to nozzle thickness to simulate the Re-pad.

```
 Nr/P    =      0.053
 Mr/P    =      0.089
 M0/P    =      0.026
 N0/P    =      0.045
 MrD/Mc  =      0.257
 NrDL/Mc =      0.099
 M0d/Mc  =      0.077
 N0DL/Mc =      0.072
 MrD/Ml  =      0.068
 NrDL/Ml =      0.060
 M0D/Ml  =      0.020
 N0DL/Ml =      0.050
```

Vessel Stresses (psi):

```
 LONGITUDINAL PLANE           Au       Al       Bu       Bl
 (Stresses Normal to         Top      Top   Bottom   Bottom
 longitudinal plane)     Outside   Inside  Outside   Inside
 -----------------------------------------------------------
```

Outplane Membrane (P)	343	343	343	343
Outplane Bending (P)	1215	-1215	1215	-1215
Outplane Membrane (Mc)	0	0	0	0
Outplane Bending (Mc)	0	0	0	0
Outplane Membrane (ML)	-1102	-1102	1102	1102
Outplane Bending (ML)	-2682	2682	2682	-2682
Normal Pressure Stress	9700	9980	9700	9980
Outplane Stress Summary	7474	10688	15042	7528

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stresses parallel to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Inplane Membrane (P)	408	408	408	408
Inplane Bending (P)	4119	-4119	4119	-4119
Inplane Membrane (Mc)	0	0	0	0
Inplane Bending (Mc)	0	0	0	0
Inplane Membrane (ML)	-1309	-1309	1309	1309
Inplane Bending (ML)	-8969	8969	8969	-8969
Inplane Pressure Stress	4850	4850	4850	4850
Inplane Stress Summary	-901	8799	19655	-6521

Vessel Stresses (psi):

LONGITUDINAL PLANE (Shear stress normal to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Outplane Shear (Vc)	197	197	-197	-197
Outplane Shear (Vl)	0	0	0	0
Outplane Shear (Mt)	570	570	570	570
Shear Stress Summary	767	767	373	373

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stress Intensities	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Two * Max Shear Stress	8514	10960	19684	14068

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses Normal to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Outplane Membrane (P)	343	343	343	343
Outplane Bending (P)	1215	-1215	1215	-1215
Outplane Membrane (Mc)	-1240	-1240	1240	1240
Outplane Bending (Mc)	-8004	8004	8004	-8004
Outplane Membrane (ML)	0	0	0	0
Outplane Bending (ML)	0	0	0	0
Normal Pressure Stress	4850	4850	4850	4850
Outplane Stress Summary	-2836	10742	15652	-2786

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses parallel to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Inplane Membrane (P)	408	408	408	408

Inplane Bending (P)	4119	-4119	4119	-4119
Inplane Membrane (Mc)	-1710	-1710	1710	1710
Inplane Bending (Mc)	-26740	26740	26740	-26740
Inplane Membrane (ML)	0	0	0	0
Inplane Bending (ML)	0	0	0	0
Inplane Pressure Stress	9700	9980	9700	9980
Inplane Stress Summary	-14223	31299	42677	-18761

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Shear stress normal to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Outplane Shear (Vc)	0	0	0	0
Outplane Shear (Vl)	-197	-197	197	197
Torsional Shear (Mt)	570	570	570	570
Shear Stress Summary	373	373	767	767

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stress Intensities	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Two * Max Shear Stress	14235	31305	42698	18797

WRC 297 Stress Summations per ASME Sec. VIII Div. 2:

Vessel Stress Summation at Vessel-Nozzle Junction (psi):

Type of Stress Int. Location	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
	Stress Values at							
Circ. Pm (SUS)	4783	5063	4783	5063	4783	5063	4783	5063
Circ. Pl (SUS)	-2128	-2128	2764	2764	-776	-776	1082	1082
Circ. Q (SUS)	-4897	4897	6313	-6313	-7129	7129	9175	-9175
Long. Pm (SUS)	2391	2391	2391	2391	2391	2391	2391	2391
Long. Pl (SUS)	-657	-657	963	963	-739	-739	1375	1375
Long. Q (SUS)	-6214	6214	8260	-8260	-5768	5768	7184	-7184
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	161	161	-161	-161	-161	-161	161	161
Shear Q (SUS)	767	767	767	767	767	767	767	767
Pm (SUS)	4783	5063	4783	5063	4783	5063	4783	5063
Pm+Pl (SUS)	2682	2956	7553	7832	4017	4296	5877	6155
Pm+Pl+Q (Total)	4814	8819	14013	6533	4402	11505	15240	4172

Vessel Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	5063	20000	Passed
Pm+Pl (SUS)	7832	30000	Passed
Pm+Pl+Q (TOTAL)	15240	60000	Passed

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

WRC 297 Stress Summations per ASME Sec. VIII Div. 2:

Vessel Stress Summation at Reinforcing Pad Edge (psi):

Type of Stress Int. Location	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	9700	9980	9700	9980	9700	9980	9700	9980
Circ. Pl (SUS)	-759	-759	1445	1445	-1302	-1302	2118	2118
Circ. Q (SUS)	-1467	1467	3897	-3897	-22621	22621	30859	-30859
Long. Pm (SUS)	4850	4850	4850	4850	4850	4850	4850	4850
Long. Pl (SUS)	-901	-901	1717	1717	-897	-897	1583	1583
Long. Q (SUS)	-4850	4850	13088	-13088	-6789	6789	9219	-9219
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	197	197	-197	-197	-197	-197	197	197
Shear Q (SUS)	570	570	570	570	570	570	570	570
Pm (SUS)	9700	9980	9700	9980	9700	9980	9700	9980
Pm+Pl (SUS)	8948	9228	11153	11432	8406	8686	11825	12104
Pm+Pl+Q (Total)	8514	10960	19684	14068	14235	31305	42698	18797

Vessel Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	9980	20000	Passed
Pm+Pl (SUS)	12104	30000	Passed
Pm+Pl+Q (TOTAL)	42698	60000	Passed

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

WRC 297 Stress Summations per ASME Sec. VIII Div. 2:

Nozzle Stress Summation at Vessel-Nozzle Junction (psi):

Type of Stress Int. Location	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	3163	3499	3163	3499	3163	3499	3163	3499
Circ. Pl (SUS)	-2128	-2128	2764	2764	-739	-739	1375	1375
Circ. Q (SUS)	0	0	0	0	0	0	0	0
Long. Pm (SUS)	1581	1581	1581	1581	1581	1581	1581	1581
Long. Pl (SUS)	-3012	-3012	3320	3320	-2340	-2340	2648	2648
Long. Q (SUS)	-22170	22170	28056	-28056	-25083	25083	30969	-30969
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	369	369	-369	-369	-369	-369	369	369
Shear Q (SUS)	1753	1753	1753	1753	1753	1753	1753	1753
Pm (SUS)	3163	3499	3163	3499	3163	3499	3163	3499
Pm+Pl (SUS)	2574	2897	6045	6356	3267	3595	4783	5041
Pm+Pl+Q (Total)	24998	20968	33027	29547	28401	24412	35344	31897

Nozzle Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	3499	20000	Passed
Pm+Pl (SUS)	6356	30000	Passed
Pm+Pl+Q (TOTAL)	35344	60000	Passed

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

Input, Nozzle Desc: S2 From: 60

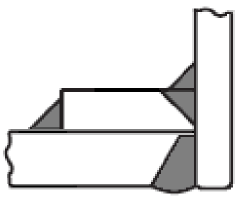
Pressure for Reinforcement Calculations	P	281.702	psig
Temperature for Internal Pressure	Temp	330	F
Design External Pressure	Pext	15.00	psig
Temperature for External Pressure	Tempex	300	F
Maximum Allowable Pressure New & Cold		377.46	psig
Parent Material [Normalized]		SA-516 70	
Parent Allowable Stress at Temperature	Sv	20000.00	psi
Parent Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Cylindrical Shell	D	44.2520	in
Design Length of Section	L	214.3491	in
Shell Finished (Minimum) Thickness	t	0.6300	in
Shell Internal Corrosion Allowance	c	0.0000	in
Shell External Corrosion Allowance	co	0.0000	in
Distance from Bottom/Left Tangent		242.23	in
User Entered Minimum Design Metal Temperature		32.00	F

Type of Element Connected to the Parent : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	17100.00	psi
Allowable Stress At Ambient	Sna	17100.00	psi
Diameter Basis (for tr calc only)		Outside	
Layout Angle		180.00	deg
Diameter		10.0000	in.
Size and Thickness Basis		Nominal	
Nominal Thickness		80	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	0.0000	in
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	10.6241	in
Weld leg size between Nozzle and Pad/Shell	Wo	0.3940	in
Groove weld depth between Nozzle and Vessel	Wgnv	0.6300	in
Inside Projection	h	0.0000	in
Weld leg size, Inside Element to Shell	Wi	0.0000	in
Pad Material [Normalized]		SA-516 70	
Pad Allowable Stress at Temperature	Sp	20000.00	psi
Pad Allowable Stress At Ambient	Spa	20000.00	psi
Diameter of Pad along vessel surface	Dp	15.7480	in
Thickness of Pad	te	0.6300	in
Weld leg size between Pad and Shell	Wp	0.4720	in
Groove weld depth between Pad and Nozzle	Wgpn	0.6300	in
Reinforcing Pad Width		2.4990	in
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was MAWP + static head (to the nozzle).

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, 2021, UG-37 to UG-45

```
 Actual Outside Diameter Used in Calculation          10.750  in.
 Actual Thickness Used in Calculation                  0.594  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)
  = 281.7*22.126/(20000*1-0.6*281.7)
  = 0.3143 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 377.46*22.126/(20000*1-0.6*377.46)
  = 0.4224 in
```

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)
  = 281.7*5.375/(17100*1+0.4*281.7)
  = 0.0880 in
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Mapnc]
```
  = P*Ro/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = 377.46*5.375/(17100*1+0.4*377.46)
  = 0.1176 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0343 in

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl     19.1240  in
 Parallel to Vessel Wall, opening length              d      9.5620  in
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp      1.5750  in
```

UG-40, Limits of Reinforcement : [Mapnc]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl     19.1240  in
 Parallel to Vessel Wall, opening length              d      9.5620  in
 Normal to Vessel Wall (Thickness Limit), pad side Tlwp      1.5750  in
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 17100/20000 )
  = 0.855
```

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

```
  = min( 1, 17100/20000 )
  = 0.855
```

Weld Strength Reduction Factor [fr4]:

```
  = min( 1, Sp/Sv )
  = min( 1, 20000/20000 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 0.855, 1 )
  = 0.855
```

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

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	3.060	1.360	4.111
Area in Shell	A1	2.964	3.292	1.950
Area in Nozzle Wall	A2	1.363	1.507	1.283
Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.356	0.356	0.356
Area in Element	A5	3.149	3.149	3.149
TOTAL AREA AVAILABLE	Atot	7.831	8.304	6.737

The MAP(nc) 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:	11.6250	0.6300	in
Based on given Pad Diameter:	15.7480	0.1250	in
Based on Shell or Nozzle Thickness:	11.6250	0.6250	in

Area Required [A]:

```
  = ( d * tr*F + 2 * tn * tr*F * (1-fr1) ) UG-37(c)
  = (9.562*0.4224*1+2*0.594*0.4224*1*(1-0.855))
  = 4.111 in^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 )
  = 9.562( 1 * 0.63 - 1 * 0.4224 ) - 2 * 0.594
    ( 1 * 0.63 - 1 * 0.4224 ) *( 1 - 0.855 )
  = 1.950 in^2
```

Area Available in Nozzle Wall Projecting Outward [A2]:

```
  = ( 2 * Tlwp ) * ( tn - trn ) * fr2
  = ( 2 * 1.575 ) *( 0.594 - 0.1176 ) * 0.855
  = 1.283 in^2
```

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

```
  = Wo² * fr3 + (Wi-can/0.707)² * fr2 + Wp² * fr4
  = 0.394² * 0.855 +(0 )² * 0.855 + 0.472² * 1
  = 0.356 in^2
```

Area Available in Element [A5]:

```
  = (min(Dp,DL)-(Nozzle OD))*(min(tp,Tlwp,te)) * fr4
  = ( 15.748 - 10.75 ) * 0.63 * 1
  = 3.149 in^2
```

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

```
Wall Thickness for Internal/External pressures       ta = 0.1176 in
Wall Thickness per UG16(b),                        tr16b = 0.0625 in
Wall Thickness, shell/head, internal pressure       trb1 = 0.3143 in
Wall Thickness                  tb1 = max(trb1, tr16b) = 0.3143 in
Wall Thickness, shell/head, external pressure       trb2 = 0.0166 in
Wall Thickness                  tb2 = max(trb2, tr16b) = 0.0625 in
Wall Thickness per table UG-45                       tb3 = 0.3190 in
```

Determine Nozzle Thickness candidate [tb]:

```
= min[ tb3, max( tb1,tb2) ]
= min[ 0.319, max( 0.3143, 0.0625 ) ]
= 0.3143 in
```

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

```
= max( ta, tb )
= max( 0.1176, 0.3143 )
= 0.3143 in
```

Available Nozzle Neck Thickness = 0.875 * 0.594 = 0.520 in --> OK

UG-45 Minimum Nozzle Neck Thickness Requirement: [MAPnc]

```
Wall Thickness for Internal/External pressures       ta = 0.1176 in
Wall Thickness per UG16(b),                        tr16b = 0.0625 in
Wall Thickness, shell/head, internal pressure       trb1 = 0.4224 in
Wall Thickness                  tb1 = max(trb1, tr16b) = 0.4224 in
Wall Thickness, shell/head, external pressure       trb2 = 0.0166 in
Wall Thickness                  tb2 = max(trb2, tr16b) = 0.0625 in
Wall Thickness per table UG-45                       tb3 = 0.3190 in
```

Determine Nozzle Thickness candidate [tb]:

```
= min[ tb3, max( tb1,tb2) ]
= min[ 0.319, max( 0.4224, 0.0625 ) ]
= 0.3190 in
```

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

```
= max( ta, tb )
= max( 0.1176, 0.319 )
= 0.3190 in
```

Available Nozzle Neck Thickness = 0.875 * 0.594 = 0.520 in --> 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  :   4340.5,  Allowable :  17100.0 psi  Passed
Expansion  :      0.0,  Allowable :  38409.5 psi  Passed
Occasional :   1067.4,  Allowable :  22743.0 psi  Passed
Shear      :   2336.6,  Allowable :  11970.0 psi  Passed
```

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, min(Curve:C, Curve:B)

Govrn. thk, tg = 0.5197, tr = 0.08797, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.1692, Temp. Reduction = 0 F

```
Min Metal Temp. w/o impact per UCS-66, Curve B              -4 F
```

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

Govrn. thk, tg = 0.5197, tr = 0.08797, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.1692, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve C            -35 F
```

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

Govrn. thk, tg = 0.5197, tr = 0.08797, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.1692, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve D            -55 F
```

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

Govrn. thk, tg = 0.63, tr = 0.3143, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.4989, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve D            -50 F
```

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

Govrn. thk, tg = 0.5197, tr = 0.08797, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.1692, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve C            -35 F

 Gov. MDMT of the Nozzle                                 :    -4 F
 Gov. MDMT of the Reinforcement Pad                      :   -50 F
 Gov. MDMT of the nozzle to shell joint welded assembly :    -4 F
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
 Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)     -20 F
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -20 F
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
 Design Pressure/Ambient Rating = 281.70/740.00 = 0.381

Note: The MDMT was not reduced based on lower stress per user request.

Weld Size Calculations, Description: S2

```
 Intermediate Calc. for nozzle/shell Welds    Tmin      0.5940  in
 Intermediate Calc. for pad/shell Welds    TminPad      0.6300  in
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
 Nozzle Weld          0.2500 = Min per Code 0.2786 = 0.7 * Wo in
 Pad Weld             0.3150 = 0.5*TminPad  0.3337 = 0.7 * Wp in
```

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,(4.1114 - 1.9497 + 2 * 0.594 * 0.855 *
    (1 * 0.63 - 0.4224 ) )20000 )
  = 47452.79 lbf
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 1.283 + 3.1487 + 0.3555 - 0 * 0.855 ) * 20000
```

```
  = 95745.95 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.283 + 0 + 0.1327 +( 0.6399 ) ) * 20000
  = 41113.79 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.283 + 0 + 0.3555 + 3.1487 +( 0.6399 ) ) * 20000
  = 108544.27 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 10.75 * 0.394 * 0.49 * 17100
  = 55746. lbf
```

Shear, Pad Element Weld [Spew]:
```
  = (pi/2) * DP * WP * 0.49 * SEW
  = ( 3.1416/2.0 ) * 15.748 * 0.472 * 0.49 * 20000
  = 114423. lbf
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 5.078 ) *( 0.594 - 0 ) * 0.7 * 17100
  = 113429. lbf
```

Tension, Pad Groove Weld [Tpgw]:
```
  = ( pi/2) * Dlo * Wgpn * 0.74 * Seg
  = (3.1416/2 ) * 10.75 * 0.63 * 0.74 * 20000
  = 157446. lbf
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 10.75 *( 0.63 - 0 ) * 0.74 * 20000
  = 157446. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:
```
  = ( SPEW + SNW ) = ( 114423 + 113429 ) = 227852 lbf
```

Failure Path [Path 2-2]:
```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 55746 + 157446 + 157446 + 0 ) = 370638 lbf
```

Failure Path [Path 3-3]:
```
  = ( Spew + Tngw + Sinw )
  = ( 114423 + 157446 + 0 ) = 271869 lbf
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 227851  lbf, must exceed W = 47452 lbf    or W1 = 95745 lbf
 Path 2-2 = 370637  lbf, must exceed W = 47452 lbf    or W2 = 41113 lbf
 Path 3-3 = 271868  lbf, must exceed W = 47452 lbf    or W3 = 108544 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Maximum Allowable Pressure in the Operating case: 280.14 psig
```

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

Nozzle is O.K. for the External Pressure: 15 psig

Approximate Maximum Allowable Pressure New & Cold: 495.52 psig

The Drop for this Nozzle is : 0.6628 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 11.9169 in

Input Echo, WRC297 Item 1, Description: S2 :

Diameter Basis for Cylindrical Shell		ID	
Shell Corrosion Allowance		0.0000	in
Shell Diameter		44.252	in
Shell Thickness		0.6300	in
Shell Stress Concentration Factor		1.000	
Vessel Material		SA-516 70	
Vessel Cold S.I. Allowable	Smc	20000.00	psi
Vessel Hot S.I. Allowable	Smh	20000.00	psi

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

Diameter Basis for Nozzle		OD	
Nozzle Corrosion Allowance		0.0000	in
Nozzle Diameter		10.750	in
Nozzle Thickness		0.5940	in
Nozzle Stress Concentration Factor		1.000	
Nozzle Material		SA-106 B	
Nozzle Cold S.I. Allowable	SNmc	17100.00	psi
Nozzle Hot S.I. Allowable	SNmh	17100.00	psi

Using 2 * Yield for Discontinuity Stress Allowable (Div 2, 4.1.6.3), Sps.
Make sure that material properties at this temperature are not
time-dependent for Material: SA-106 B

Diameter of Reinforcing Pad	15.748	in
Thickness of Reinforcing Pad	0.6300	in

Note:
External Forces and Moments in WRC 107/537 Convention:
These loads are assumed to be SUStained loads.

Design Internal Pressure	Dp	281.70	psig
Radial Load	P	-2580.00	lbf
Circumferential Shear	Vc	3239.99	lbf
Longitudinal Shear	Vl	3239.99	lbf
Circumferential Moment	Mc	8020.03	ft-lb
Longitudinal Moment	Ml	10180.00	ft-lb
Torsional Moment	Mt	12960.00	ft-lb

Include Axial Pressure Thrust	No
Include Pressure Stress Indices per Div. 2	No
Local Loads applied at end of Nozzle/Attachment	No

Stress Computations at the Edge of the Nozzle:

Stress Attenuation Diameter (for Insert Plates) per WRC 297:
= NozzleOD + 2 * 1.65 * sqrt(Rmean(t - ca))
= 10.75 + 2 * 1.65 * sqrt(22.756(0.63 - 0.0))
= 23.245 in

WRC 297 Curve Access Parameters:

```
 Vessel Mean Diameter      (D) =     45.512 in
 Nozzle Outside Diameter   (d) =     10.750 in
 Vessel Thickness used     (T) =      1.260 in
 Nozzle Thickness used     (t) =      0.594 in
 T / t                         =      2.121
 d / t                         =     18.098

Lambda = [(d/D) * sqrt(D/T)]  = 1.420

 Nr/P    =      0.094
 Mr/P    =      0.102
 M0/P    =      0.064
 N0/P    =      0.156
 MrD/Mc  =      0.202
 NrDL/Mc =      0.149
 M0d/Mc  =      0.150
 N0DL/Mc =      0.120
 MrD/Ml  =      0.148
 NrDL/Ml =      0.108
 M0D/Ml  =      0.107
 N0DL/Ml =      0.236
```

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stresses Normal to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Outplane Membrane (P)	254	254	254	254
Outplane Bending (P)	623	-623	623	-623
Outplane Membrane (Mc)	0	0	0	0
Outplane Bending (Mc)	0	0	0	0
Outplane Membrane (ML)	-1691	-1691	1691	1691
Outplane Bending (ML)	-4592	4592	4592	-4592
Normal Pressure Stress	4809	5091	4809	5091
Outplane Stress Summary	-597	7623	11969	1821

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stresses parallel to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Inplane Membrane (P)	152	152	152	152
Inplane Bending (P)	993	-993	993	-993
Inplane Membrane (Mc)	0	0	0	0
Inplane Bending (Mc)	0	0	0	0
Inplane Membrane (ML)	-773	-773	773	773
Inplane Bending (ML)	-6364	6364	6364	-6364
Inplane Pressure Stress	2404	2404	2404	2404
Inplane Stress Summary	-3588	7154	10686	-4028

Vessel Stresses (psi):

LONGITUDINAL PLANE (Shear stress normal to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Outplane Shear (Vc)	152	152	-152	-152
Outplane Shear (Vl)	0	0	0	0
Outplane Shear (Mt)	679	679	679	679

Shear Stress Summary	831	831	527	527

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stress Intensities	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Two * Max Shear Stress	3803	8251	12157	5943

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses Normal to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Outplane Membrane (P)	254	254	254	254
Outplane Bending (P)	623	-623	623	-623
Outplane Membrane (Mc)	-674	-674	674	674
Outplane Bending (Mc)	-5066	5066	5066	-5066
Outplane Membrane (ML)	0	0	0	0
Outplane Bending (ML)	0	0	0	0
Normal Pressure Stress	2404	2404	2404	2404
Outplane Stress Summary	-2459	6427	9021	-2357

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses parallel to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Inplane Membrane (P)	152	152	152	152
Inplane Bending (P)	993	-993	993	-993
Inplane Membrane (Mc)	-838	-838	838	838
Inplane Bending (Mc)	-6837	6837	6837	-6837
Inplane Membrane (ML)	0	0	0	0
Inplane Bending (ML)	0	0	0	0
Inplane Pressure Stress	4809	5091	4809	5091
Inplane Stress Summary	-1721	10249	13629	-1749

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Shear stress normal to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Outplane Shear (Vc)	0	0	0	0
Outplane Shear (Vl)	-152	-152	152	152
Torsional Shear (Mt)	679	679	679	679
Shear Stress Summary	527	527	831	831

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stress Intensities	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Two * Max Shear Stress	2733	10320	13774	2937

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Stresses in the hoop direction)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Hoop Membrane (P)	254	254	254	254
Hoop Bending (P)	0	0	0	0

Hoop Membrane (Mc)	0	0	0	0
Hoop Bending (Mc)	0	0	0	0
Hoop Membrane (ML)	-1691	-1691	1691	1691
Hoop Bending (ML)	0	0	0	0
Hoop Pressure Stress	2561	2899	2561	2899
Hoop Stress Summary	1124	1462	4506	4844

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Stresses Normal to pipe cross-section)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Axial Membrane (P)	136	136	136	136
Axial Bending (P)	2408	-2408	2408	-2408
Axial Membrane (Mc)	0	0	0	0
Axial Bending (Mc)	0	0	0	0
Axial Membrane (ML)	-2677	-2677	2677	2677
Axial Bending (ML)	-18203	18203	18203	-18203
Axial Pressure Stress	1280	1280	1280	1280
Axial Stress Summary	-17056	14534	24704	-16518

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Shear stress)	Au Outside	Al Inside	Bu Outside	Bl Inside
Shear due to (Vc)	323	323	-323	-323
Shear due to (Vl)	0	0	0	0
Shear due to Torsion	1442	1442	1442	1442
Shear Stress Summary	1765	1765	1119	1119

Nozzle Stresses (psi):

LONGITUDINAL PLANE (Stress Intensities	Au Outside	Al Inside	Bu Outside	Bl Inside
Two * Max Shear Stress	18519	14768	24765	21478

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses in the hoop direction)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Hoop Membrane (P)	254	254	254	254
Hoop Bending (P)	0	0	0	0
Hoop Membrane (Mc)	-674	-674	674	674
Hoop Bending (Mc)	0	0	0	0
Hoop Membrane (ML)	0	0	0	0
Hoop Bending (ML)	0	0	0	0
Hoop Pressure Stress	2561	2899	2561	2899
Hoop Stress Summary	2141	2479	3489	3827

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses Normal to pipe cross-section)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Axial Membrane (P)	136	136	136	136
Axial Bending (P)	2408	-2408	2408	-2408
Axial Membrane (Mc)	-2109	-2109	2109	2109
Axial Bending (Mc)	-19445	19445	19445	-19445
Axial Membrane (ML)	0	0	0	0

Axial Bending (ML)	0	0	0	0
Axial Pressure Stress	1280	1280	1280	1280
Axial Stress Summary	-17730	16344	25378	-18328

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Shear stress)	Cu Outside	Cl Inside	Du Outside	Dl Inside
Shear due to (Vc)	0	0	0	0
Shear due to (Vl)	-323	-323	323	323
Shear due to Torsion	1442	1442	1442	1442
Shear Stress Summary	1119	1119	1765	1765

Nozzle Stresses (psi):

CIRCUMFERENTIAL PLANE (Stress Intensities	Cu Outside	Cl Inside	Du Outside	Dl Inside
Two * Max Shear Stress	19996	16433	25519	22434

Stress Computations at the Edge of the Reinforcing Pad:

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

```
  = NozzleOD + 2 * 1.65 * sqrt( Rmean( t - ca ) )
  = 10.75 + 2 * 1.65 * sqrt( 22.441( 0.63 - 0.0 ) )
  = 23.158 in
```

WRC 297 Curve Access Parameters:

```
 Vessel Mean Diameter      (D) =     44.882 in
 Nozzle Outside Diameter   (d) =     15.748 in
 Vessel Thickness used     (T) =      0.630 in
 Nozzle Thickness used     (t) =      3.093 in
 T / t                         =      0.204
 d / t                         =     10.000

Lambda = [(d/D) * sqrt(D/T)]  = 2.962
```

Note: Re-pad thickness is added to nozzle thickness to simulate the Re-pad.

```
 Nr/P     =       0.058
 Mr/P     =       0.107
 M0/P     =       0.032
 N0/P     =       0.063
 MrD/Mc   =       0.267
 NrDL/Mc  =       0.091
 M0d/Mc   =       0.080
 N0DL/Mc  =       0.085
 MrD/Ml   =       0.084
 NrDL/Ml  =       0.065
 M0D/Ml   =       0.024
 N0DL/Ml  =       0.078
```

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stresses Normal to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Outplane Membrane (P)	410	410	410	410
Outplane Bending (P)	1258	-1258	1258	-1258
Outplane Membrane (Mc)	0	0	0	0
Outplane Bending (Mc)	0	0	0	0

Outplane Membrane (ML)	-1515	-1515	1515	1515
Outplane Bending (ML)	-2823	2823	2823	-2823
Normal Pressure Stress	9754	10036	9754	10036
Outplane Stress Summary	7084	10496	15760	7880

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stresses parallel to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Inplane Membrane (P)	379	379	379	379
Inplane Bending (P)	4191	-4191	4191	-4191
Inplane Membrane (Mc)	0	0	0	0
Inplane Bending (Mc)	0	0	0	0
Inplane Membrane (ML)	-1272	-1272	1272	1272
Inplane Bending (ML)	-9888	9888	9888	-9888
Inplane Pressure Stress	4877	4877	4877	4877
Inplane Stress Summary	-1713	9681	20607	-7551

Vessel Stresses (psi):

LONGITUDINAL PLANE (Shear stress normal to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Outplane Shear (Vc)	207	207	-207	-207
Outplane Shear (Vl)	0	0	0	0
Outplane Shear (Mt)	633	633	633	633
Shear Stress Summary	840	840	426	426

Vessel Stresses (psi):

LONGITUDINAL PLANE (Stress Intensities	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
Two * Max Shear Stress	8955	11022	20644	15454

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses Normal to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Outplane Membrane (P)	410	410	410	410
Outplane Bending (P)	1258	-1258	1258	-1258
Outplane Membrane (Mc)	-1316	-1316	1316	1316
Outplane Bending (Mc)	-7415	7415	7415	-7415
Outplane Membrane (ML)	0	0	0	0
Outplane Bending (ML)	0	0	0	0
Normal Pressure Stress	4877	4877	4877	4877
Outplane Stress Summary	-2186	10128	15276	-2070

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stresses parallel to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Inplane Membrane (P)	379	379	379	379
Inplane Bending (P)	4191	-4191	4191	-4191
Inplane Membrane (Mc)	-1404	-1404	1404	1404
Inplane Bending (Mc)	-24703	24703	24703	-24703
Inplane Membrane (ML)	0	0	0	0

Inplane Bending (ML)	0	0	0	0
Inplane Pressure Stress	9754	10036	9754	10036
Inplane Stress Summary	-11783	29523	40431	-17075

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Shear stress normal to circumferential plane)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Outplane Shear (Vc)	0	0	0	0
Outplane Shear (Vl)	-207	-207	207	207
Torsional Shear (Mt)	633	633	633	633
Shear Stress Summary	426	426	840	840

Vessel Stresses (psi):

CIRCUMFERENTIAL PLANE (Stress Intensities	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
Two * Max Shear Stress	11801	29532	40459	17121

WRC 297 Stress Summations per ASME Sec. VIII Div. 2:

Vessel Stress Summation at Vessel-Nozzle Junction (psi):

Type of Stress Int. Location	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	4809	5091	4809	5091	4809	5091	4809	5091
Circ. Pl (SUS)	-1437	-1437	1945	1945	-686	-686	990	990
Circ. Q (SUS)	-3969	3969	5215	-5215	-5844	5844	7830	-7830
Long. Pm (SUS)	2404	2404	2404	2404	2404	2404	2404	2404
Long. Pl (SUS)	-621	-621	925	925	-420	-420	928	928
Long. Q (SUS)	-5371	5371	7357	-7357	-4443	4443	5689	-5689
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	152	152	-152	-152	-152	-152	152	152
Shear Q (SUS)	679	679	679	679	679	679	679	679
Pm (SUS)	4809	5091	4809	5091	4809	5091	4809	5091
Pm+Pl (SUS)	3386	3666	6760	7042	4133	4414	5808	6089
Pm+Pl+Q (Total)	3803	8251	12157	5943	2733	10320	13774	2937

Vessel Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	5091	20000	Passed
Pm+Pl (SUS)	7042	30000	Passed
Pm+Pl+Q (TOTAL)	13774	60000	Passed

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

WRC 297 Stress Summations per ASME Sec. VIII Div. 2:

Vessel Stress Summation at Reinforcing Pad Edge (psi):

Type of Stress Int. Location	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	9754	10036	9754	10036	9754	10036	9754	10036
Circ. Pl (SUS)	-1105	-1105	1925	1925	-1025	-1025	1783	1783
Circ. Q (SUS)	-1565	1565	4081	-4081	-20512	20512	28894	-28894
Long. Pm (SUS)	4877	4877	4877	4877	4877	4877	4877	4877
Long. Pl (SUS)	-893	-893	1651	1651	-906	-906	1726	1726
Long. Q (SUS)	-5697	5697	14079	-14079	-6157	6157	8673	-8673
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	207	207	-207	-207	-207	-207	207	207
Shear Q (SUS)	633	633	633	633	633	633	633	633
Pm (SUS)	9754	10036	9754	10036	9754	10036	9754	10036
Pm+Pl (SUS)	8658	8939	11687	11968	8737	9019	11545	11827
Pm+Pl+Q (Total)	8955	11022	20644	15454	11801	29532	40459	17121

Vessel Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	10036	20000	Passed
Pm+Pl (SUS)	11968	30000	Passed
Pm+Pl+Q (TOTAL)	40459	60000	Passed

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

WRC 297 Stress Summations per ASME Sec. VIII Div. 2:

Nozzle Stress Summation at Vessel-Nozzle Junction (psi):

Type of Stress Int. Location	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	2561	2899	2561	2899	2561	2899	2561	2899
Circ. Pl (SUS)	-1437	-1437	1945	1945	-420	-420	928	928
Circ. Q (SUS)	0	0	0	0	0	0	0	0
Long. Pm (SUS)	1280	1280	1280	1280	1280	1280	1280	1280
Long. Pl (SUS)	-2541	-2541	2813	2813	-1973	-1973	2245	2245
Long. Q (SUS)	-15795	15795	20611	-20611	-17037	17037	21853	-21853
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	323	323	-323	-323	-323	-323	323	323
Shear Q (SUS)	1442	1442	1442	1442	1442	1442	1442	1442
Pm (SUS)	2561	2899	2561	2899	2561	2899	2561	2899
Pm+Pl (SUS)	2470	2798	4682	4963	2906	3237	3830	4032
Pm+Pl+Q (Total)	18519	14768	24765	21478	19996	16433	25519	22434

Nozzle Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	2899	17100	Passed
Pm+Pl (SUS)	4963	25650	Passed
Pm+Pl+Q (TOTAL)	25519	51300	Passed

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

Input, Nozzle Desc: Aux3 Parent: S1

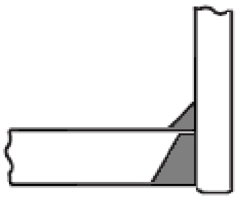
Pressure for Reinforcement Calculations	P	280.140	psig
Temperature for Internal Pressure	Temp	330	F
Design External Pressure	Pext	15.00	psig
Temperature for External Pressure	Tempex	300	F
Maximum Allowable Pressure New & Cold		377.46	psig
Parent Material [Normalized]		SA-516 70	
Parent Allowable Stress at Temperature	Sv	20000.00	psi
Parent Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Cylindrical Shell	D	10.8976	in
Design Length of Section	L	10.1241	in
Shell Finished (Minimum) Thickness	t	0.5512	in
Shell Internal Corrosion Allowance	c	0.0000	in
Shell External Corrosion Allowance	co	0.0000	in
User Entered Minimum Design Metal Temperature		32.00	F

Type of Element Connected to the Parent : Nozzle

Material [Normalized]		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	20000.00	psi
Allowable Stress At Ambient	Sna	20000.00	psi
Diameter Basis (for tr calc only)		Inside	
Layout Angle		90.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	0.6540	in
Flange Type		Long Weld Neck	
Corrosion Allowance	can	0.0000	in
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	8.5870	in
Weld leg size between Nozzle and Pad/Shell	Wo	0.3940	in
Groove weld depth between Nozzle and Vessel	Wgnv	0.5510	in
Inside Projection	h	0.0000	in
Weld leg size, Inside Element to Shell	Wi	0.0000	in
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was MAWP + static head (to the nozzle).

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



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

Reinforcement CALCULATION, Description: Aux3

ASME Code, Section VIII, Div. 1, 2021, 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)
  = 280.14*5.4488/(20000*1-0.6*280.14)
  = 0.0770 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]
```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 377.46*5.4488/(20000*1-0.6*377.46)
  = 0.1040 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Int. Press]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1(exp([280.14/(20000*1]-1)
  = 0.0141 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Mapnc]
```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1(exp([377.46/(20000*1]-1)
  = 0.0191 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0158 in

UG-40, Limits of Reinforcement : [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl      4.4104  in
 Parallel to Vessel Wall                        Rn+tn+t      2.2052  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp      1.3780  in
```

UG-40, Limits of Reinforcement : [Mapnc]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl      4.4104  in
 Parallel to Vessel Wall                        Rn+tn+t      2.2052  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp      1.3780  in
```

Weld Strength Reduction Factor [fr1]:
```
  = min( 1, Sn/Sv )
  = min( 1, 20000/20000 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:
```
  = min( 1, Sn/Sv )
  = min( 1, 20000/20000 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:
```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

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

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	0.154	0.036	0.208
Area in Shell	A1	1.143	1.242	1.078
Area in Nozzle Wall	A2	1.763	1.759	1.750
Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.155	0.155	0.155
Area in Element	A5	0.000	0.000	0.000
TOTAL AREA AVAILABLE	Atot	3.062	3.156	2.983

The MAP(nc) 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)
  = (2*0.104*1+2*0.654*0.104*1*(1-1))
  = 0.208 in^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 )
  = 2.4104( 1 * 0.5512 - 1 * 0.104 ) - 2 * 0.654
    ( 1 * 0.5512 - 1 * 0.104 ) *( 1 - 1 )
  = 1.078 in^2
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 1.378 )( 0.654 - 0.01905 )1
  = 1.750 in^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:
```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 0.394² * 1 +( 0 )² * 1
  = 0.155 in^2
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures      ta = 0.0191 in
Wall Thickness per UG16(b),                       tr16b = 0.0625 in
Wall Thickness, shell/head, internal pressure      trb1 = 0.0770 in
Wall Thickness                  tb1 = max(trb1, tr16b) = 0.0770 in
Wall Thickness                  tb2 = max(trb2, tr16b) = 0.0625 in
Wall Thickness per table UG-45                      tb3 = 0.1890 in
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.189, max( 0.07697, 0.0625 ) ]
  = 0.0770 in
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 0.01905, 0.07697 )
  = 0.0770 in
```

Available Nozzle Neck Thickness = 0.6540 in --> OK

UG-45 Minimum Nozzle Neck Thickness Requirement: [MAPnc]

```
 Wall Thickness for Internal/External pressures      ta = 0.0191 in
 Wall Thickness per UG16(b),                       tr16b = 0.0625 in
 Wall Thickness, shell/head, internal pressure      trb1 = 0.1040 in
 Wall Thickness                   tb1 = max(trb1, tr16b) = 0.1040 in
 Wall Thickness                   tb2 = max(trb2, tr16b) = 0.0625 in
 Wall Thickness per table UG-45                      tb3 = 0.1890 in
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.189, max( 0.104, 0.0625 ) ]
  = 0.1040 in
```

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

```
  = max( ta, tb )
  = max( 0.01905, 0.104 )
  = 0.1040 in
```

Available Nozzle Neck Thickness = 0.6540 in --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 0.5512, tr = 0.07697, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.1396, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve B              -1 F

 Gov. MDMT of the nozzle to shell joint welded assembly :    -1 F
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
 Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)     -20 F
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -20 F
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :

```
 Design Pressure/Ambient Rating = 280.14/740.00 = 0.379
```

Note: The MDMT was not reduced based on lower stress per user request.

Weld Size Calculations, Description: Aux3

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.5512  in
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
 Nozzle Weld         0.2500 = Min per Code 0.2786 = 0.7 * Wo in
```

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,(0.208 - 1.0778 + 2 * 0.654 * 1 *
    (1 * 0.5512 - 0.104 ) )20000 )
  = max( 0, -5698.33) lbf
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
```

```
  = ( 1.7499 + 0 + 0.1552 - 0 * 1 ) * 20000
  = 38101.85 lbf
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.7499 + 0 + 0.1552 +( 0.7209 ) ) * 20000
  = 52520.74 lbf
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.7499 + 0 + 0.1552 + 0 +( 0.7209 ) ) * 20000
  = 52520.74 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 3.308 * 0.394 * 0.49 * 20000
  = 20064. lbf
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 1.327 ) *( 0.654 - 0 ) * 0.7 * 20000
  = 38170. lbf
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * Wgnvi * 0.74 * Sng
  = ( 3.1416/2.0 ) * 3.308 *( 0.551 - 0 ) * 0.74 * 20000
  = 42374. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:
```
  = ( SONW + SNW ) = ( 20064 + 38170 ) = 58234 lbf
```

Failure Path [Path 2-2]:
```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 20064 + 0 + 42374 + 0 ) = 62437 lbf
```

Failure Path [Path 3-3]:
```
  = ( Sonw + Tngw + Sinw )
  = ( 20064 + 42374 + 0 ) = 62437 lbf
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 58233   lbf, must exceed W = 0 lbf        or W1 = 38101 lbf
 Path 2-2 = 62437   lbf, must exceed W = 0 lbf        or W2 = 52520 lbf
 Path 3-3 = 62437   lbf, must exceed W = 0 lbf        or W3 = 52520 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:
```
 Converged Maximum Allowable Pressure in the Operating case: 1907.4 psig
```

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

```
 Nozzle is O.K. for the External Pressure: 15 psig

 Approximate Maximum Allowable Pressure New & Cold: 1907.4 psig
```

Note: The M.A.P.(NC) of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 0.2571 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 9.3953 in

Input, Nozzle Desc: Aux4 **Parent: S2**

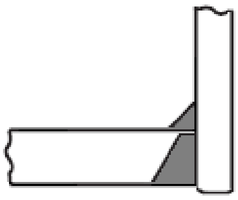
Pressure for Reinforcement Calculations	P	281.702	psig
Temperature for Internal Pressure	Temp	330	F
Design External Pressure	Pext	15.00	psig
Temperature for External Pressure	Tempex	300	F
Maximum Allowable Pressure New & Cold		377.46	psig
Parent Material		SA-106 B	
Parent Allowable Stress at Temperature	Sv	17100.00	psi
Parent Allowable Stress At Ambient	Sva	17100.00	psi
Inside Diameter of Cylindrical Shell	D	9.5620	in
Design Length of Section	L	10.6241	in
Shell Finished (Minimum) Thickness	t	0.5940	in
Shell Internal Corrosion Allowance	c	0.0000	in
Shell External Corrosion Allowance	co	0.0000	in
User Entered Minimum Design Metal Temperature		32.00	F

Type of Element Connected to the Parent : Nozzle

Material [Normalized]		SA-105	
Material UNS Number		K03504	
Material Specification/Type		Forgings	
Allowable Stress at Temperature	Sn	20000.00	psi
Allowable Stress At Ambient	Sna	20000.00	psi
Diameter Basis (for tr calc only)		Inside	
Layout Angle		90.00	deg
Diameter		2.0000	in.
Size and Thickness Basis		Actual	
Actual Thickness	tn	0.6540	in
Flange Type		Long Weld Neck	
Corrosion Allowance	can	0.0000	in
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	9.5860	in
Weld leg size between Nozzle and Pad/Shell	Wo	0.3940	in
Groove weld depth between Nozzle and Vessel	Wgnv	0.5940	in
Inside Projection	h	0.0000	in
Weld leg size, Inside Element to Shell	Wi	0.0000	in
Flange Class		300	
Flange Grade		GR 1.1	

The Pressure Design option was MAWP + static head (to the nozzle).

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



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

Reinforcement CALCULATION, Description: Aux4

ASME Code, Section VIII, Div. 1, 2021, 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)
  = 281.7*4.781/(17100*1-0.6*281.7)
  = 0.0795 in
```

Reqd thk per UG-37(a) of Cylindrical Shell, tr [Mapnc]

```
  = P*R/(Sv*E-0.6*P) per UG-27 (c)(1)
  = 377.46*4.781/(17100*1-0.6*377.46)
  = 0.1069 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Int. Press]

```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1(exp([281.7/(20000*1]-1)
  = 0.0142 in
```

Reqd thk per App. 1 of Nozzle Wall, trn [Mapnc]

```
  = R( exp([P/(Sn*E)] - 1 ) per Appendix 1-2 (a)(1)
  = 1(exp([377.46/(20000*1]-1)
  = 0.0191 in
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0166 in

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

```
 Parallel to Vessel Wall (Diameter Limit)            Dl     4.4960  in
 Parallel to Vessel Wall                        Rn+tn+t     2.2480  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     1.4850  in
```

UG-40, Limits of Reinforcement : [Mapnc]

```
 Parallel to Vessel Wall (Diameter Limit)            Dl     4.4960  in
 Parallel to Vessel Wall                        Rn+tn+t     2.2480  in
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     1.4850  in
```

Weld Strength Reduction Factor [fr1]:

```
  = min( 1, Sn/Sv )
  = min( 1, 20000/17100 )
  = 1.000
```

Weld Strength Reduction Factor [fr2]:

```
  = min( 1, Sn/Sv )
  = min( 1, 20000/17100 )
  = 1.000
```

Weld Strength Reduction Factor [fr3]:

```
  = min( fr2, fr4 )
  = min( 1, 1 )
  = 1.000
```

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

AREA AVAILABLE, A1 to A5		MAWP	External	Mapnc
Area Required	Ar	0.159	0.034	0.214
Area in Shell	A1	1.284	1.397	1.216
Area in Nozzle Wall	A2	1.900	1.893	1.886
Area in Inward Nozzle	A3	0.000	0.000	0.000
Area in Welds	A41+A42+A43	0.155	0.155	0.155
Area in Element	A5	0.000	0.000	0.000
TOTAL AREA AVAILABLE	Atot	3.340	3.445	3.257

The MAP(nc) 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)
  = (2*0.1069*1+2*0.654*0.1069*1*(1-1))
  = 0.214 in^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 )
  = 2.496( 1 * 0.594 - 1 * 0.1069 ) - 2 * 0.654
    ( 1 * 0.594 - 1 * 0.1069 ) *( 1 - 1 )
  = 1.216 in^2
```

Area Available in Nozzle Projecting Outward [A2]:

```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 1.485 )( 0.654 - 0.01905 )1
  = 1.886 in^2
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 0.394² * 1 +( 0 )² * 1
  = 0.155 in^2
```

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

```
 Wall Thickness for Internal/External pressures      ta = 0.0191 in
 Wall Thickness per UG16(b),                       tr16b = 0.0625 in
 Wall Thickness, shell/head, internal pressure      trb1 = 0.0795 in
 Wall Thickness                  tb1 = max(trb1, tr16b) = 0.0795 in
 Wall Thickness                  tb2 = max(trb2, tr16b) = 0.0625 in
 Wall Thickness per table UG-45                      tb3 = 0.1890 in
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.189, max( 0.07955, 0.0625 ) ]
  = 0.0795 in
```

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

```
  = max( ta, tb )
  = max( 0.01905, 0.07955 )
  = 0.0795 in
```

Available Nozzle Neck Thickness = 0.6540 in --> OK

UG-45 Minimum Nozzle Neck Thickness Requirement: [MAPnc]

```
Wall Thickness for Internal/External pressures      ta = 0.0191 in
Wall Thickness per UG16(b),                       tr16b = 0.0625 in
Wall Thickness, shell/head, internal pressure     trb1 = 0.1069 in
Wall Thickness                 tb1 = max(trb1, tr16b) = 0.1069 in
Wall Thickness                 tb2 = max(trb2, tr16b) = 0.0625 in
Wall Thickness per table UG-45                     tb3 = 0.1890 in
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.189, max( 0.1069, 0.0625 ) ]
  = 0.1069 in
```

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

```
  = max( ta, tb )
  = max( 0.01905, 0.1069 )
  = 0.1069 in
```

Available Nozzle Neck Thickness = 0.6540 in --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

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

Govrn. thk, tg = 0.594, tr = 0.07955, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.1339, Temp. Reduction = 0 F

```
Min Metal Temp. w/o impact per UCS-66, Curve B              3 F

Gov. MDMT of the nozzle to shell joint welded assembly :     3 F
```

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)     -20 F
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -20 F
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :

```
Design Pressure/Ambient Rating = 281.70/740.00 = 0.381
```

Note: The MDMT was not reduced based on lower stress per user request.

Weld Size Calculations, Description: Aux4

```
Intermediate Calc. for nozzle/shell Welds   Tmin      0.5940  in
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
Nozzle Weld          0.2500 = Min per Code 0.2786 = 0.7 * Wo in
```

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,(0.2139 - 1.2157 + 2 * 0.654 * 1 *
    (1 * 0.594 - 0.1069 ) )17100 )
  = max( 0, -6236.64) lbf
```

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

Weld Load [W1]:

```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
```

```
  = ( 1.8858 + 0 + 0.1552 - 0 * 1 ) * 17100
  = 34901.63 lbf
```

Weld Load [W2]:

```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 1.8858 + 0 + 0.1552 +( 0.777 ) ) * 17100
  = 48187.51 lbf
```

Weld Load [W3]:

```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 1.8858 + 0 + 0.1552 + 0 +( 0.777 ) ) * 17100
  = 48187.51 lbf
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:

```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.1416/2.0 ) * 3.308 * 0.394 * 0.49 * 17100
  = 17154. lbf
```

Shear, Nozzle Wall [Snw]:

```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.1416 * 1.327 ) *( 0.654 - 0 ) * 0.7 * 20000
  = 38170. lbf
```

Tension, Shell Groove Weld [Tngw]:

```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.1416/2.0 ) * 3.308 *( 0.594 - 0 ) * 0.74 * 20000
  = 45681. lbf
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:

```
  = ( SONW + SNW ) = ( 17154 + 38170 ) = 55325 lbf
```

Failure Path [Path 2-2]:

```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 17154 + 0 + 45681 + 0 ) = 62835 lbf
```

Failure Path [Path 3-3]:

```
  = ( Sonw + Tngw + Sinw )
  = ( 17154 + 45681 + 0 ) = 62835 lbf
```

Summary of Failure Path Calculations:

```
 Path 1-1 = 55324   lbf, must exceed W = 0 lbf        or W1 = 34901 lbf
 Path 2-2 = 62835   lbf, must exceed W = 0 lbf        or W2 = 48187 lbf
 Path 3-3 = 62835   lbf, must exceed W = 0 lbf        or W3 = 48187 lbf
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Maximum Allowable Pressure in the Operating case: 1977.1 psig
```

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

```
 Nozzle is O.K. for the External Pressure: 15 psig

 Approximate Maximum Allowable Pressure New & Cold: 1977.1 psig
```

Note: The M.A.P.(NC) of this junction was limited by the parent Shell/Head.

The Drop for this Nozzle is : 0.2952 in
The Cut Length for this Nozzle is, Drop + Ho + H + T : 10.4752 in

Bill of Materials:

QTY	DESCRIPTION	MATERIAL
1	BODY FLANGE: 4.921" THK X 54.724" OD	SA-266 2
3	BODY FLANGE: 5.787" THK X 54.724" OD	SA-266 2
1	CYLINDER: 0.630" THK X 44.252" ID X 2'-9.46"	SA-516 70
1	CYLINDER: 0.630" THK X 44.252" ID X 17'-4.66"	SA-516 70
1	ELLIPTICAL HEAD: 2.0 X 1, 0.551" THK X 44.252" ID X 2.00"	SA-516 70
1	INSULATION: 4.528" X 1.500" THK	IH
3	INSULATION: 7.031" X 1.500" THK	IH
3	LINING: 7.087" X 0.252" THK	...
1	INSULATION: 33.465" X 1.500" THK	IH
1	LINING: 33.465" X 0.125" THK	...
12	BAFFLES: 43.748" DIA X 0.315" THK	SA-240 316
8	TIE RODS: 0.472" DIA X 194.090"	SA-479
8	SPACERS: 0.750" DIA X 194.090"	SA-213
1	TUBESHEET: 46.850" X 4.474" THK	SA-182 F316L
1320	TUBES: 193.160" X 0.750" DIA X 0.058" THK	SA-213 TP316L
2	SADDLE: 7.425" X 120 DEG	SA-516 70
1	INSULATION: 208.661" X 1.500" THK	IH
1	LINING: 208.661" X 0.125" THK	...
2	LIFTING LUGS:	SA-516 70
2	LIFTING LUG PADS: 7.874" X 15.748" X 0.630" THK	
1	INSULATION: 13.062" X 1.500" THK	IH
1	LINING: 13.062" X 0.157" THK	...
6	CLASS 300 GR 1.1,2.0" BLIND FLANGE(S)	SA-105
2	GASKET: 46.850" OD X 45.276" ID	...
88	BODY FLANGE BOLTS: 1.500" DIA	SA-193 B7M
176	NUTS FOR BODY FLANGE BOLTS: 1.500" DIA	...
1	NAMEPLATE	...

Nozzle Schedule:

Description	Nominal or Actual Size	Schd or FVC Type	Flg Type	Nozzle O/Dia in	Wall Thk in	Reinforcing Pad Diameter	Thk in	Cut Length in	Flg Class
V1	2.000 in	Actual	LWN	3.308	0.654	...	...	11.7	300
D1	2.000 in	Actual	LWN	3.308	0.654	...	...	11.7	300
Aux1	2.000 in	Actual	LWN	3.308	0.654	...	...	10.4	300
Aux2	2.000 in	Actual	LWN	3.308	0.654	...	...	10.4	300
Aux3	2.000 in	Actual	LWN	3.308	0.654	...	...	9.4	300
Aux4	2.000 in	Actual	LWN	3.308	0.654	...	...	10.4	300
T2	10.000 in	80	WNF	10.750	0.594	17.72	0.63	15.5	300
T1	10.000 in	80	WNF	10.750	0.594	17.72	0.63	15.5	300
S2	10.000 in	80	WNF	10.750	0.594	15.75	0.63	11.9	300
S1	12.000 in	Actual	WNF	12.000	0.551	19.68	0.63	11.5	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 (in):

Description	Material	Shl Grve Weld	Noz Shl/Pad Weld	Pad OD Weld	Pad Grve Weld	Inside Weld
V1	SA-105	0.630	0.394	...	...	...
D1	SA-105	0.630	0.395	...	...	...
Aux1	SA-105	0.594	0.394	...	...	...
Aux2	SA-105	0.594	0.394	...	...	...
Aux3	SA-105	0.551	0.394	...	...	...
Aux4	SA-105	0.594	0.394	...	...	...
T2	SA-106 B	0.630	0.394	0.472	0.630	...
T1	SA-106 B	0.630	0.394	0.472	0.630	...
S2	SA-106 B	0.630	0.394	0.472	0.630	...
S1	SA-516 70	0.630	0.394	0.472	0.630	...

Note: The Outside projections below do not include the flange thickness.

Nozzle Miscellaneous Data:

Description	Elev/Distance From Datum in	Layout Angle deg	Proj Outside in	Proj Inside in	Installed in Component
V1	28.957	-25.6	10.17	0.00	CHANNEL
D1	28.957	205.6	10.17	0.00	CHANNEL
Aux1	18.012	90.0	9.59	0.00	T1
Aux2	18.012	90.0	9.59	0.00	T2
Aux3	69.924	90.0	8.59	0.00	S1
Aux4	69.924	90.0	9.59	0.00	S2
T2	28.957	23.3	11.48	0.00	CHANNEL
T1	28.957	156.7	11.48	0.00	CHANNEL
S2	242.232	180.0	10.62	0.00	SHELL

S1		77.823	0.0	10.12	0.00	SHELL

```
PV Elite 24        Licensee: WCE
FileName : 1.18-X-262-04    ---------------------------------
Nozzle Summary:                          Step:   34   8:44am  Jan 17,2023
```

Nozzle Calculation Summary (psig & in):

Description	MAWP	Ext	MAPNC	UG-45	[tr]	Weld Path	Areas or Stresses
T2	280.14	OK	526.56	OK	0.319	OK	Passed
T2	280.14	OK	537.97	OK	0.319	OK	Passed
T1	280.14	OK	526.57	OK	0.319	OK	Passed
T1	280.14	OK	537.98	OK	0.319	OK	Passed
V1	280.14	OK	559.9	OK	0.189	OK	Passed
D1	280.14	OK	559.9	OK	0.189	OK	Passed
Aux1	1977.1	OK	1977.1	OK	0.107	OK	Passed
Aux2	1977.1	OK	1977.1	OK	0.107	OK	Passed
S1	280.14	OK	545.72	OK	0.328	OK	Passed
S2	280.14	OK	495.52	OK	0.319	OK	Passed
Aux3	1907.4	OK	1907.4	OK	0.104	OK	Passed
Aux4	1977.1	OK	1977.1	OK	0.107	OK	Passed

Nozzle MAWP Summary:

```
Minimum MAWP Nozzles        :        280.14 Nozzle  : S1  [Shellside]
Minimum MAPnc Nozzles       :        495.52 Nozzle  : S2  [Shellside]
Minimum MAWP Nozzles        :        280.14 Nozzle  : T2  [Tubeside]
Minimum MAPnc Nozzles       :        526.56 Nozzle  : T2  [Tubeside]
```

Multiple output lines for the same nozzle indicates required Code calculations in both the longitudinal and circumferential planes of reinforcement where applicable.

Check the Spatial Relationship between the Nozzles:

From Node	Nozzle Description	X Coordinate in	Layout Angle deg	Dia. Limit in
30	T2	28.957	23.297	19.124
30	T1	28.957	156.703	19.124
30	V1	28.957	-25.629	4.568
30	D1	28.957	205.628	4.568
30	Aux1	0.000	90.000	4.496
30	Aux2	0.000	90.000	4.496
60	S1	77.823	0.000	21.795
60	S2	242.232	180.000	19.124
60	Aux3	0.000	90.000	4.410
60	Aux4	0.000	90.000	4.496

The nozzle spacing is computed by the following:

= sqrt($ll^2 + lc^2$) where

ll - Arc length along the inside vessel surface in the long. direction.
lc - Arc length along the inside vessel surface in the circ. direction

If any interferences/violations are found, they will be noted below.

No interference violations have been detected!

Input Echo, Tubesheet Number 1, Description:

Shell Data:

Main Shell Description: SHELL

Shell Maximum Design Pressure	Psd,max	150.00	psig
Shell Maximum Operating Pressure	Psox,max	150.00	psig
Shell Minimum Operating Pressure	Psox,min	-15.00	psig
Shell Thickness	ts	0.6300	in
Shell Internal Corrosion Allowance	cas	0.0000	in
Shell External Corrosion Allowance	caext	0.0000	in
Inside Diameter of Shell	Ds	44.252	in
Shell Temperature for Internal Pressure	Ts	330.00	F
Shell Material		SA-516 70	

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	20000.00	psi
Shell Allowable Stress at Ambient		20000.00	psi

Channel Description: CHANNEL

Channel Type:		Cylinder	
Channel Maximum Design Pressure	Ptd,max	195.00	psig
Channel Maximum Operating Pressure	Ptox,max	195.00	psig
Channel Minimum Operating Pressure	Ptox,min	-15.00	psig
Channel Thickness	tc	0.6300	in
Channel Corrosion Allowance	cac	0.0000	in
Inside Diameter of Channel	Dc	44.252	in
Channel Design Temperature	TEMPC	300.00	F
Channel Material		SA-516 70	

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	20000.00	psi
Channel Allowable Stress at Ambient		20000.00	psi

Tube Data:

Number of Tube Holes	Nt	1320	
Tube Wall Thickness	et	0.0585	in
Tube Outside Diameter	D	0.7500	in
Straight Tube Length (bet. inner tubsht faces)	L	193.16	in
Design Temperature of the Tubes		330.00	F
Tube Material		SA-213 TP316L	
Tube Material UNS Number		S31603	
Is this a Welded Tube		No	
Tube Material Specification used		Smls. tube	
Tube Allowable Stress at Temperature		16400.00	psi
Tube Allowable Stress At Ambient		16700.00	psi
Tube Yield Stress At design Temperature	Syt	18550.00	psi
Tube Pitch (Center to Center Spacing)	P	1.0000	in
Tube Layout Pattern		Square	

Radius to Outermost Tube Hole Center	ro	21.350	in
Largest Center-to-Center Tube Distance	Ul	2.2500	in
Length of Expanded Portion of Tube	ltx	4.1339	in
Tube-side pass partition groove depth	hg	0.1970	in

Tubesheet Data:

Tubesheet TYPE: U-tube, Gasketed both Sides, Conf. d

Tubesheet Design Metal Temperature	T	330.00	F
Tubesheet Material		SA-182 F316L	
Tubesheet Material UNS Number		S31603	
Tubesheet Allowable Stress at Temperature	S	12400.00	psi
Tubesheet Allowable Stress at Ambient	Tt	16700.00	psi
Thickness of Tubesheet	h	4.4740	in
Tubesheet Corr. Allowance (Shell side)	Cats	0.0310	in
Tubesheet Corr. Allowance (Channel side)	Catc	0.0310	in
Tubesheet Outside Diameter	A	46.850	in
Dimension G for the Channel Side	Gc	46.223	in
Area of the Untubed Lanes	AL	159.977	in^2
Junction Stress Reduction option		Perform Plastic Calculation	
Perform Differential Pressure Design		NO	
Run Multiple Load Cases		YES	
Shell Side Min. Design Pressure	Psd,min	15.0000	psig
Channel Side Min. Design Pressure	Ptd,min	15.0000	psig

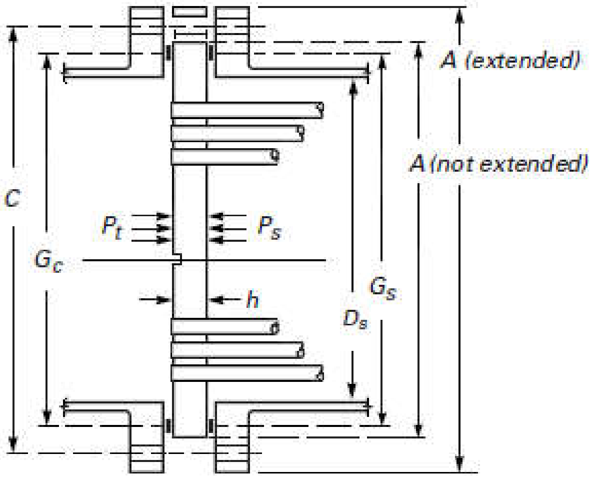
Additional Data for Gasketed Tubesheets:

Tubesheet Gasket on which Side		Both	
Flange Outside Diameter	A	54.724	in
Flange Inside Diameter	B	44.504	in
Flange Face Outside Diameter	Fod	46.969	in
Flange Face Inside Diameter	Fid	44.504	in
Gasket Outside Diameter	Go	46.850	in
Gasket Inside Diameter	Gi	45.276	in
Small end Hub thk.	g0	0.5040	in
Large end Hub thk.	g1	0.8190	in
Gasket Factor,	m	4.25	
Gasket Design Seating Stress	y	10100.00	psi
Flange Facing Sketch		Code Sketch 1a	
Column for Gasket Seating		Code Column II	
Gasket Thickness	tg	0.1570	in
Full face Gasket Flange Option		Program Selects	

Bolting Information:

Diameter of Bolt Circle	C	50.984	in
Nominal Bolt Diameter	dB	1.5000	in
Type of Thread Series		TEMA Thread Series	
Number of Bolts	n	44	
Bolt Material		SA-193 B7M	
Bolt Allowable Stress At Temperature	Sb	20000.00	psi
Bolt Allowable Stress At Ambient	Sa	20000.00	psi
Weld between Flange and Shell/Channel		0.0000	in
Alternate Flange Operating Bolt Load, Wm1		428514.19	lbf
Alternate Flange Seating Bolt Load, Wm2		595137.88	lbf
Alternate Flange Design Bolt Load, W		915768.88	lbf
Tubesheet Integral with		None	
Tubesheet Extended as Flange		No	

Tubesheet Gasketed With Shell and Channel



Configuration d:

ASME TubeSheet Results per Part UHX, 2021

Elasticity/Expansion Material Properties :

Shell   - TM-1   Carbon Steels with C<= 0.3%

```
 -----------------------------------------------------------------
 Elastic Mod. at Design Temperature      330.0 F       0.28180E+08 psi
 Elastic Mod. at Ambient Temperature      70.0 F       0.29400E+08 psi
```

Channel   - TM-1   Carbon Steels with C<= 0.3%

```
 -----------------------------------------------------------------
 Elastic Mod. at Design Temperature      300.0 F       0.28300E+08 psi
 Elastic Mod. at Ambient Temperature      70.0 F       0.29400E+08 psi
```

Tubes   - TM-1   Material Group G

```
 -----------------------------------------------------------------
 Elastic Mod. at Tubsht. Design Temp.    330.0 F       0.26820E+08 psi
 Elastic Mod. at Ambient Temperature      70.0 F       0.28300E+08 psi
```

TubeSheet - TM-1   Material Group G

```
 -----------------------------------------------------------------
 Elastic Mod. at Design Temperature      330.0 F       0.26820E+08 psi
 Elastic Mod. at Ambient Temperature      70.0 F       0.28300E+08 psi
```

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)
  = (210*(0.75/2-0)/(16400*1+0.4*210)
  = 0.0048 + 0.0000 = 0.0048 in
```

Tube Required Thickness under External Pressure (Shellside pressure) :

```
 External Pressure Chart     HA-4            at       330.00  F
 Elastic Modulus for Material                     26400000.00  psi
```

Results for Max. Allowable External Pressure (Emawp):

TCA	ODCA	SLEN	D/T	L/D	Factor A	B
0.0585	0.75	214.51	12.82	50.0000	0.0066924	9818.86

EMAWP = (4*B)/(3*(D/T)) = (4 *9818.9)/(3 *12.821) = 1021.2 psig

Results for Reqd Thickness for Ext. Pressure (Tca):

TCA	ODCA	SLEN	D/T	L/D	Factor A	B
0.0156	0.75	214.51	47.95	50.0000	0.0004785	5933.87

EMAWP = (4*B)/(3*(D/T)) = (4 *5933.9)/(3 *47.947) = 165.01 psig

Summary of Tube Required Thickness Results:

Total Required Thickness including Corrosion all.	0.0156	in
Allowable Internal Pressure at Corroded thickness	2728.67	psig
Required Internal Design Pressure	210.00	psig
Allowable External Pressure at Corroded thickness	1021.16	psig
Required External Design Pressure	165.00	psig
Required Thickness due to Shell Side pressure	0.0156	in

Detailed Results for load Case D3 un-corr. (Psd,max + Ptd,max)

Intermediate Calculations For Gasketed Tubesheets:

ASME Code, Section VIII Division 1, 2021

Gasket Contact Width,	N = (Goc-Gic) / 2	0.787	in
Basic Gasket Width,	b0 = N / 2	0.393	in
Effective Gasket Width,	b = sqrt(b0) * 0.5	0.314	in
Gasket Reaction Diameter,	G = Go-2.0*b	46.223	in

Flange Design Bolt Load, Seating Condition	W :	915768.88	lbf
Flange Design Bolt Load, Operating Condition	Wm1:	309775.72	lbf

Results for ASME U-tube Tubesheet Calculations for Configuration d,
Per Edition 2021, Original Thickness :

UHX-12.5.1 Step 1:

Compute the Equivalent Outer Tube Limit Circle Diameter [Do]:
= 2 * ro + dt
= 2 * 21.35 + 0.75 = 43.45 in

Determine the Basic Ligament Efficiency for Shear [μ]:
= (p - dt) / p
= (1 - 0.75)/1 = 0.25

UHX-12.5.2 Step 2:

Compute the Ratio [rhos]:
= Gs / Do (Configurations d, e, f)
= 46.223/43.45 = 1.0638

Compute the Ratio [rhoc]:
= Gc / Do (Configurations d)
= 46.223/43.45 = 1.0638

Moment on Tubesheet due to Pressures (Ps, Pt) [Mts]:
= $Do^2/16$ * [(Rhos-1)*($Rhos^2$+1)* Ps - (rhoc-1) * ($rhoc^2$+1) * Pt]
= $43.45^2/16$ * [(1.0638 - 1) * (1.0638^2 + 1) * 150 -
(1.0638 - 1) * (1.0638^2 + 1) * 195]
= -722.2892 psig*in^2

UHX-12.5.3 Step 3, Determination of Effective Elastic Properties :

Compute the Ratio [rho]:

```
  = ltx/h = 4.1339/4.474 = 0.924 ( must be 0 <= rho <= 1 )
```

Compute the Effective Tube Hole Diameter [d^✱]:

```
  = max( dt - 2tt( EtT/E )( StT/S )( rho ), dt - 2tt)
  = max( 0.75 -2*0.0585 (26820000/26820000 )*
       ( 16400/12400 )*(0.924 ), 0.75 -2*0.0585 )
  = 0.6330 in
```

Compute the Effective Tube Pitch [p✱]:

```
  = p / sqrt( 1 - 4 * min( Al, 4*Do*p)/( pi * Do^2 ) )
  = 1/sqrt( 1 - 4 * min( 159.98, 4*43.45 *1 )/( pi * 43.45^2) )
  = 1.0587 in
```

Compute the Effective Ligament Efficiency for Bending [μ✱]:

```
  = (p✱ - d✱)/p✱ = (1.0587 - 0.633 )/1.0587 = 0.4021
```

```
E✱/E, nu✱ for Square pattern from Fig. UHX-11.4.
h/p = 4.474000 ;  mu✱ = 0.402122 ;  E✱ = 12376287 psi
E✱/E = 0.461457 ;  nu✱ = 0.316018
```

Note: As h/p (4.474) 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 = 46.85/43.45 = 1.0783
```

Coefficient [F]:

```
  = (1 - nu✱)/E✱ * ( E * ln(K) )
  = (1 - 0.316 )/12376287 * ( 26820000 * ln(1.0783 ) )
  = 0.1117
```

UHX-12.5.6 Step 6:

Moment Acting on Unperforated Tubesheet Rim [M✱]

```
  = Mts + W✱ * (Gc - Gs)/(2 * pi * Do)
  = -722.29 + 428514 * (46.223 - 46.223 )/(2 * pi * 43.45 )
  = -722.2892 psig*in^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*) - Do^2/32 * F(Ps - Pt) ) / (1 + F)
  = ((-722.29 ) - 43.45^2/32 * 0.1117 (150 - 195 ) )/(1 + 0.1117 )
  = -383.0439 psig*in^2
```

Maximum Bending Moment acting on Center of Tubesheet [Mo]:

```
  = Mp + Do^2/64 * (3 + nu✱)(Ps - Pt)
  = -383.04 + 43.45^2/64 * (3 + 0.316 )(150 - 195 )
  = -4784.8301 psig*in^2
```

Maximum Bending Moment acting on Tubesheet [M]:

```
  = max( abs(Mp), abs(Mo) )
  = max( abs(-383.04 ), abs(-4784.8 ) )
  = 4784.8301 psig*in^2
```

UHX-12.5.8 Step 8:

Tubesheet Bending Stress at Original Thickness:

= 6 * M / (mu*(h - hg')^2)
= 6 * 4784.8/(0.4021 (4.474 - 0.197)^2)
= 3902.8452 psi

The Allowable Tubesheet Bending Stress [sigma_(All)]:
= 2 * S = 2 * 12400 = 24800 psi

Tubesheet Bending Stress at Final Thickness [sigma]:
= 6 * M / (mu*(h - hg')^2)
= 6 * 4783.8/(0.4021 (1.8937 - 0.197)^2)
= 24794.5039 psi

Required Tubesheet Thickness, for Bending Stress [HreqB]:
= h + Cats + Catc = 1.8937 + 0 + 0 = 1.8937 in

Required Tubesheet Thickness for Given Loadings (includes CA) [Hreq]:
= max(HreqB, HreqS) = max(1.8937, 0.1978) = 1.8937 in

UHX-12.5.9 Step 9:

abs(Ps - Pt) = abs(150 - 195) = 45 psig

Shear Stress check [Tau_(limit)]:
= 4 * mu * h/Do * min(0.8 * S, 0.533 * Sy)
= 4 * 0.25 * 4.474/43.45 * min(0.8 * 12400, 0.533 * 18550)
= 1018.069 psi

[Ps - Pt] is <= the Shear Stress limit (Tau_limit). Therefore, the required thickness for shear is for information only.

Minimum Required Thickness for Shear [HreqS]:
= 1/(4 * mu) * (Do/(min(0.8*S, 0.533*Sy)))[Ps - Pt] + Cats + Catc
= 1/(4 * 0.25) * (43.45/9887.1)[150 - 195] + 0
= 0.1978 in

Note: Analysis Completed for Tubesheet Configuration d.

Stress/Force summary for loadcase D3 un-corr. (Psd,max + Ptd,max):

Stress Description	Actual		Allowable	Pass/Fail
Tubesheet bend. stress	3902.8	<=	24800.0 psi	Ok
Tubesheet shear stress	437.0	<=	9887.1 psi	Ok

Thickness results for loadcase D3 un-corr. (Psd,max + Ptd,max):

Thickness (in)	Required	Actual	P/F
Tubesheet Thickness :	1.8937	4.4740	Ok

U-Tube Tubesheet results per ASME UHX-12 2021

Results for 6 Load Cases:

	--Reqd. Thk. + CA		---- Tubesheet Stresses				Case	Pass/
Case#	Tbsht	Extnsn	Bend	Allwd	Shear	Allwd	Type	Fail
D1uc	3.864	0.240	18213	24800	2039	9887	Ps+Pt D1	Ok
D2uc	3.449	0.188	14310	24800	1602	9887	Ps+Pt D2	Ok
D3uc	1.894	0.051	3903	24800	437	9887	Ps+Pt D3	Ok
D1c	3.894	0.240	18480	24800	2068	9887	Ps+Pt-c D1	Ok

D2c	3.479	0.188	14520	24800	1625	9887	Ps+Pt-c D2	Ok
D3c	1.925	0.051	3960	24800	443	9887	Ps+Pt-c D3	Ok
Max:	3.8943	0.240 in		0.745		0.209	(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)

Note:
Because there was no net pressure differential across the tubesheet due to
the specified pressures psd,min and ptd,min; load case D4 was not processed as
the resulting tubesheet bending stress would be zero.

Summary of Thickness Comparisons for 6 Load Cases:

Thickness (in)	Required	Actual	P/F
Tubesheet Thickness :	3.8943	4.4740	Ok
Tube Thickness :	0.0156	0.0585	Ok

Tubesheet MAWP used to Compute Hydrotest Pressure:

Stress / Force Condition	Tubeside MAWP	@ shellside Stress Rat.	Shellside MAWP	@ tubeside Stress Rat.
Tubesheet Bending Stress	281.81	1.000	281.81	1.000
Tubesheet Shear Stress	1003.95	1.000	1003.95	1.000
Tube Pressure Stress	2728.66	1.000	1021.15	1.000
Minimum MAWP	281.81		281.81	

Tubesheet MAPnc used to Compute Hydrotest Pressure:

Stress / Force Condition	Tubeside MAPnc	@ shellside Stress Rat.	Shellside MAPnc	@ tubeside Stress Rat.
Tubesheet Bending Stress	377.46	1.000	377.46	1.000
Tubesheet Shear Stress	1372.05	1.000	1368.61	0.997
Tube Pressure Stress	2778.57	1.000	1368.61	1.000
Minimum MAPnc	377.46		377.46	

(*) Only the design load cases were analyzed to compute the MAWP for determining the test pressure.

SA-182 F316L, Min Metal Temp without impact per UHA-51: -320 F

Minimum Design Metal Temperature Results Summary (F):

Description	Notes	Curve	Basic MDMT	Reduced MDMT	UG-20(f) MDMT	Thickness ratio	Gov Thk in	E*	PWHT reqd
SHELL FLG	[11]	C	-36	-36		0.531	0.504	1.00	No
SHELL	[8]	D	-50	-50		0.496	0.630	1.00	No
HEAD	[10]	D	-55	-55		0.658	0.472	1.00	No
HEAD	[7]	D	-55	-55		0.567	0.551	1.00	No
Fixed Saddle	[24]	D	-50	-50		0.496	0.630	1.00	No
Fixed Saddle	[24]	D	-50	-50		0.496	0.630	1.00	No
S1	[1]	D	-1	-1		0.152	0.551	1.00	No
Nozzle Flg	[4]	B	-20	-20					
S2	[1]	C	-4	-4		0.169	0.520	1.00	No
Nozzle Flg	[4]	B	-20	-20					
Aux3	[1]	B	-1	-1		0.140	0.551	1.00	No
Nozzle Flg	[4]	B	-20	-20					
Aux4	[1]	B	3	3		0.134	0.594	1.00	No
Nozzle Flg	[4]	B	-20	-20					
Tubesheet: SS	[13]		-320						
Warmest MDMT:			3	3					
COVER	[11]	C	0	0		0.806	1.112	1.00	No
CHANNEL FLG1	[11]	C	-36	-36		0.557	0.504	1.00	No
CHANNEL FLG2	[11]	C	-36	-36		0.557	0.504	1.00	No
CHANNEL	[8]	D	-50	-50		0.496	0.630	1.00	No
T2	[1]	C	-4	-4		0.168	0.520	1.00	No
Nozzle Flg	[4]	B	-20	-20					
T1	[1]	C	-4	-4		0.169	0.520	1.00	No
Nozzle Flg	[4]	B	-20	-20					
V1	[1]	B	7	7		0.496	0.630	1.00	No
Nozzle Flg	[4]	B	-20	-20					
D1	[1]	B	7	7		0.499	0.630	1.00	No
Nozzle Flg	[4]	B	-20	-20					
Aux1	[1]	B	3	3		0.134	0.594	1.00	No
Nozzle Flg	[4]	B	-20	-20					
Aux2	[1]	B	3	3		0.133	0.594	1.00	No
Nozzle Flg	[4]	B	-20	-20					
Bolting	[21]		-55						
Bolting	[21]		-55						
Warmest MDMT:			7	7					

Exchanger Side	Computed MDMT	Required MDMT	Pass/Fail
Shell	3.0	32.0	Pass
Channel/Tube	7.0	32.0	Pass

Notes:
[!] - This was an impact tested material.
[1] - Governing Nozzle Weld.
[4] - ASME Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-c).
[5] - ASME 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] - Body Flange Bolting Material
[22] - Nozzle Flange Bolting Material
[23] - Stiffening Ring to Shell Weld
[24] - Saddle to Shell Weld

UG-84(b)(2) was not considered.
UCS-66(g) was not considered.
UCS-66(i) was not considered.

Notes:
Impact test temps were not entered in and not considered in the analysis.
UCS-66(i) applies to impact tested materials not by specification and
UCS-66(g) applies to materials impact tested per UG-84.1 General Note (c).
The Basic MDMT includes the (30F) PWHT credit if applicable.

Vessel Design Summary:

ASME Code, Section VIII Division 1, 2021

Diameter Spec : 44.252 in ID		
Vessel Design Length, Tangent to Tangent	275.69	in
Specified Datum Line Distance	0.00	in
Shell Side Design Temperature	330	F
Channel Side Design Temperature	300	F
Shell Side Design Pressure	150.000	psig
Channel Side Design Pressure	195.000	psig
Shop Shell Side Test Pressure	488.718	psig
Field Shell Side Test Pressure	364.182	psig
Shop Channel Side Test Pressure	488.718	psig
Field Channel Side Test Pressure	364.182	psig
Wind Design Code	ASCE/SEI 7-16	
Earthquake Design Code	ASCE/SEI 7-16	

Materials of Construction:

Component Type	Material	Class	Thickness	UNS #	Normalized	Impact Tested
Shell	SA-516 70	...	...	K02700	Yes	No
Head	SA-516 70	...	...	K02700	Yes	No
Flange	SA-266 2	...	...	K03506	No	No
Nozzle	SA-106 B	...	...	K03006	No	No
Nozzle	SA-105	...	...	K03504	Yes	No
Nozzle	SA-516 70	...	...	K02700	Yes	No
Re-Pad	SA-516 70	...	...	K02700	Yes	No
Nozzle Flg	SA-105	...	...	K03504	Yes	No
Tubes	SA-213 TP316L	...	...	S31603	No	No
Tubesheet	SA-182 F316L	...	> 5	S31603	No	No
Flg Bolting	SA-193 B7M	...	<= 2 1/2	G41400	No	No
Hrz Bolting		...	...		No	No
Saddles	SA-516 70	...	...	K02700	Yes	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 (psig & in):

Element Description or Type	Design Pressure + Stat. head	Ext. Press.	Element M.A.W.P	Total Corrosion Allowance	Str. Flg. Gov.	In Creep Range
COVER	196.666	15.00	345.940	0.0000	N/A	No
CHANNEL FLG1	196.666	15.00	445.250	0.0000	N/A	No
CHANNEL	196.666	15.00	558.230	0.0000	N/A	No
CHANNEL FLG2	196.666	15.00	445.250	0.0000	N/A	No
SHELL FLG	151.562	15.00	445.360	0.0000	N/A	No
SHELL	151.562	15.00	558.340	0.0000	N/A	No
HEAD	151.562	15.00	424.180	0.0000	No	No

Liquid Level: 44.00 in Dens.: 61.358 lbm/ft^3 Sp. Gr.: 0.983

Element Types and Properties:

Element Type	"To" Elev in	Element Length in	Nominal Thickness in	Finished Thickness in	Reqd Thk Internal in	Reqd Thk External in	Long Eff	Circ Eff
Body Flg	4.86	4.449	4.921	4.449	4.097	3.574	1.00	1.00
Body Flg	12.22	7.087	5.787	5.315	4.569	5.315	1.00	1.00
Cylinder	45.69	33.465	0.630	0.630	0.219	0.128	1.00	1.00
Body Flg	52.78	7.087	5.787	5.315	4.569	5.315	1.00	1.00
Body Flg	65.03	7.087	5.787	5.315	4.569	5.315	1.00	1.00
Cylinder	273.69	208.661	0.630	0.630	0.168	0.279	1.00	1.00
Ellipse	275.69	2.000	0.551	0.472	0.168	0.117	1.00	1.00

Saddle Parameters:

Saddle Width	7.425	in
Saddle Bearing Angle	120.000	deg.
Centerline Dimension	40.000	in
Wear Pad Width	9.000	in
Wear Pad Thickness	0.630	in
Wear Pad Bearing Angle	132.000	deg.
Distance from Saddle to Tangent	20.354	in
Baseplate Length	40.000	in
Baseplate Thickness	1.260	in
Baseplate Width	9.000	in
Number of Ribs (including outside ribs)	3	
Rib Thickness	0.551	in
Web Thickness	0.551	in
Height of Center Web	17.000	in
Number of Bolts in Baseplate	2	

Baseplate Sketch

```
|------------------ 40.000 in ---------------------|
-------------------------------------------------------- ---
|                                                  |
|                                                  | 9.000 in
|                                                  |
-------------------------------------------------------- ---
```

Baseplate Plan View

```
-------------------------------------------------------- ---
|                                                  | 1.260 in
-------------------------------------------------------- ---
```

Baseplate Side View

Maximum Tensile Bolt Load	9430.	lbf

Summary of Maximum Saddle Loads, Operating Case:

Maximum Vertical Saddle Load	73050.08	lbf
Maximum Transverse Saddle Shear Load	13221.54	lbf
Maximum Longitudinal Saddle Shear Load	26443.08	lbf

Summary of Maximum Saddle Loads, Operating Case, Un-Factored:

Maximum Vertical Saddle Load	90049.20	lbf
Maximum Transverse Saddle Shear Load	18887.92	lbf
Maximum Longitudinal Saddle Shear Load	37775.83	lbf

Summary of Maximum Saddle Loads, Hydrotest Case :

Maximum Vertical Saddle Load	34089.83	lbf

Maximum Transverse Saddle Shear Load 306.02 lbf
Maximum Longitudinal Saddle Shear Load 231.22 lbf

Local Stress Analysis Results:

Description	Analysis Type	Max Stress Ratio	High Stress Location	Pass Fail
Lift Lug	WRC-107/537	0.747	n/a	Passed
Lift Lug	WRC-107/537	0.158	n/a	Passed
T2	WRC-297	0.613	Shell	Passed
T1	WRC-297	0.614	Shell	Passed
S1	WRC-297	0.712	Shell	Passed
S2	WRC-297	0.674	Shell	Passed

Weights:

Fabricated - Bare W/O Removable Internals	34175.6	lbm
Shop Test - Fabricated + Water (Full)	48182.8	lbm
Shipping - Fab. + Rem. Intls.+ Shipping App.	34545.6	lbm
Erected - Fab. + Rem. Intls.+ Insul. (etc)	34545.6	lbm
Empty - Fab. + Intls. + Details + Wghts.	34545.6	lbm
Operating - Empty + Operating Liquid (No CA)	48715.3	lbm
Field Test - Empty Weight + Water (Full)	48359.6	lbm

Tabular Results

Results were generated with the finite element program FE/Pipe®. Stress results are post-processed in accordance with the rules specified in ASME Section III and ASME Section VIII, Division 2.

Analysis Time Stamp: Sat Mar 05 15:53:44 2022.

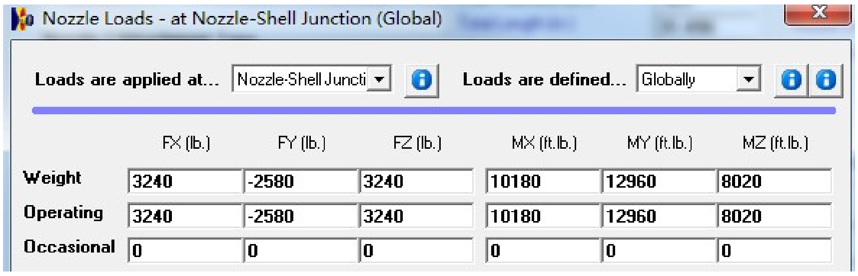
Model Notes
Model Notes

```
  Input Echo:

  Model Type                    : Cylindrical Shell

  Parent Geometry
         Parent Outside Diam.   :      45.354 in.
         Thickness              :       0.551 in.
         Fillet Along Shell     :       0.375 in.

  Parent Properties:
         Cold Allowable         :     20000.0 psi
         Hot  Allowable         :     20000.0 psi
         Material ID #2         :  Low Alloy Steel
         Ultimate Tensile (Amb) :     70000.0 psi
         Yield Strength (Amb)   :     38000.0 psi
         Yield Strength (Hot)   :     33600.0 psi
         Elastic Modulus (Amb)  :  29400000.0 psi
         Poissons Ratio         :       0.300
         Weight Density         :  0.2830E+00 lb./cu.in.

  Hillside Offset Distance      :       6.125 in.

  Nozzle Geometry
         Nozzle Outside Diam.   :      10.750 in.
         Thickness              :       0.594 in.
         Length                 :       6.276 in.
         Nozzle Weld Length     :       0.375 in.
         Nozzle Tilt Angle      :       0.000 deg.
         Distance from Top      :      18.504 in.
         Distance from Bottom   :      12.992 in.

  Nozzle Properties
         Cold Allowable         :     17100.0 psi
         Hot  Allowable         :     17100.0 psi
         Material ID #2         :  Low Alloy Steel
         Ultimate Tensile (Amb) :     60000.0 psi
         Yield Strength (Amb)   :     35000.0 psi
         Yield Strength (Hot)   :     31000.0 psi
         Elastic Modulus (Amb)  :  29400000.0 psi
         Poissons Ratio         :       0.300
         Weight Density         :  0.2830E+00 lb./cu.in.

  Design Operating Cycles       :          0.
  Ambient Temperature (Deg.)    :       70.00

  Uniform thermal expansion produces no stress in this geometry.
```

Any thermal loads will come through operating forces and moments applied through the nozzle.

Nozzle Inside Temperature	:	300.00 deg.
Nozzle Outside Temperature	:	300.00 deg.
Vessel Inside Temperature	:	300.00 deg.
Vessel Outside Temperature	:	300.00 deg.

Nozzle Pressure	:	291.2 psi
Vessel Pressure	:	291.2 psi


Nozzle Loads - at Nozzle-Shell Junction (Global)

Loads are applied at... Nozzle-Shell Juncti Loads are defined... Globally

	FX (lb.)	FY (lb.)	FZ (lb.)	MX (ft.lb.)	MY (ft.lb.)	MZ (ft.lb.)
Weight	3240	-2580	3240	10180	12960	8020
Operating	3240	-2580	3240	10180	12960	8020
Occasional	0	0	0	0	0	0

FEA Model Loads:
These are the user defined loads applied to the FEA model at the end of the nozzle in global coordinates.

Forces(lb.) Moments (ft-lb)

Load Case	FX	FY	FZ	MX	MY	MZ
WEIGHT:	3240.0	-2580.0	3240.0	8485.6	12960.0	9714.4
OPER:	3240.0	-2580.0	3240.0	8485.6	12960.0	9714.4

Both ends of the model are "fixed," except that one end is free axially so that longitudinal pressure stresses may be developed in the geometry.

Stresses are NOT averaged.

Vessel Centerline Vector	:	0.000	0.000	1.000
Nozzle Orientation Vector	:	0.000	1.000	0.000

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Load Case Report
FEPipe Version 14.0   Jobname: NOZZLE $P
Released Mar 2019   3:53pm   MAR 5,2022

Load Case Report $X

Inner and outer element temperatures are the same throughout the model. No thermal ratcheting calculations will be performed.

THE   9 LOAD CASES ANALYZED ARE:

1   WEIGHT ONLY   (Wgt Only)

Weight ONLY case run to get the stress range between the installed and the operating states.

/-------- Loads in Case   1
Loads due to Weight

2   SUSTAINED   (Wgt+Pr)

Sustained case run to satisfy local primary membrane and bending stress limits.

/-------- Loads in Case   2
Loads due to Weight
Pressure Case   1

3   OPERATING

Case run to compute the operating stresses used in secondary, peak and range calculations as needed.

/-------- Loads in Case   3
Pressure Case   1
Loads from (Operating)

4   RANGE   (Fatigue Calc Performed)

Case run to get the RANGE of stresses.
as described in NB-3222.2, 5.5.3.2, 5.5.5.2 or 5.6.1.

```
/-------- Combinations in Range Case    4
  Plus  Stress Results from CASE    3
  Minus Stress Results from CASE    1

5    Program Generated -- Force Only

     Case run to compute sif's and flexibilities.
     /-------- Loads in Case    5
       Loads from (Axial)

6    Program Generated -- Force Only

     Case run to compute sif's and flexibilities.
     /-------- Loads in Case    6
       Loads from (Inplane)

7    Program Generated -- Force Only

     Case run to compute sif's and flexibilities.
     /-------- Loads in Case    7
       Loads from (Outplane)

8    Program Generated -- Force Only

     Case run to compute sif's and flexibilities.
     /-------- Loads in Case    8
       Loads from (Torsion)

9    Program Generated -- Force Only

     Case run to compute sif's and flexibilities.
     /-------- Loads in Case    9
       Pressure Case    1
```

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```
Solution Data
FEPipe Version 14.0          Jobname: NOZZLE              $P
Released Mar 2019            3:53pm    MAR   5,2022
```

Solution Data

```
Maximum Solution Row Size =     672
Number of Nodes           =    1979
Number of Elements        =     636
Number of Solution Cases  =       8
```

Summation of Loads per Case

Case #	FX	FY	FZ
1	3239.	-3299.	3241.
2	3239.	-5978.	451174.
3	3239.	-5978.	451174.
4	-1.	379043.	2.
5	-2.	0.	5.
6	-5.	0.	2.
7	0.	0.	0.
8	0.	-2679.	447933.

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```
ASME Code Stress Output Plots
FEPipe Version 14.0          Jobname: NOZZLE              $P
Released Mar 2019            3:53pm    MAR   5,2022
```

ASME Code Stress Output Plots $X

1) Pl < SPL (SUS,Membrane) Case 2

2) Qb < SPS (SUS,Bending) Case 2

3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

5) S1+S2+S3 < 4S (SUS,S1+S2+S3) Case 2

6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

8) Membrane < User (OPE,Membrane) Case 3

9) Bending < User (OPE,Bending) Case 3

10) Pl+Pb+Q+F < Sa (SIF,Outside) Case 5

11) Pl+Pb+Q+F < Sa (SIF,Outside) Case 6

12) Pl+Pb+Q+F < Sa (SIF,Outside) Case 7

13) Pl+Pb+Q+F < Sa (SIF,Outside) Case 8

14) Pl+Pb+Q+F < Sa (SIF,Outside) Case 9

15) Pl+Pb+Q < SPS (EXP,Inside) Case 4

16) Pl+Pb+Q < SPS (EXP,Outside) Case 4

17) Pl+Pb+Q+F < Sa (EXP,Inside) Case 4

18) Pl+Pb+Q+F < Sa (EXP,Outside) Case 4

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Stress Results - Notes
FEPipe Version 14.0 Jobname: NOZZLE $P
Released Mar 2019 3:53pm MAR 5,2022

Stress Results - Notes

- Results in this analysis were generated using the finite element solution method.

- Using 2013-2017 ASME Section VIII Division 2

- Use Polished Bar fatigue curve.

- Assume free end displacements of attached pipe (e.g. thermal loads) are secondary loads.

- Primary bending stresses at discontinuities are treated like secondary stresses.

- Use Equivalent Stress (Von Mises).

- TRIAXIAL Stress Guidelines:
  S1+S2+S3 evaluation omitted from operating stress.
  Include S1+S2+S3 evaluation in primary case evaluation.
  Bending stress NOT included for all S1+S2+S3 calculations.

- Use local tensor values for averaged and not averaged stresses.

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ASME Overstressed Areas

FEPipe Version 14.0 Jobname: NOZZLE $P
Released Mar 2019 3:53pm MAR 5,2022

ASME Overstressed Areas $X

*** NO OVERSTRESSED NODES IN THIS MODEL ***

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Highest Primary Stress Ratios
FEPipe Version 14.0 Jobname: NOZZLE $P
Released Mar 2019 3:53pm MAR 5,2022

Highest Primary Stress Ratios $X

Header at Junction

Pl	SPL	Primary Membrane Load Case 2
21,201	33,600	Plot Reference:
psi	psi	1) Pl < SPL (SUS,Membrane) Case 2

63%

Branch at Junction

Pl	SPL	Primary Membrane Load Case 2
20,472	31,000	Plot Reference:
psi	psi	1) Pl < SPL (SUS,Membrane) Case 2

66%

Branch Transition

Pl	SPL	Primary Membrane Load Case 2
7,074	31,000	Plot Reference:
psi	psi	1) Pl < SPL (SUS,Membrane) Case 2

22%

Header/Pad removed from Junction

Pl	SPL	Primary Membrane Load Case 2
17,559	33,600	Plot Reference:
psi	psi	1) Pl < SPL (SUS,Membrane) Case 2

52%

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Highest Secondary Stress Ratios
FEPipe Version 14.0 Jobname: NOZZLE $P
Released Mar 2019 3:53pm MAR 5,2022

Highest Secondary Stress Ratios $X

Header at Junction

Pl+Pb+Q	SPS	Primary+Secondary (Outer) Load Case 2
42,812	71,600	Plot Reference:
psi	psi	4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

```
          59%

  Pl+Pb+Q         SPS     Primary+Secondary (Outer) Load Case 3
   42,812      71,600     Plot Reference:
      psi         psi     7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

          59%


Branch at Junction

  Pl+Pb+Q         SPS     Primary+Secondary (Inner) Load Case 2
   27,448      66,000     Plot Reference:
      psi         psi     3) Pl+Pb+Q < SPS (SUS,Inside) Case 2

          41%

  Pl+Pb+Q         SPS     Primary+Secondary (Inner) Load Case 3
   27,448      66,000     Plot Reference:
      psi         psi     6) Pl+Pb+Q < SPS (OPE,Inside) Case 3

          41%


Branch Transition

  Pl+Pb+Q         SPS     Primary+Secondary (Outer) Load Case 2
   11,302      66,000     Plot Reference:
      psi         psi     4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

          17%

  Pl+Pb+Q         SPS     Primary+Secondary (Outer) Load Case 3
   11,302      66,000     Plot Reference:
      psi         psi     7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

          17%


Header/Pad removed from Junction

  Pl+Pb+Q         SPS     Primary+Secondary (Outer) Load Case 2
   26,761      71,600     Plot Reference:
      psi         psi     4) Pl+Pb+Q < SPS (SUS,Outside) Case 2

          37%

  Pl+Pb+Q         SPS     Primary+Secondary (Outer) Load Case 3
   26,761      71,600     Plot Reference:
      psi         psi     7) Pl+Pb+Q < SPS (OPE,Outside) Case 3

          37%
```

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```
Highest Fatigue Stress Ratios
FEPipe Version 14.0          Jobname: NOZZLE             $P
Released Mar 2019            3:53pm   MAR  5,2022



Highest Fatigue Stress Ratios                          $X


Header at Junction

Pl+Pb+Q+F    Damage Ratio   Primary+Secondary+Peak (Inner) Load Case 4
   13,949     0.000 Life    Stress Concentration Factor = 1.350
      psi     0.008 Stress  Strain Concentration Factor = 1.000
                            Cycles Allowed for this Stress = 392,650.
Allowable                   "B31" Fatigue Stress Allowable = 50000.0
1,799,215                   Markl Fatigue Stress Allowable = 245000.0
      psi                   WRC 474 Mean Cycles to Failure = 1,573,470.
                            WRC 474 99% Probability Cycles = 365,538.
       0%                   WRC 474 95% Probability Cycles = 507,511.
                            BS5500 Allowed Cycles(Curve F) = 239,553.
                            Membrane-to-Bending Ratio = 2.184
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                        Bending-to-PL+PB+Q Ratio = 0.314
                        Plot Reference:
                        17) Pl+Pb+Q+F < Sa (EXP,Inside) Case 4


Branch at Junction

Pl+Pb+Q+F   Damage Ratio   Primary+Secondary+Peak (Inner) Load Case 4
   11,648    0.000 Life    Stress Concentration Factor = 1.350
      psi    0.006 Stress  Strain Concentration Factor = 1.000
                           Cycles Allowed for this Stress = 2,761,630.
Allowable                  "B31" Fatigue Stress Allowable = 42750.0
1,799,215                  Markl Fatigue Stress Allowable = 245000.0
      psi                  WRC 474 Mean Cycles to Failure = 2,559,355.
                           WRC 474 99% Probability Cycles = 594,573.
       0%                  WRC 474 95% Probability Cycles = 825,501.
                           BS5500 Allowed Cycles(Curve F) = 411,476.
                           Membrane-to-Bending Ratio = 5.712
                           Bending-to-PL+PB+Q Ratio = 0.149
                           Plot Reference:
                           17) Pl+Pb+Q+F < Sa (EXP,Inside) Case 4


Branch Transition

Pl+Pb+Q+F   Damage Ratio   Primary+Secondary+Peak (Outer) Load Case 4
    4,616    0.000 Life    Stress Concentration Factor = 1.000
      psi    0.003 Stress  Strain Concentration Factor = 1.000
                           Cycles Allowed for this Stress = 1.0000E11
Allowable                  "B31" Fatigue Stress Allowable = 42750.0
1,799,215                  Markl Fatigue Stress Allowable = 245000.0
      psi                  WRC 474 Mean Cycles to Failure = 19,916,816.
                           WRC 474 99% Probability Cycles = 4,626,941.
       0%                  WRC 474 95% Probability Cycles = 6,424,016.
                           BS5500 Allowed Cycles(Curve F) = 2,686,885.
                           Membrane-to-Bending Ratio = 0.490
                           Bending-to-PL+PB+Q Ratio = 0.671
                           Plot Reference:
                           18) Pl+Pb+Q+F < Sa (EXP,Outside) Case 4


Header/Pad removed from Junction

Pl+Pb+Q+F   Damage Ratio   Primary+Secondary+Peak (Inner) Load Case 4
    7,481    0.000 Life    Stress Concentration Factor = 1.000
      psi    0.004 Stress  Strain Concentration Factor = 1.000
                           Cycles Allowed for this Stress = 1.9205E10
Allowable                  "B31" Fatigue Stress Allowable = 50000.0
1,799,215                  Markl Fatigue Stress Allowable = 245000.0
      psi                  WRC 474 Mean Cycles to Failure = 4,196,508.
                           WRC 474 99% Probability Cycles = 974,905.
       0%                  WRC 474 95% Probability Cycles = 1,353,553.
                           BS5500 Allowed Cycles(Curve F) = 631,171.
                           Membrane-to-Bending Ratio = 9.618
                           Bending-to-PL+PB+Q Ratio = 0.094
                           Plot Reference:
                           17) Pl+Pb+Q+F < Sa (EXP,Inside) Case 4
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Stress Intensification Factors
FEPipe Version 14.0          Jobname: NOZZLE          $P
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Stress Intensification Factors                   $X


Branch/Nozzle Sif Summary
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	Peak	Primary	Secondary	SSI
Axial :	10.973	8.128	16.256	1.870
Inplane :	4.381	3.245	6.490	1.763
Outplane:	9.151	6.778	13.557	1.794
Torsion :	1.496	1.391	2.216	1.318
Pressure:	1.164	1.473	1.724	1.116

The above stress intensification factors are to be used in a beam-type analysis of the piping system. Inplane, Outplane and Torsional sif's should be used with the matching branch pipe whose diameter and thickness is given below. The axial sif should be used to intensify the axial stress in the branch pipe calculated by F/A. The pressure sif should be used to intensify the nominal pressure stress in the PARENT or HEADER, calculated from PDo/2T. B31 calculations use mean diameters and Section VIII calculations use outside diameters. SSIs are based on peak stress factors and correlated test results.

Pipe OD :	10.750	in.
Pipe Thk:	0.594	in.
Z approx:	48.120	cu. in.
Z exact :	45.616	cu. in.

(SSI = SIF^x)	Axial	Inpl	Outpl	Tors	Pres
SIF/SSI Exponents:	0.875	0.797	0.864	0.820	2.553

SIF/SSI exponent based on relationship between primary and peak stress factors from the finite element analysis.

B31.3 Branch Pressure i-factor =	11.205
Header Pressure i-factor =	2.356

The B31.3 pressure i-factors should be used with with F/A, where F is the axial force due to pressure, and A is the area of the pipe wall. This is equivalent to finding the pressure stress from (ip)(PD/4T).

B31.3 (Branch)		
Peak Stress Sif	0.000	Axial
	8.873	Inplane
	11.472	Outplane
	1.000	Torsional
B31.1 (Branch)		
Peak Stress Sif	0.000	Axial
	8.600	Inplane
	8.600	Outplane
	8.600	Torsional
WRC 330 (Branch)		
Peak Stress Sif	0.000	Axial
	5.805	Inplane
	5.805	Outplane
	1.316	Torsional

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Allowable Loads
FEPipe Version 14.0 Jobname: NOZZLE $P
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Allowable Loads $X

SECONDARY Load Type (Range):	Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force (lb.)	83473.	20252.	30378.
Inplane Moment (in. lb.)	503227.	86332.	183138.
Outplane Moment (in. lb.)	240920.	41332.	87678.
Torsional Moment (in. lb.)	1474112.	357647.	536470.
Pressure (psi)	1009.08	291.24	291.24

PRIMARY Load Type:	Maximum Individual Occuring	Conservative Simultaneous Occuring	Realistic Simultaneous Occuring
Axial Force (lb.)	78343.	12394.	18591.
Inplane Moment (in. lb.)	472302.	52833.	112075.
Outplane Moment (in. lb.)	226115.	25294.	53656.
Torsional Moment (in. lb.)	1101901.	174317.	261476.
Pressure (psi)	554.32	291.24	291.24

NOTES:

1) Maximum Individual Occuring Loads are the maximum

allowed values of the respective loads if all other load components are zero, i.e. the listed axial force may be applied if the inplane, outplane and torsional moments, and the pressure are zero.

2) The Conservative Allowable Simultaneous loads are the maximum loads that can be applied simultaneously. A conservative stress combination equation is used that typically produces stresses within 50-70% of the allowable stress.

3) The Realistic Allowable Simultaneous loads are the maximum loads that can be applied simultaneously. A more realistic stress combination equation is used based on experience at Paulin Research. Stresses are typically produced within 80-105% of the allowable.

4) Secondary allowable loads are limits for expansion and operating piping loads.

5) Primary allowable loads are limits for weight, primary and sustained type piping loads.

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Flexibilities
FEPipe Version 14.0 Jobname: NOZZLE $P
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Flexibilities $X

The following stiffnesses should be used in a piping, "beam-type" analysis of the intersection. The stiffnesses should be inserted at the surface of the branch/header or nozzle/vessel junction. The general characteristics used for the branch pipe should be:

Outside Diameter = 10.750 in.
Wall Thickness = 0.594 in.

Axial Translational Stiffness	=	2089625.	lb./in.
Inplane Rotational Stiffness	=	1402838.	in.lb./deg
Outplane Rotational Stiffness	=	531656.	in.lb./deg
Torsional Rotational Stiffness	=	11996628.	in.lb./deg

Intersection Flexibility Factors for Branch/Nozzle :

Find axial stiffness: K = 3EI/(kd)^3 lb./in.
Find bending and torsional stiffnesses: K = EI/(kd) in.lb.per radian.
The EI product is 0.72085E+10 lb.in.^2
The value of (d) to use is: 10.156 in..
The resulting bending stiffness is in units of force x length per radian.

Axial Flexibility Factor	(k)	=	2.146
Inplane Flexibility Factor	(k)	=	8.831
Outplane Flexibility Factor	(k)	=	23.301
Torsional Flexibility Factor	(k)	=	1.033

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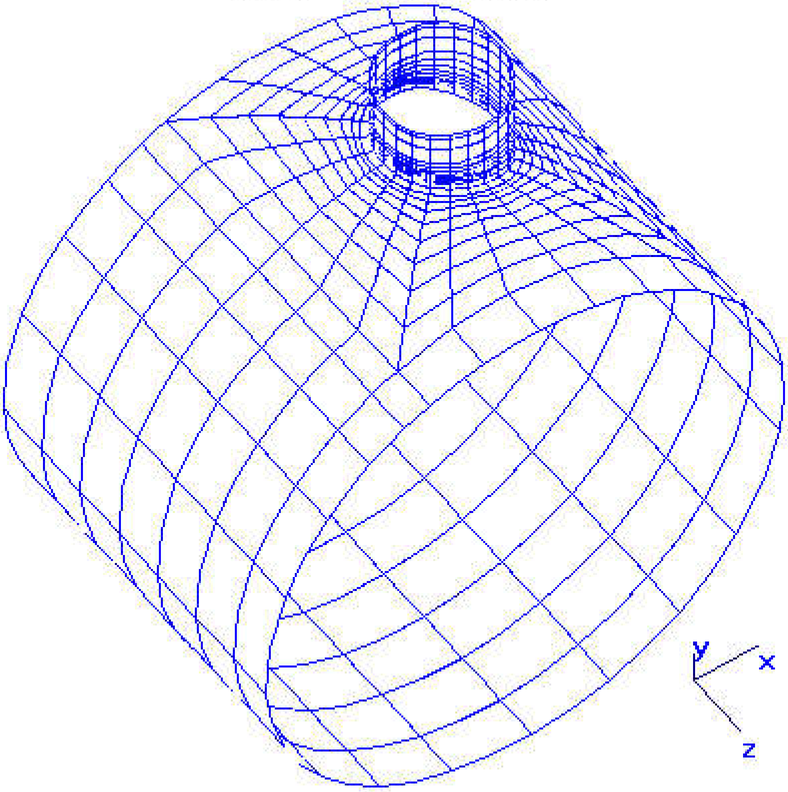
Finite Element Model

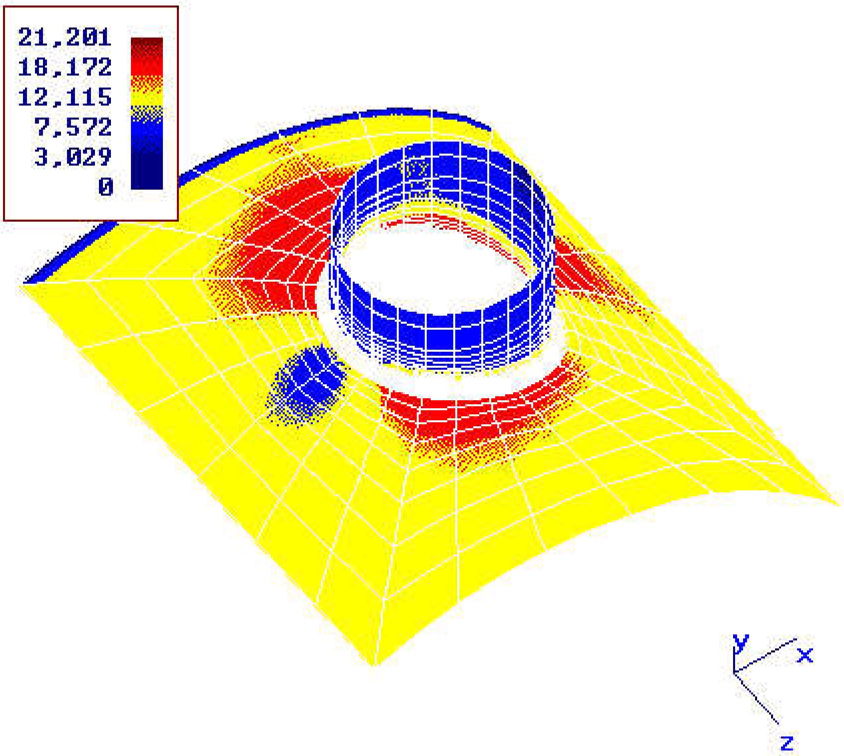
Elements at Discontinuity

Finite Element Model



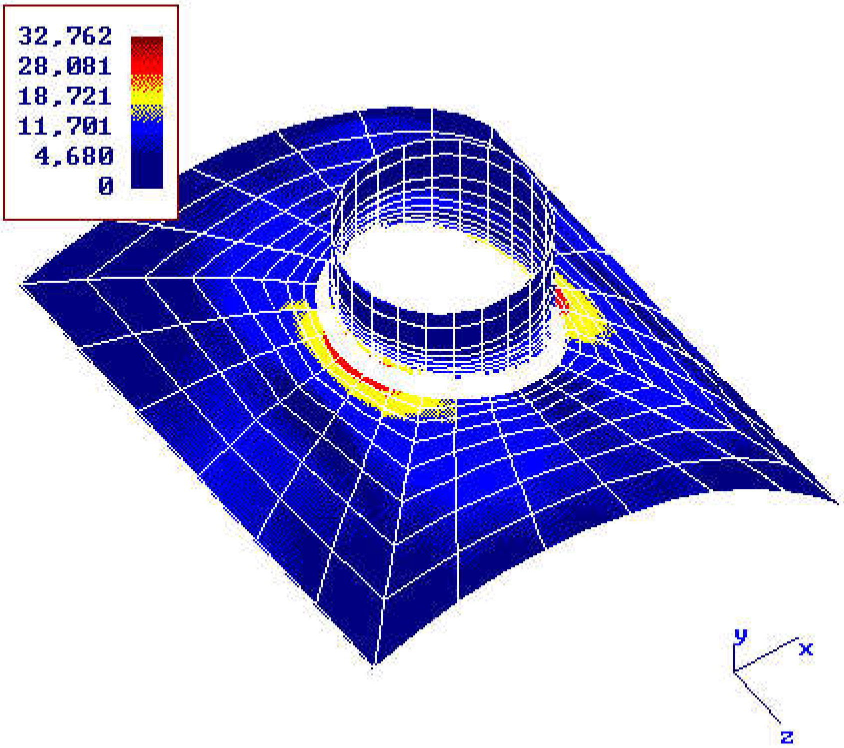
3d

1) P1 < SPL (SUS Membrane) Case 2



3d(Small) 3d 3d(Deformed)

2) Qb < SPS (SUS Bending) Case 2



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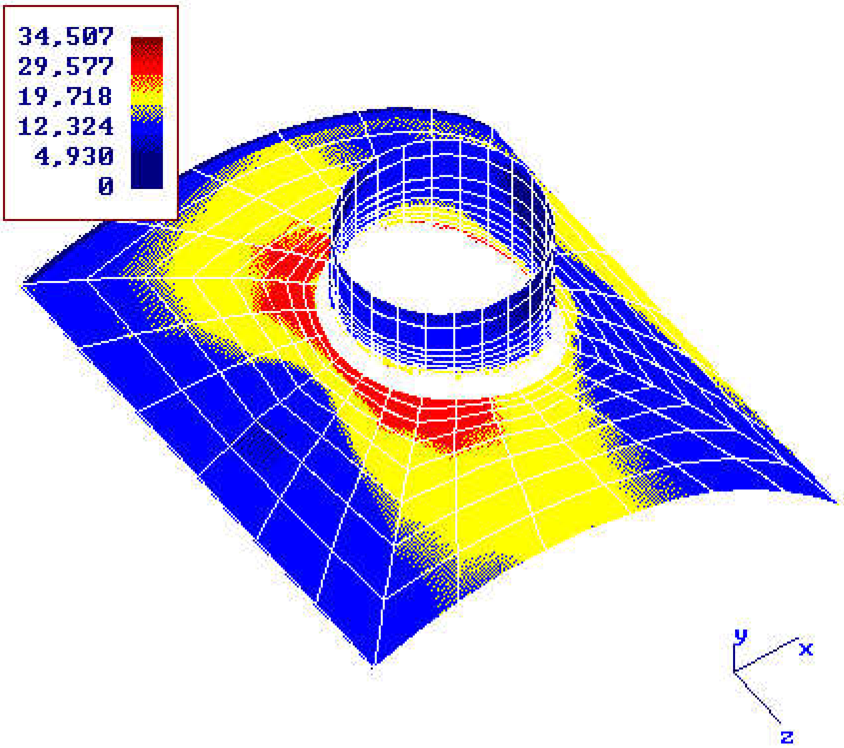
3) Pl+Pb+Q < SPS (SUS Inside) Case 2



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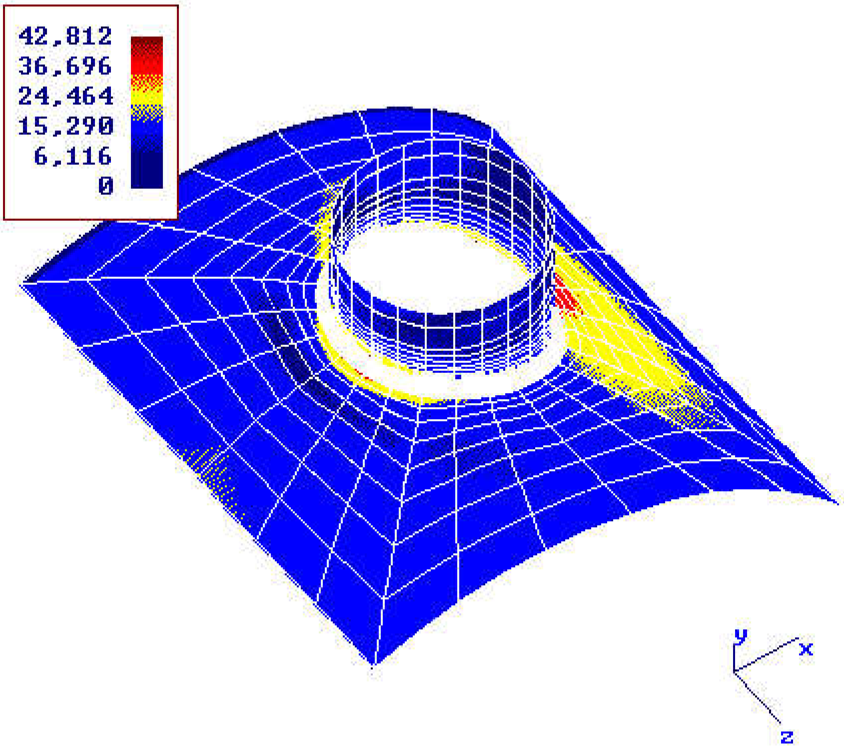
4) Pl+Pb+Q < SPS (SUS Outside) Case 2



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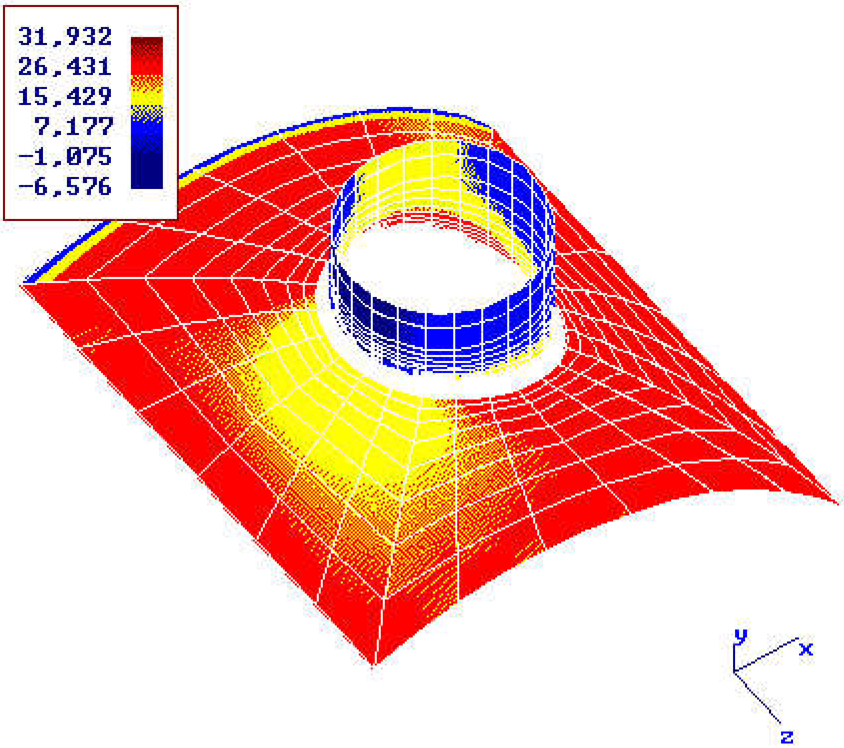
5) S1+S2+S3 < 4S (SUS S1+S2+S3) Case 2



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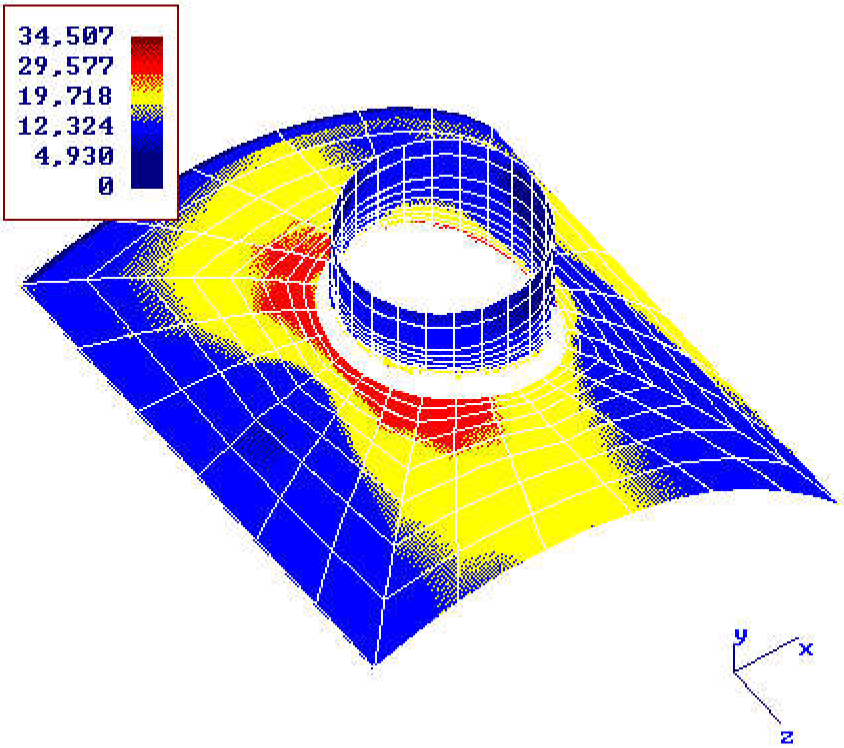
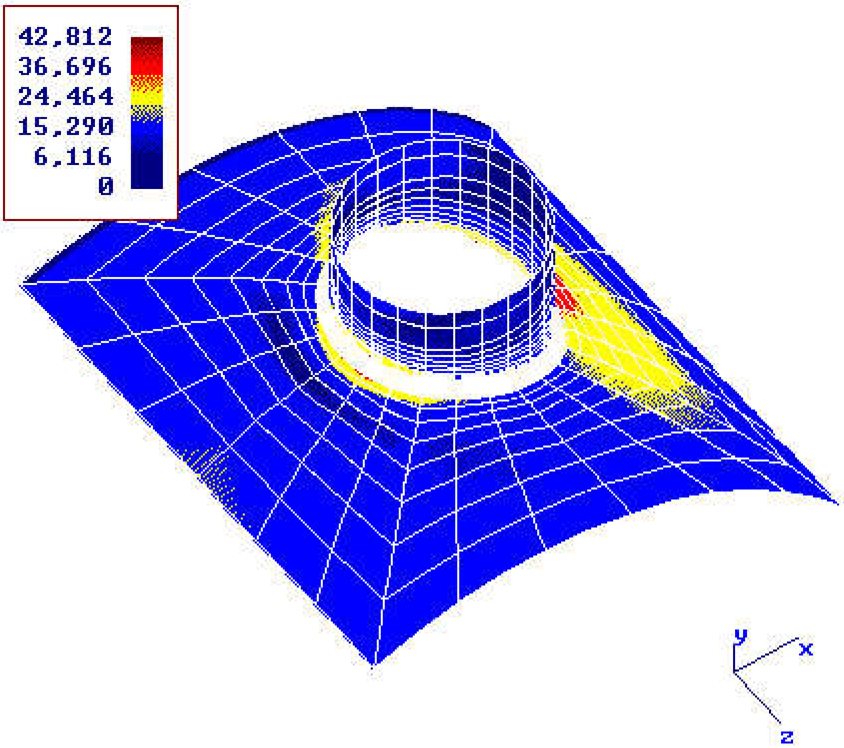
6) Pl+Pb+Q < SPS (OPE Inside) Case 3



3d(Small) 3d 3d(Deformed)

7) Pl+Pb+Q < SPS (OPE Outside) Case 3



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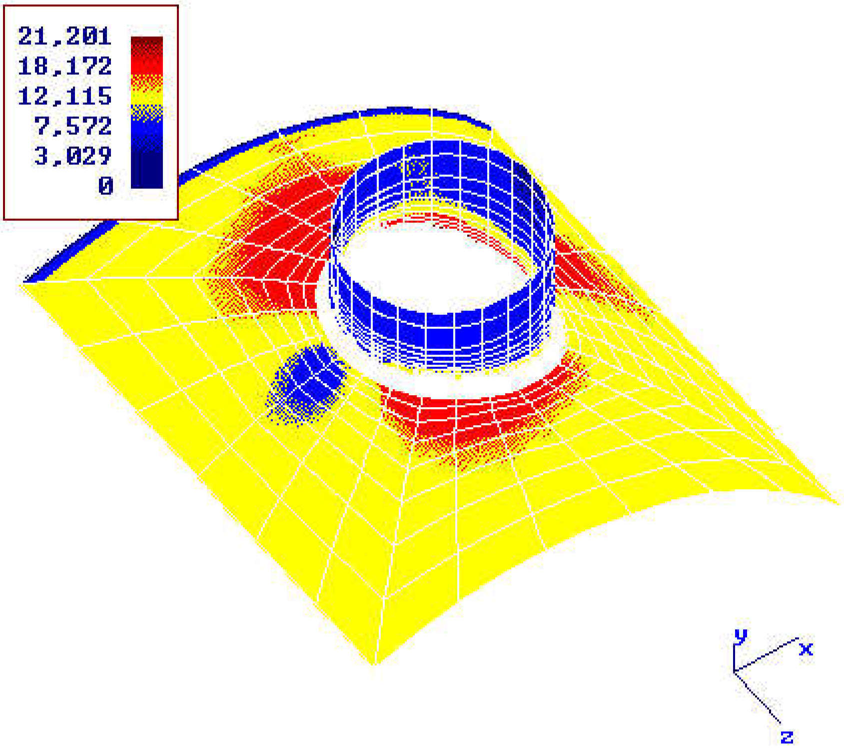
8) Membrane < User (OPE Membrane) Case 3



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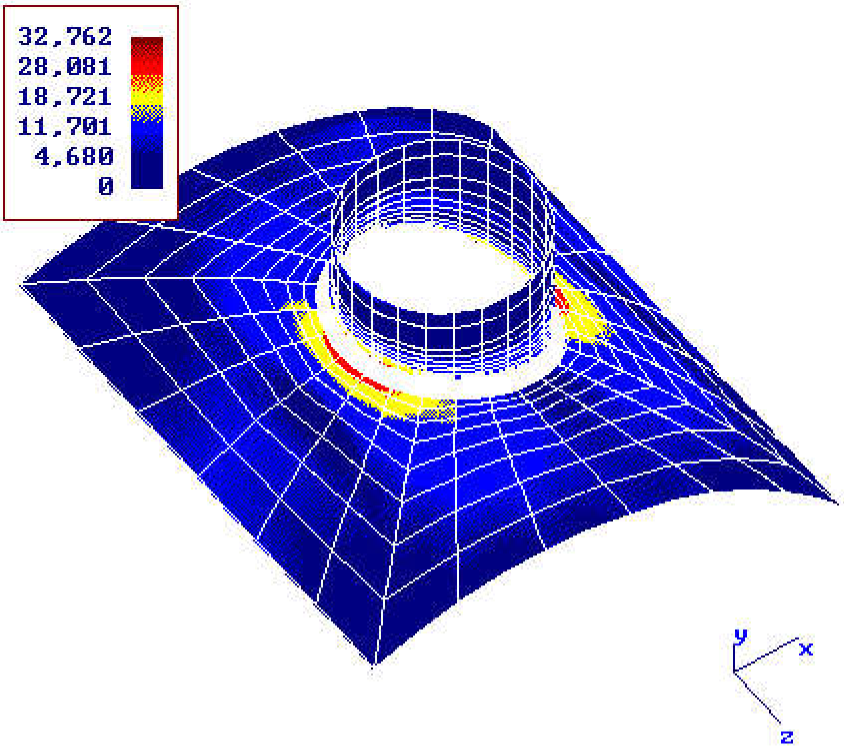
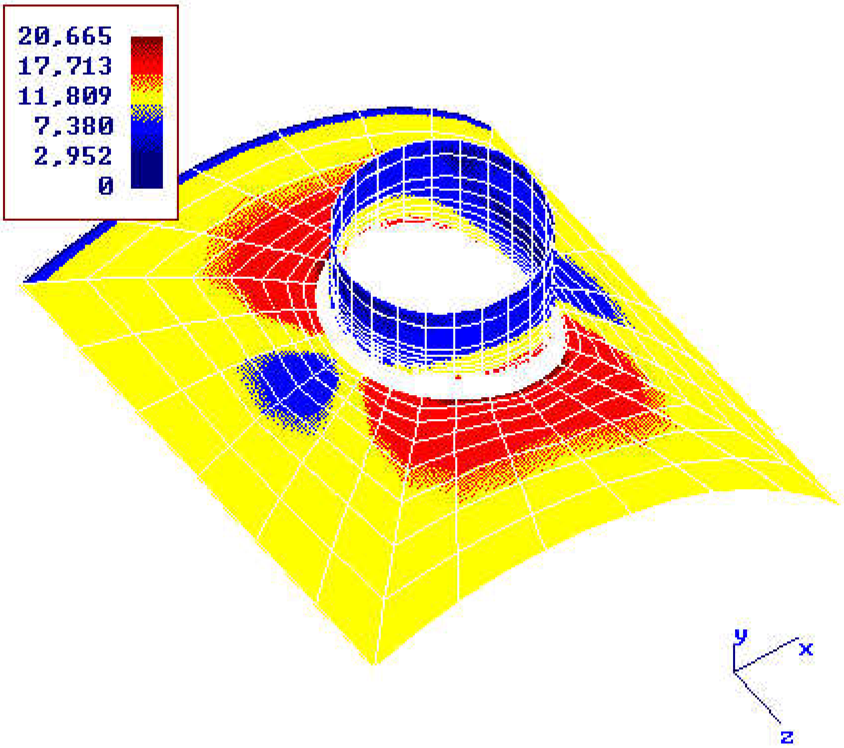
9) Bending < User (OPE Bending) Case 3



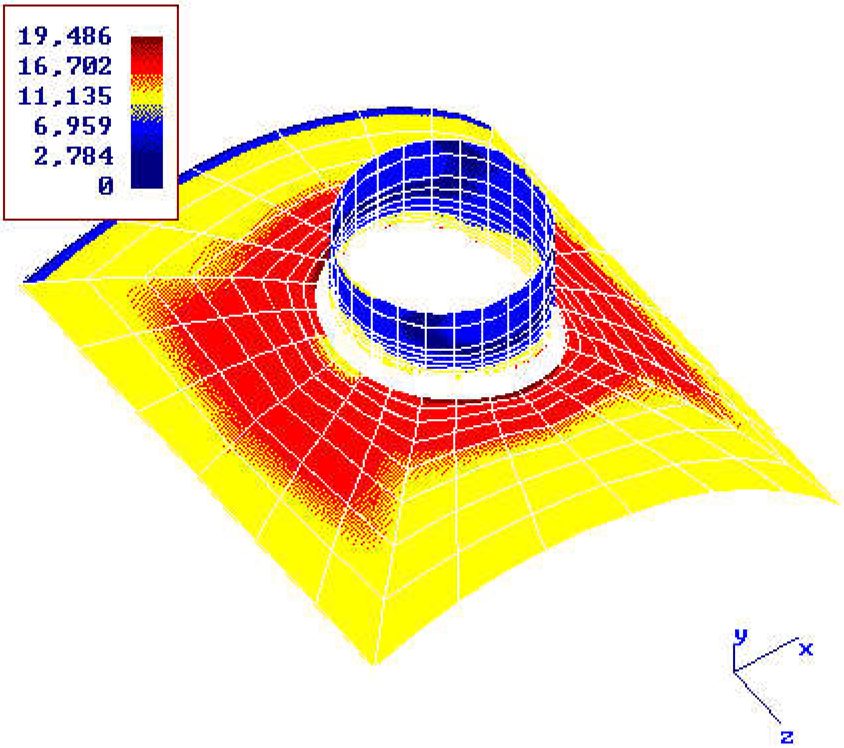
3d(Small) 3d 3d(Deformed)

15) Pl+Pb+Q < SPS (EXP Inside) Case 4



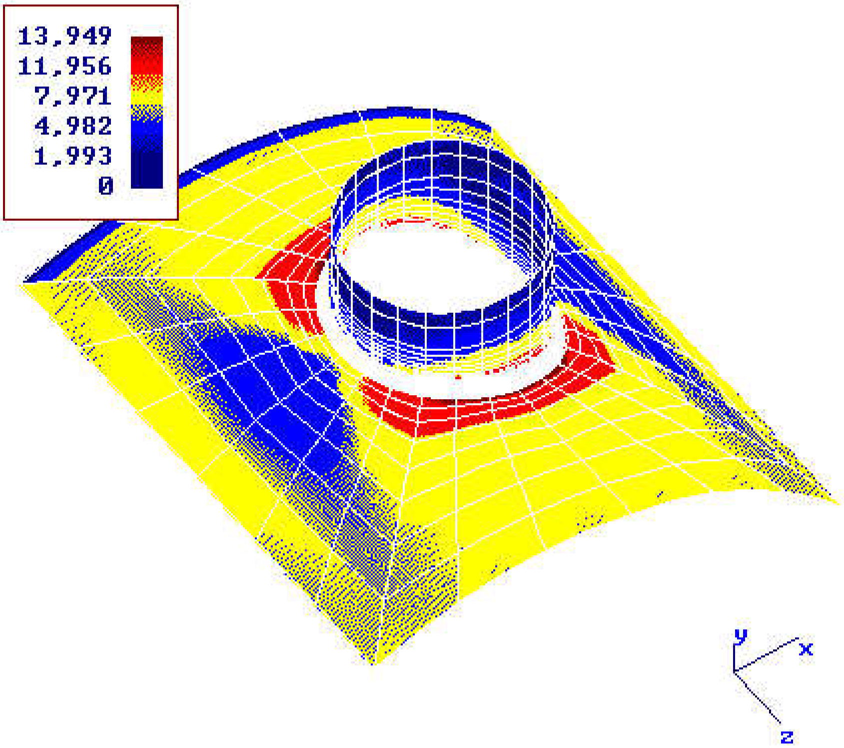
3d(Small) 3d

16) Pl+Pb+Q < SPS (EXP Outside) Case 4



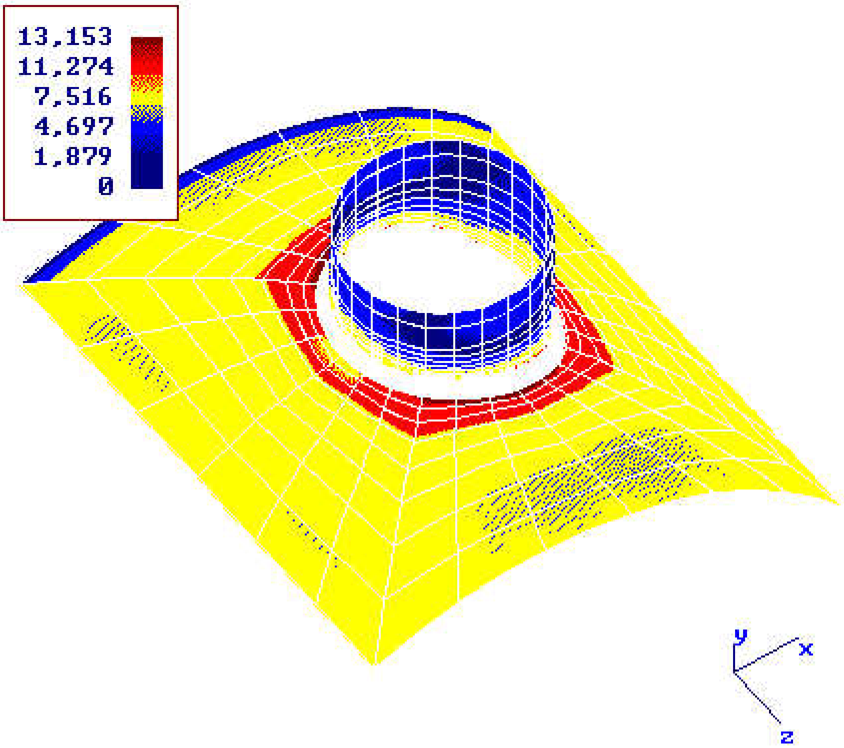
3d(Small) 3d

17) Pl+Pb+Q+F < Sa (EXP Inside) Case 4



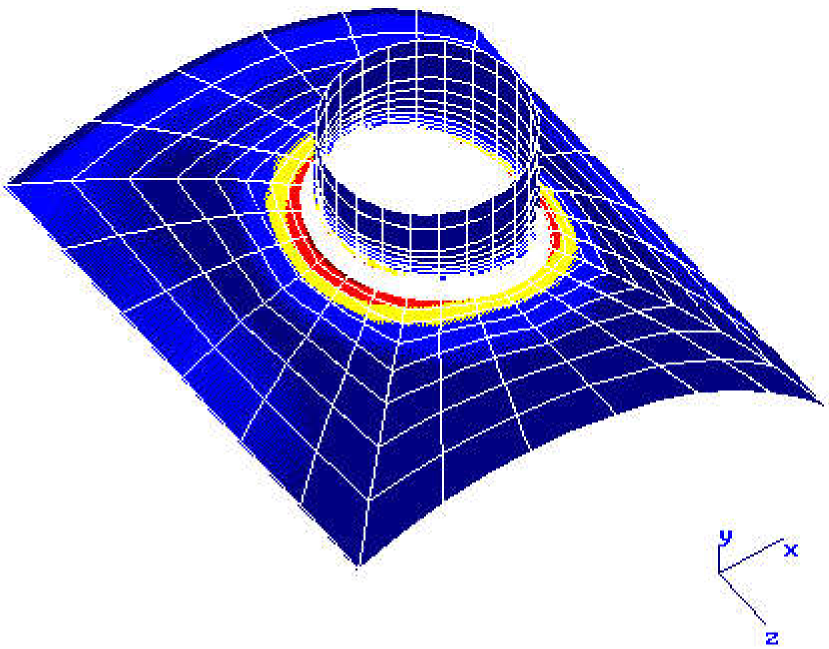
3d(Small) 3d

18) Pl+Pb+Q+F < Sa (EXP Outside) Case 4



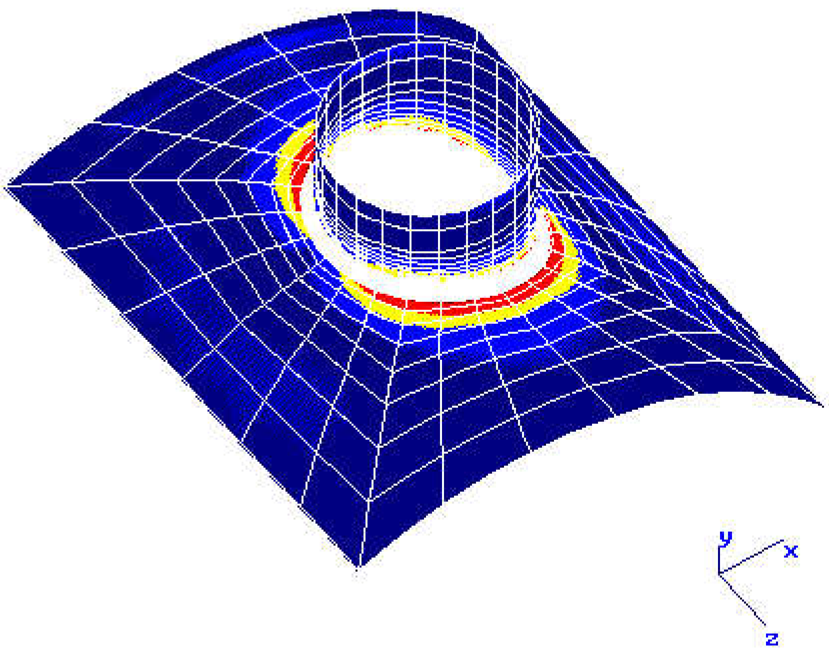
3d(Small) 3d

10) Pl+Pb+Q+F < Sa (SIF Outside) Case 5



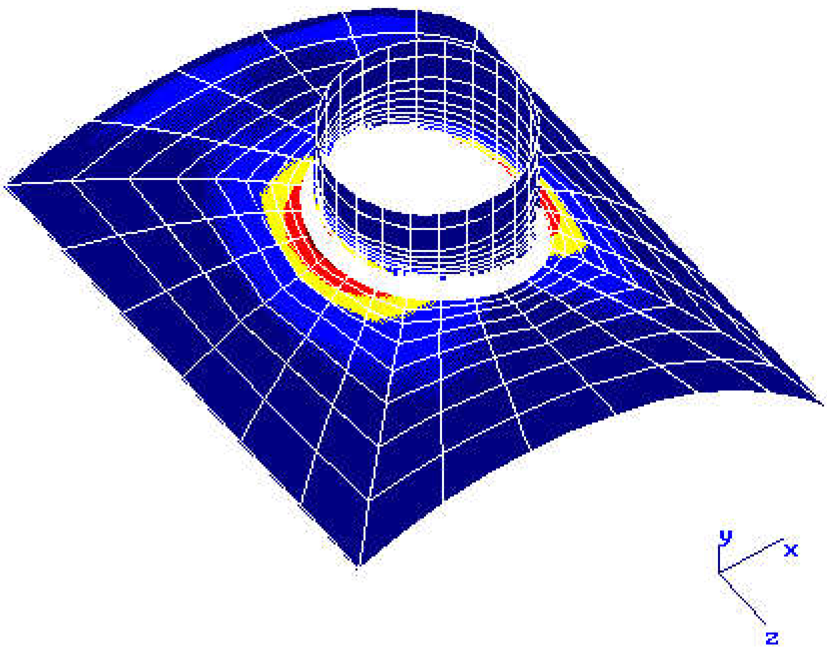
3d(Small) 3d 3d(Deformed)

11) Pl+Pb+Q+F < Sa (SIF Outside) Case 6



3d(Small) 3d 3d(Deformed)

12) Pl+Pb+Q+F < Sa (SIF Outside) Case 7



3d(Small) 3d 3d(Deformed)

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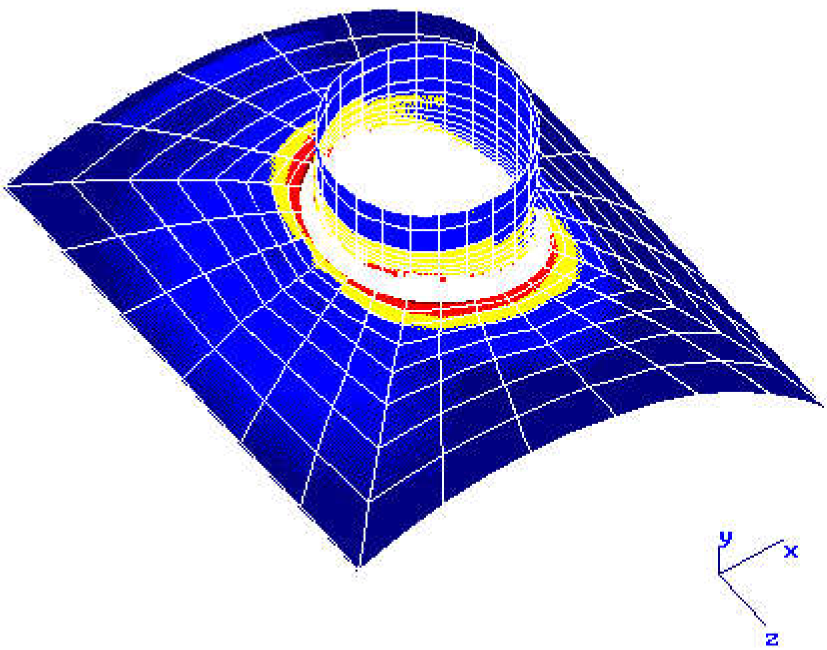
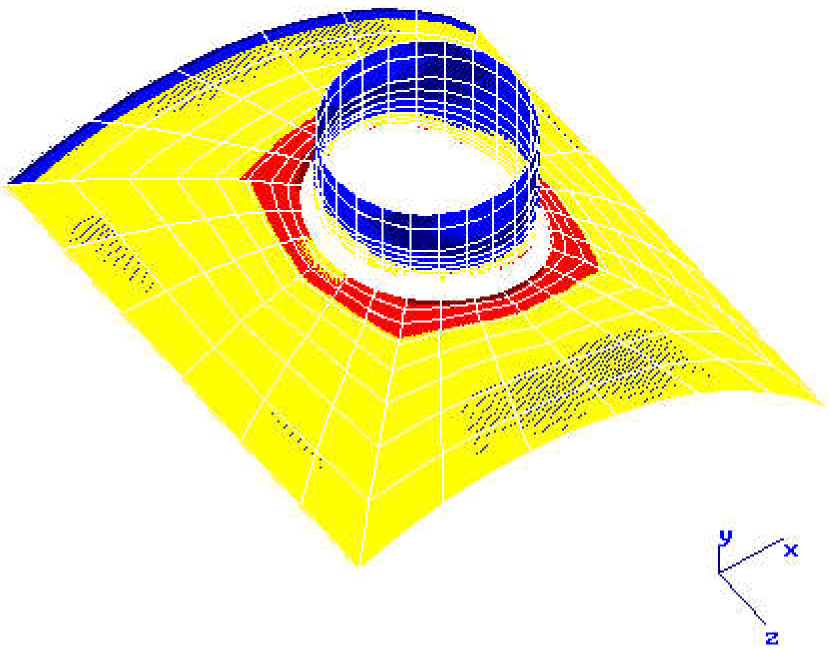
13) Pl+Pb+Q+F < Sa (SIF Outside) Case 8



3d(Small) 3d 3d(Deformed)

14) Pl+Pb+Q+F < Sa (SIF Outside) Case 9



3d(Small) 3d 3d(Deformed)

Flange Inputs-Channel Flange

Design Pressure	P	289.7	psig
Design Temperature	T	300	F
Corrosion Allowance	ci	0	in
Flange Material		SA-266 Gr.2	
Flange Allowable Stress at Ambient	S_fa	20000	psi
Flange Allowable Stress at Operating Temperature	S_fo	20000	psi
Flange Yield Stress at Ambient	S_ya	36000	psi
Flange Yield Stress at Operating Temperature	S_yo	31805.7	psi
Flange Modulus of Elasticity, Ambient	Eamb	2.94E+07	psi
Flange Modulus of Elasticity, Operating	Eop	2.83E+07	psi
Flange Thickness	t	5.315	in
Flange ID	B	44.504	in
Flange OD	A	54.724	in
Thickenss of Hub at Small End	g0	0.504	in
Thickenss of Hub at Large End	g1	0.819	in
Length of Hub	h	1.771	in
Rigidity Factor	K_I	0.3	
Bolt Material		SA - 193 B7M	
Bolt Allowable Stress at Ambient	S_ba	20000	psi
Bolt Allowable Stress At Operating Temperature	S_bo	20000	psi
Bolt Yield Stress at Ambient Temperature	S_ya	80000	psi
Bolt Yield Stress at Operating Temperature	S_yo	71700	psi
Diameter of Bolt Circle	C	50.984	in
Nominal Bolt Diameter	a	1-1/2	in
Number of Bolts	n	44	
Flange Face OD	F_od	47.362	in
Flange Face ID	F_id	44.504	in
Gasket OD	G_o	46.85	in
Gasket ID	G_i	45.276	in
Gasket Factor	m	4.25	
Gasket Design Seating Stress	y	10100	psi
Gasket thickness	tg	0.157	in
Gasket Partition Width	W	0.394	in
Gasket Partition Length	L	67.913	in
Minimum Gasket Seating Stress	Sg_min_s	20000	psi
Minimum Gasket Operating Stress	Sg_min_o	14000	psi
Max Gasket Stress	Sg_max	55000	psi
Target Gasket Stress	Sg_t	49500	psi
Maximum Allowable Flange Rotation	θ_g	1	degrees
Gasket Relaxation Fraction	ϕ_g	0.7	
Nut Factor (K = Friction + 0.04)	K	0.2	
Corroded Flange ID	Bcor	44.504	in
Corroded Large Hub	g1cor	0.8190	in
Corroded Small Hub	g0cor	0.504	in
Gasket Contact Width	N	0.787	in
Basic Gasket Width	b0	0.394	in
Effective Gasket Width	b	0.3136	in
Effective Partition Width	b_part	0.197	in
Gasket Reaction Diameter	G	46.223	in
Hub Small End Required Thickenss	t_min	0.3251	in
Hydro End Load Due to Pressure	H	486125.5	lb
Contact Load on Gasket Surface	Hp	145098.8	lb
Hydro End Load at Flange ID	Hd	450646.3	lb
Pressure Force on Flange Face	Ht	35479.2	lb
Operating Bolt Load	Wm1	631224.4	lb
Gasket Sealing Bolt Load	Wm2	595138.3	lb
Required Bolt Area	Am	31.561	in^2
Bolt Root Area	Ab	1.405	in^2
Actual Bolt Area	Ab_tot	61.820	in^2
Moment Multiplier of Bolt Spacing	Bsc	1.000	
Flange Design Bolt Load, Seating	W	933812.2	lb
Gasket Seating Force	Hg	145098.8	lb
Distance to Hub Large End	R	2.4210	in
Distance to Gasket Load Reaction	hg	2.3806	in
Distance to Face Pressure Reaction	ht	2.8103	in
Distance to End Pressure Reaction	hd	2.8305	in
Effective Hub Length	ho	4.7360	in
Hub Ratio	h/ho	0.3739	
Thickness Ratio	g1/go	1.625	
Area of Gasket	Ag	127.27	in^2

Flange Anaylsis Results Per ASME Section VIII, Div 1, App. 2

Summary of Bolting Information

	Minimum	Actual	Maximum	
Bolt Area	31.561	61.820	-	in^2
Circ. Spacing Between Bolts	3.25	3.637	9.7137	in

Summary of Moments for Internal Pressure

Loading		Force	Distance	Moment	
End Pressure	Md	450646	2.8305	106296	ft-lb
Face Pressure	Mt	35479	2.8103	8309	ft-lb
Gasket Load	Mg	145099	2.3806	28786	ft-lb
Total Operating	Mo			143391	ft-lb
Gasket Seating	Ma	933812	2.3806	185257	ft-lb

Stress Computation Results

		Gasket Seating		Operating		
		Actual	**Allowed**	**Actual**	**Allowed**	psi
Longitudinal Hub	Sh	16989.6	30000	13150.2	30000	psi
Radial Flange	Sr	826.8	20000	640.0	20000	psi
Tangential Flange	St	12761.4	20000	9877.5	20000	psi
Maximum Average	Savg	14875.5	20000	11513.8	20000	psi
Bolting		9627.0	20000	10210.7	20000	psi

Flange Rigidity Check

	Gasket Seating		Operating	
	Actual	**Allowed**	**Actual**	**Allowed**
Flange Rigidity Index	0.714	1.0	0.574	1.0

WRC Bulletin 538 & ASME PCC-1 Appendix O Analysis

WRC Bulletin 538 Analysis

Max. Bolt Stress for Flange	S_fmax	59075	psi
Hub Stress Correction Factor	f	1.131477469	
Hub Stress Correction Factor #2	f_2	0.39269	
Modified Moment	Mo_mod	724519	ft-lb
Elevated Yield Stress Reduction	S_yo'	36349	psi
Modified Yield Stress	S_y	36000	psi

WRC Bulletin 538 Stress Computation Results

		Actual	**Seating**	**Operating**	
Longitudinal Hub Stress	Sh	66444	72000	72000	psi
Tangential Stress at Hub/Flang	St	49908	54000	54000	psi
Tangential Stress at Hub/Shell	Sto	23060	36000	36000	psi
Combined Stress at Hub/Flange	Sh/f +St	108632	108000	108000	psi
Combined Stress at Hub/Flange	Sr + St	53142	108000	108000	psi
Combined Stress at Hub/Shell	Sh + Sto	89504	108000	108000	psi
Radial Stress at Hub/Flange	Sr	3234	72000	72000	psi

Flange Rotation Check

Bolt Load, Seating	W_mod	3461920	lb
Gasket Seating Moment	Ma_mod	686801	ft-lb
Actual Flange Rotation	θ_f	0.7937	degrees

ASME PCC-1 Appendix O Analysis

Step 1:	Target Bolt Stress (O-1)	S_bsel	101904	psi
Step 2:	Maximum Bolt Stress	S_bmax	56000	psi
	Upper Control Limit (O-4)	S_bsel	56000	psi
Step 3:	Minimum Bolt Stress	S_bmin	32000	psi
	Lower Control Limit (O-5)	S_bsel	56000	psi
Step 4:	Max. Bolt Stress for Flange	S_fmax	59075	psi
	Flange Limit Control (O-6)	S_bsel	56000	psi
Step 5a:	Actual Gasket Seating Stress	Sg_s	27202	psi
Step 5b:	Is the gasket seated?	S_bsel ≥	41173	
Step 6a:	Actual Gasket Op. Stress	Sg_o	15377	psi
Step 6b:	Is gasket operating stress maintained?	S_bsel ≥	51951	
Step 7:	Is the gasket maximum stress exceeded?	S_bsel ≤	113226	
Step 8:	Is the flange rotation limit exceeded?	S_bsel ≤	74430	

Bolt Tension/Torque Value Selection

Selected Bolt Stress	**Tension**	**56000**	**psi**
Applied Bolt Torque (O-2)	**Torque**	**1967**	**ft-lbs**

Flange Inputs-Shell Flange

Design Pressure	P	289.7	psig
Design Temperature	T	330	F
Corrosion Allowance	ci	0	in
Flange Material		SA-266 Gr.2	
Flange Allowable Stress at Ambient	S_fa	20000	psi
Flange Allowable Stress at Operating Temperature	S_fo	20000	psi
Flange Yield Stress at Ambient	S_ya	36000	psi
Flange Yield Stress at Operating Temperature	S_yo	31500	psi
Flange Modulus of Elasticity, Ambient	Eamb	2.94E+07	psi
Flange Modulus of Elasticity, Operating	Eop	2.82E+07	psi
Flange Thickness	t	5.315	in
Flange ID	B	44.504	in
Flange OD	A	54.724	in
Thickenss of Hub at Small End	g0	0.504	in
Thickenss of Hub at Large End	g1	0.819	in
Length of Hub	h	1.771	in
Rigidity Factor	K_I	0.3	
Bolt Material		SA - 193 B7M	
Bolt Allowable Stress at Ambient	S_ba	20000	psi
Bolt Allowable Stress At Operating Temperature	S_bo	20000	psi
Bolt Yield Stress at Ambient Temperature	S_ya	80000	psi
Bolt Yield Stress at Operating Temperature	S_yo	71700	psi
Diameter of Bolt Circle	C	50.984	in
Nominal Bolt Diameter	a	1-1/2	in
Number of Bolts	n	44	
Flange Face OD	F_od	47.362	in
Flange Face ID	F_id	44.504	in
Gasket OD	G_o	46.85	in
Gasket ID	G_i	45.276	in
Gasket Factor	m	4.25	
Gasket Design Seating Stress	y	10100	psi
Gasket thickness	tg	0.157	in
Gasket Partition Width	W	0	in
Gasket Partition Length	L	0	in
Minimum Gasket Seating Stress	Sg_min_s	20000	psi
Minimum Gasket Operating Stress	Sg_min_o	14000	psi
Max Gasket Stress	Sg_max	55000	psi
Target Gasket Stress	Sg_t	49500	psi
Maximum Allowable Flange Rotation	θ_g	1	degrees
Gasket Relaxation Fraction	ϕ_g	0.7	
Nut Factor (K = Friction + 0.04)	K	0.2	
Corroded Flange ID	Bcor	44.504	in
Corroded Large Hub	g1cor	0.8190	in
Corroded Small Hub	g0cor	0.504	in
Gasket Contact Width	N	0.787	in
Basic Gasket Width	b0	0.394	in
Effective Gasket Width	b	0.3136	in
Effective Partition Width	b_part	0.000	in
Gasket Reaction Diameter	G	46.223	in
Hub Small End Required Thickenss	t_min	0.3251	in
Hydro End Load Due to Pressure	H	486125.5	lb
Contact Load on Gasket Surface	Hp	112154.1	lb
Hydro End Load at Flange ID	Hd	450646.3	lb
Pressure Force on Flange Face	Ht	35479.2	lb
Operating Bolt Load	Wm1	598279.6	lb
Gasket Sealing Bolt Load	Wm2	460011.8	lb
Required Bolt Area	Am	29.914	in^2
Bolt Root Area	Ab	1.405	in^2
Actual Bolt Area	Ab_tot	61.820	in^2
Moment Multiplier of Bolt Spacing	Bsc	1.000	
Flange Design Bolt Load, Seating	W	917339.8	lb
Gasket Seating Force	Hg	112154.1	lb
Distance to Hub Large End	R	2.4210	in
Distance to Gasket Load Reaction	hg	2.3806	in
Distance to Face Pressure Reaction	ht	2.8103	in
Distance to End Pressure Reaction	hd	2.8305	in
Effective Hub Length	ho	4.7360	in
Hub Ratio	h/ho	0.3739	
Thickenss Ratio	g1/go	1.625	
Area of Gasket	Ag	113.89	in^2

Flange Anaylsis Results Per ASME Section VIII, Div 1, App. 2

Summary of Bolting Information

	Minimum	Actual	Maximum	
Bolt Area	29.914	61.820	-	in^2
Circ. Spacing Between Bolts	3.25	3.637	9.7137	in

Summary of Moments for Internal Pressure

Loading		Force	Distance	Moment	
End Pressure	Md	450646	2.8305	106296	ft-lb
Face Pressure	Mt	35479	2.8103	8309	ft-lb
Gasket Load	Mg	112154	2.3806	22250	ft-lb
Total Operating	Mo			136855	ft-lb
Gasket Seating	Ma	917340	2.3806	181989	ft-lb

Stress Computation Results

		Gasket Seating		Operating		
		Actual	**Allowed**	**Actual**	**Allowed**	psi
Longitudinal Hub	Sh	16689.9	30000	12550.8	30000	psi
Radial Flange	Sr	812.3	20000	610.8	20000	psi
Tangential Flange	St	12536.3	20000	9427.3	20000	psi
Maximum Average	Savg	14613.1	20000	10989.0	20000	psi
Bolting		7441.1	20000	9677.8	20000	psi

Flange Rigidity Check

	Gasket Seating		Operating	
	Actual	**Allowed**	**Actual**	**Allowed**
Flange Rigidity Index	0.701	1.0	0.550	1.0

WRC Bulletin 538 & ASME PCC-1 Appendix O Analysis

WRC Bulletin 538 Analysis

Max. Bolt Stress for Flange	S_fmax	59037	psi
Hub Stress Correction Factor	f	1.131477469	
Hub Stress Correction Factor #2	f_2	0.39269	
Modified Moment	Mo_mod	724044	ft-lb
Elevated Yield Stress Reduction	S_yo'	36000	psi
Modified Yield Stress	S_y	36000	psi

WRC Bulletin 538 Stress Computation Results

		Actual	**Seating**	**Operating**	
Longitudinal Hub Stress	Sh	66401	72000	72000	psi
Tangential Stress at Hub/Flange	St	49876	54000	54000	psi
Tangential Stress at Hub/Shell	Sto	23045	36000	36000	psi
Combined Stress at Hub/Flange	Sh/f +St	108561	108000	108000	psi
Combined Stress at Hub/Flange	Sr + St	53107	108000	108000	psi
Combined Stress at Hub/Shell	Sh + Sto	89446	108000	108000	psi
Radial Stress at Hub/Flange	Sr	3232	72000	72000	psi

Flange Rotation Check

Bolt Load, Seating	W_mod	3461920	lb
Gasket Seating Moment	Ma_mod	686801	ft-lb
Actual Flange Rotation	θ_f	0.7937	degrees

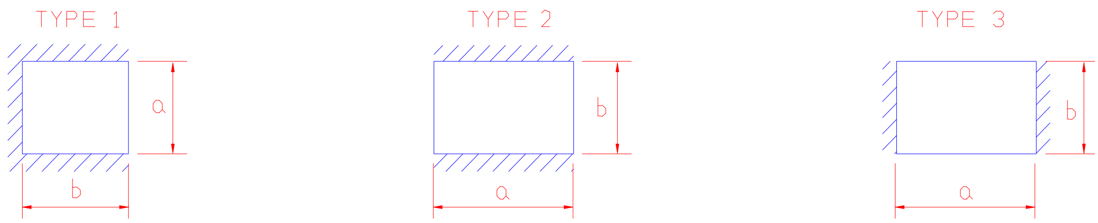
ASME PCC-1 Appendix O Analysis

Step 1:	Target Bolt Stress (O-1)	S_bsel	91191	psi
Step 2:	Maximum Bolt Stress	S_bmax	56000	psi
	Upper Control Limit (O-4)	S_bsel	56000	psi
Step 3:	Minimum Bolt Stress	S_bmin	32000	psi
	Lower Control Limit (O-5)	S_bsel	56000	psi
Step 4:	Max. Bolt Stress for Flange	S_fmax	59037	psi
	Flange Limit Control (O-6)	S_bsel	56000	psi
Step 5a:	Actual Gasket Seating Stress	Sg_s	30398	psi
Step 5b:	Is the gasket seated?	S_bsel ≥	36845	
Step 6a:	Actual Gasket Op. Stress	Sg_o	17183	psi
Step 6b:	Is gasket operating stress maintained?	S_bsel ≥	47623	
Step 7:	Is the gasket maximum stress exceeded?	S_bsel ≤	101324	
Step 8:	Is the flange rotation limit exceeded?	S_bsel ≤	74381	

Bolt Tension/Torque Value Selection

Selected Bolt Stress	**Tension**	**56000**	**psi**
Applied Bolt Torque (O-2)	**Torque**	**1967**	**ft-lbs**

Appendix 3 Pass partation plate calculation

PASS PARTITION PLATE THICKNESS CALCULATION					
CODE: TEMA 10th ED.-2019(RCB-9.13)					
DESIGN DATA [PASS PARITION PLATE]					
PRESS.DROP ACROSS PLATE q	11.68	psi	DESIGN TEMPERATURE T		300°F
PLATE a	48.189	in	PASS PARTITION TYPE		2
PLATE b	44	in	MAX. ALLOWABLE STRESS S psi		16700.0
MATERIAL OF PLATE		SA-240 316L			
TABLE RCB-9.132 PASS PARTITION FACTOR					
					
THREE SIDE FIXED		LONG SIDE FIXED		SHORT SIDE FIXED	
a/b	B	a/b	B	a/b	B
0.25	0.02	1	0.4182	1	0.4182
0.5	0.081	1.2	0.4626	1.2	0.5208
0.75	0.173	1.4	0.486	1.4	0.5988
1	0.307	1.6	0.4968	1.6	0.654
1.5	0.539	1.8	0.4971	1.8	0.6912
2	0.657	2	0.4973	2	0.7146
3	0.718	∞	0.5	∞	0.75
PASS PARTITION PLATE FORMULA(TEMA RBC-9.132)					
From a/b = 1.095204545 Get B = 0.4393354					
1. DESIGN THICKNESS		$t = b\sqrt{\dfrac{qB}{1.5S}}$ =		0.63	in
2. CODE MIN.THICKNESS		t_m		0.375	in
3. REQUIRED THICKNESS		t_r = MAX(t, t_m)		0.709	in
USED NOMINAL PASS PARTITION THICKNESS t_u =0.709≥ t_r = 0.63, O.K. !!					

Appendix 4:

Checking the bend portion before bending as per TEMA RCB-2.31

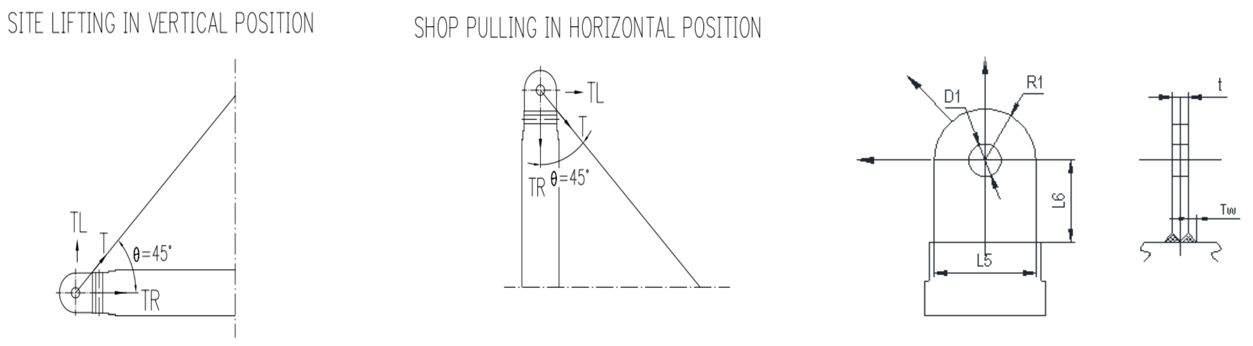
Parameters	Unit	Value
d_0-- Outside tube diameter	In	0.75
R-- Mean radius of bend (considering the smallest radius)	In	1.125
t_n-- Tube normal thickness	In	0.065
Tube thickness maximum down tolerance	%	0
tm-- Tube minimum thickness (consider down tolerance)	in	0.065
t_1-- Minimum tube wall thickness calculated by Code rules for a straight tube subjected to the same pressure and metal temperature, it can be read from the Pvelite calculation result: ASME TS Calc: Summary of thickness comparisons	in	0.0156
t_0-- Required tube wall thickness prior to bending $t_0 = t_1 \times (1+\frac{d_0}{4R})$	in	0.018
$t_0 < t_m$		OK
Calculated thickness reducing ration, shall be less than 17%	%	14.3
Conculsion: The tube wall thickness can meet with the requirements of RCB-2.31 U-Tubes of TEMA standard.		

Attachment 5 **PULLING LUG CAL FOR BUNDLE(PART NO.60)**

(Reference code : ASME BTH-1 for deriving the allowable stresses of tension, Bending, bearing, shear , combined,The allowable tensile strength through the pinhole Pt,The allowable single plane fracture strength beyond the pinhole Pb)

管束拉耳计算

0.DESIGN DATE(设计详细)			
MATERIAL NANME（材料名称）		SA-240 316L	
TENSILE STRESS AT ROOM TEMPERATURE,(常温抗拉应力)	Fu=	469.5	N/mm^2
YIELD STRESS AT ROOM TEMPERATURE,(常温屈服应力)	S_Y=	172.40	N/mm^2
ALLOWABLE STRESS,TENSION,（许用拉伸应力）	Ft=Min（Sy/Nd，Fu/1.2*Nd）（Nd=3） （Formula 3-1 and 3-2 of ASME BTH-1）	57.47	N/mm^2
ALLOWABLE STRESS,BENDING,（许用弯曲应力）	Fb=1.1*Sy/Nd （Nd=3）（Formula 3-6 of ASME BTH-1）	63.21	N/mm^2
ALLOWABLE STRESS,BEARING,（许用支撑应力）	Fp=（1.8*Sy）/（1.2*Nd）（Formula 3-38 of ASME BTH-1）	86.20	N/mm^2
ALLOWABLE STRESS,SHEAR,（许用剪应力）	Fv=Sy/（Nd*√3） （Formula 3-28 of ASME BTH-1）	33.18	N/mm^2
ALLOWABLE STRESS,COMBINED,（许用总应力）	Fa=0.55S_Y	94.82	N/mm^2
The allowable tensile strength through the pinhole Pt	Pt=Cr*（Fu/（1.2*Nd））*2t*beff （Cr=1） （Formula 3-45 of ASME BTH-1）	504824.20	N
The effective width	b_{eff}=min（4t，be*0.6*（Fu/Fy）*√（D_1/be））≤be （Formula 3-47 and 3-48 of ASME BTH-1）	54	mm
actual width of a pin-connected plate between the edge of the hole and the edge of the plate	be	34.15	mm
The allowable single plane fracture strength beyond the pinhole Pb	Pb=Cr*（Fu/（1.2*Nd））*[1.13*（R1-D_1/2）+0.92*be/（1+be/D_1）]*t（Cr=1）（Formula 3-49 of ASME BTH-1）	252187	N
LOAD FACTOR（载荷系数）	K_L=	1.5	
SLING FACTOR（吊索系数）	Ks=	1.4	
DESIGN ERECTION WEIGHT,（设计安装重量）	We=1.1*weight	7485.5	Kg
The number of lifting lugs（吊耳的数量）	n=	4	
ERECTION WEIGHT,（安装重量）	W_L=K_L*Ks*We*9.806/n	38536.48	N
NOTE:（注意：） B,L,Lsp,Hsp SEE DWG	L5=	100	mm
	L6=	80	mm
THK. OF LIFTTING LUG,（吊耳厚度）	t=	36	mm
LUG HOLE DIAMETER,（吊耳开孔直径）	D_I=	31.7	mm
WELD SIZE,LUG TO TUBESHEET（吊耳与垫板焊角高度）	t_W=	17	mm
AREA 1（面积1）	A_1=L5*t_L=	3600	mm^2
AREA 2（面积2）	A_2=(L5-D_1)*t_L=	2458.8	mm^2
SECTION MODULUS OF LUG（吊耳的断面系数）	Z=t_L*$L5^2$/6=	60000.00	mm^3
1.STRESS IN LUG(吊耳上的应力)			
Force Along the Sling,T，(N) (θ=45°)（吊索方向载荷）	T=W_L/Sinθ	54507.03936	N
RADIAL FORCE（径向应力）	T_R=T*Cosθ	38536.47683	N
LONGITUDINAL FORCE（纵向应力）	T_L=T*SINθ	38536.48	N
5% lateral design force	Tc=0.05*T	2725.351968	N
LONGITUDINAL MOMENT (N-mm)（纵向弯矩）	ML=TL*L6	3082918.146	(N-mm)
lateral MOMEN（环向弯矩）	Mc=Tc*L6	218028.1574	(N-mm)
BENDING MOMENT (N-mm)（弯曲力矩）	Mb=√[（T_L*L6）^2+(Tc*L6)^2]	3090618.154	(N-mm)
BENDING STRESS IN LUG (N/mm^2)（吊耳的弯曲应力）	σb=Mb/Z	51.51030256	N/mm^2
TENSLIE STRESS (N/mm2)（拉伸应力）	σt=Mb/Z+T_R/A_2	67.18318235	N/mm^2
SHEAR STRESS (N/mm2)（剪应力）	τ=T_L/A_2	15.67287979	N/mm^2
COMBINED STRESS (N/mm2)（总应力）	σ=$(3τ^2+σt^2)^{1/2}$	72.46031654	N/mm^2



RADIAL FORCE,（径向应力）	T_R=	38536.48	N	<ALLOW	252187.39	OK
LONGITUDINAL FORCE,（纵向应力）	T_L=	38536.48	N			
5% lateral design force（侧向应力）	Tc=	2725.35	N			
COMBINED STRESS（总应力）	σ=	72.46	N/mm^2	<ALLOW	94.82	OK
BENDING STRESS,（弯曲应力）	σ_b=	51.51	N/mm^2	<ALLOW	63.21	OK
TENSILE STRESS（拉应力）	σ_T=	67.18	N/mm^2	<ALLOW	57.47	NO
SHEAR STRESS,（剪应力）	τ=	15.67	N/mm^2	<ALLOW	33.18	OK
SHEAR STRESS AT PIN HOLE,（销钉孔处的剪应力）	$\tau ph=T_R/A_2$=	15.67	N/mm^2	<ALLOW	33.18	OK
	Pt=Cr*（Fu/（1.2*Nd））*2t*b_{eff} （Cr=1）					
					(N/mm^2)	
2 STRESS IN WELD（焊缝处的应力）						
WELD EFFICIENCY（焊接系数）	E_W=	1.00				
WELD AREA（焊接面积）	A_{WELD1}=	3269.17	mm^2			
A_{WELD1}=0707 * tw1*(2 * L5+2*tL)						
SHEAR STRESS,LUG WELD（吊耳焊缝处的剪应力）	$\tau_W=T_L/A_{WELD1}$=	11.79	N/mm^2	<ALLOW	33.18	OK
BENDING MOMENT（弯曲力矩）	$M_{bW}=T_L*L_6$+Tc*L6=	3300946.30	N/mm^2			
SECTION MODULUS OF LUG（吊耳的断面系数）	$Z_W=t_L*L_5^2/3$=	120000.00	mm^3			
BENDING STRESS,LUG WELD, (N/mm2)（吊耳焊缝处	$\sigma_{bW}=M_{bW}/Z_W$=	27.51	N/mm^2	<ALLOW	63.21	OK
TENSILE STRESS,LUG WELD,（吊耳焊缝处的拉应力）	σ_{TW}=	39.30	N/mm^2	<ALLOW	57.47	OK
$\sigma_{TW}=TR/A_{WELD1}+\sigma_{bW}$					(N/mm^2)	

Appendix 6	鞍座热膨胀计算 Saddle Thermal Expansion calculation	项目号 ITEM NO. 文件号 DOC. NO.

输入数据 Input Data

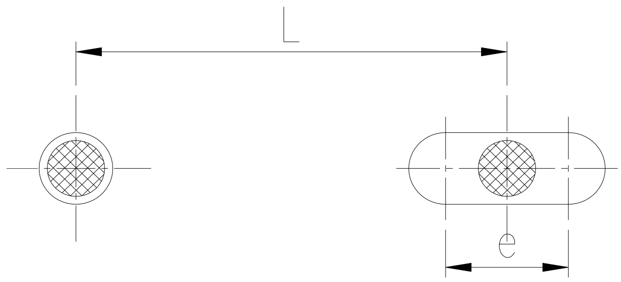


FIG: saddle base plate anchor bolt hole

设备材料The material of vessel		SA-516 Gr.70N	
最高设计温度The max. design temperature	T_1=	165.6	°C
最低设计温度The min. design temperature	T_2=	0	°C
设备材料在最高设计温度下的热膨胀系数 The expansion coefficient at the max. design temperature	a_1=	1.20E-05	mm/mm°C
设备材料在最低设计温度下的热膨胀系数 The expansion coefficient at the min. design temperature	a_2=	1.08E-05	mm/mm°C
鞍座间距The distance of saddle	L=	3530.6	mm
鞍座底板长圆孔长度 The slot hole of saddle base plate	e=	12.5	mm

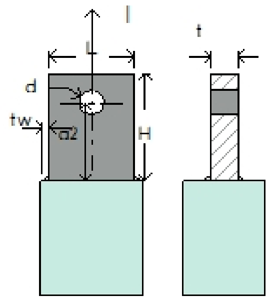
设计计算 Checking strength

设备的安装温度 The install temperature	t=	21.1	°C
最高设计温度下热膨胀长度 The expansion length at max. temp.	$\Delta L_1=a_1L(T_1\text{-}t)=$	6.12	mm
最低设计温度下热膨胀长度 The expansion length at min. temp.	$\Delta L_2=a_2L(T_2\text{-}t)=$	-0.80	mm
最大热膨胀长度 The max. expansion length	$\Delta L=\max(\lvert\Delta L_1\rvert,\lvert\Delta L_2\rvert)=$	6.12	mm

判别依据 Evaluate ΔL <= e/2

The slot hole length is OK!

Channel Lifting Lug 1



Geometry Inputs	
Attached To	CHANNEL FLANGE 1
Material	SA-516 Gr.70
Orientation	Circumferential
Distance of Lift Point From Datum	7.579"
Angular Position	°
Length, L	3.937"
Height, H	5"
Thickness, t	.6299"
Hole Diameter, d	1.1024"
Pin Diameter, Dp	.9843"
Load Eccentricity, a_1	"
Distance from Load to Shell or Pad, a_2	3.622"
Load Angle Normal to Vessel, β	°
Load Angle from Vertical, ϕ	°
Welds	
Size, t_w	.315"

Intermediate Values	
Load Factor	1.5000
Vessel Weight (new, incl. Load Factor), W	13,035.6 lb
Lug Weight (new), W_{lug}	3.5 lb
Distance from Center of Gravity to this lug, x_1	10.7631"
Distance from Center of Gravity to second lug, x_2	28.7244"
Allowable Stress, Tensile, σ_t	12,000 psi
Allowable Stress, Shear, σ_s	8,000 psi
Allowable Stress, Bearing, σ_p	18,000 psi
Allowable Stress, Bending, σ_b	13,334 psi
Allowable Stress, Weld Shear, $\tau_{allowable}$	8,000 psi
Allowable Stress set to 1/3 Sy per ASME B30.20	Yes

Summary Values	
Required Lift Pin Diameter, d_{reqd}	.8687"
Required Lug Thickness, t_{reqd}	.5946"
Lug Stress Ratio, σ_{ratio}	0.32
Weld Shear Stress Ratio, τ_{ratio}	0.58
Lug Design	Acceptable
Local Stresses WRC 537	Acceptable

Lift Forces

F_r = force on vessel at lug

F_r = $[W / \cos(\phi_1)]*(1 - x_1 / (x_1 + x_2))$

= (13,035.6) / cos()*(1 - 10.7631/ (10.7631 + 28.7244))

= 9,482 lb_f

where 'x_1' is the distance between this lug and the center of gravity

'x_2' is the distance between the second lift lug and the center of gravity

Lug Pin Diameter - Shear stress

d_{reqd} = $(2*F_r / (\pi*\sigma_s))^{.5}$

= $(2*9{,}482 / (\pi*8{,}000))^{.5}$ = .8687"

d_{reqd} / D_p = .8687 / .9843 = 0.88 Acceptable

σ = F_r / A

= $F_r / (2*(.25*\pi*D_p^2))$

= $9{,}482 / (2*(.25*\pi*.9843^2))$ = 6,231 psi

σ / σ_s = 6,231 / 8,000 = 0.78 Acceptable

Lug Thickness - Tensile stress

t_{reqd} = $F_r / ((L - d)*\sigma_t)$

= 9,482 / ((3.937 - 1.1024)*12,000) = .2788"

t_{reqd} / t = .2788 / .6299 = 0.44 Acceptable

σ = F_r / A

= $F_r / ((L - d)*t)$

= 9,482 / ((3.937 - 1.1024)*.6299) = 5,311 psi

σ / σ_t = 5,311 / 12,000 = 0.44 Acceptable

Lug Thickness - Bearing stress

t_{reqd} = $F_v / (D_p*\sigma_p)$

= 9,482 / (.9843*18,000) = .5352"

t_{reqd} / t = .5352 / .6299 = 0.85 Acceptable

σ = $F_v / A_{bearing}$

= $F_v / (D_p*(t))$

= 9,482 / (.9843*(.6299)) = 15,294 psi

σ / σ_p = 15,294 / 18,000 = 0.85 Acceptable

Lug Thickness - Shear stress

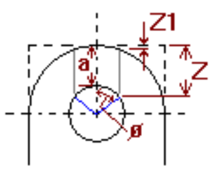
t_{reqd} = $[F_v / \sigma_s] / (2{*}L_{shear})$
= (9,482 / 8,000) / (2*.9967) = .5946"

t_{reqd} / t = .5946 / .6299 = 0.94 Acceptable

τ = F_v / A_{shear}
= $F_v / (2{*}t{*}L_{shear})$
= 9,482 / (2*.6299*.9967) = 7,551 psi

τ / σ_s = 7,551 / 8,000 = 0.94 Acceptable

Shear stress length (per Pressure Vessel and Stacks, A. Keith Escoe)



ϕ = $55{*}D_p / d$
= 55*.9843 / 1.1024
= 49.1071°

L_{shear} = $(H - a2 - 0.5{*}d) + 0.5{*}D_p{*}(1 - \cos(\phi))$
= (5 - 3.622 - 0.5*1.1024) + 0.5*.9843*(1 - cos(49.1071))
= .9967"

Lug Plate Stress

Lug stress tensile + bending during lift:

σ_{ratio} = $[F_{ten} / (A_{ten}{*}\sigma_t)] + [M_{bend} / (Z_{bend}{*}\sigma_b)] \le 1$
= $[(F_r{*}\cos(\beta)) / (t{*}L{*}\sigma_t)] + [(6{*}abs(F_r{*}\sin(\beta){*}Hght - F_r{*}\cos(\beta){*}a_1)) / (t{*}L^2{*}\sigma_b)] \le 1$
= 9,482*cos(0.0) / (.6299*3.937*12,000) + 6*abs(9,482*sin(0.0)*3.622 - 9,482*cos(0.0)*) / (.6299*3.937^2*13,334)
= 0.32 Acceptable

Weld Stress

Weld stress, tensile, bending and shear during lift:

Direct shear:

Shear stress at lift angle 0.00°; lift force = 9,482 lb_f

A_{weld} = $2{*}(.707){*}t_w{*}(L + t)$
= 2*(.707)*.315*(3.937 + .6299) = 2.0339 in^2

τ_t = $F_{lug}{*}\cos(\beta) / A_{weld}$
= 9,482*cos(0.0) / 2.0339 = 4,662 psi

τ_s = $F_{lug}{*}\sin(\beta) / A_{weld}$
= 9,482*sin(0.0) / 2.0339 = 0 psi

τ_b = M * c / I
= $3{*}(F_{lug}{*}\sin(\beta){*}Hght - F_{lug}{*}\cos(\beta){*}a_1) / (.707{*}h{*}L{*}(3{*}t + L))$
= 3*abs(9,482*sin(0.0)*3.622 - 9,482*cos(0.0)*()) / (5.1082)

= 0 psi

τ_{ratio} = sqr($(\tau_t + \tau_b)^2 + \tau_s^2$) / $\tau_{allowable} \leq 1$
= sqr ($(4{,}662 + 0)^2 + (0)^2$) / 8,000
= 0.58 Acceptable

WRC 537 Analysis

Geometry	
Height (radial)	5"
Width (circumferential)	3.937"
Length	.6299"
Fillet Weld Size:	.315"
Located On	CHANNEL FLANGE 1 (7.264" from right end)
Location Angle	0.00°

Applied Loads	
Radial load, P_r	-9,482.48 lb_f
Circumferential moment, M_c	0 lb_f-in
Circumferential shear, V_c	0 lb_f
Longitudinal moment, M_L	0 lb_f-in
Longitudinal shear, V_L	0 lb_f
Torsion moment, M_t	0 lb_f-in
Internal pressure, P	0 psi
Mean shell radius, R_m	24.681"
Design factor	3

Maximum stresses due to the applied loads at the lug edge

$\gamma = R_m / T$ = 24.681 / 5.362 = 4.6029

WRC 537: R_m / t < 5 (ratio not covered by WRC 537; R_m / t = 5 used)

C_1 = 2.2835, C_2 = 0.6299 in

Local circumferential pressure stress = $P*R_i / T$ =0 psi

Local longitudinal pressure stress = $P*R_i / (2*T)$ =0 psi

Maximum combined stress (P_L+P_b+Q) = 627 psi
Allowable combined stress (P_L+P_b+Q) = ±3*S = ±60,000 psi

The maximum combined stress (P_L+P_b+Q) is within allowable limits.

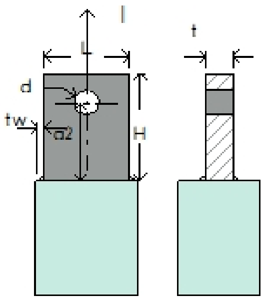
Maximum local primary membrane stress (P_L) = 77 psi
Allowable local primary membrane stress (P_L) = ±1.5*S = ±30,000 psi

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the lug edge per WRC Bulletin 537										
Figure	Y	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	1.0469	0.0448	0	0	0	0	75	75	75	75
4C*	1.0617	0.0775	76	76	76	76	0	0	0	0
1C	0.2398	0.0809	0	0	0	0	475	-475	475	-475
2C-1	0.219	0.0809	433	-433	433	-433	0	0	0	0
3A*	0.021	0.0602	0	0	0	0	0	0	0	0
1A	0.1081	0.0855	0	0	0	0	0	0	0	0
3B*	0.0506	0.0392	0	0	0	0	0	0	0	0
1B-1	0.0671	0.0677	0	0	0	0	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total circumferential stress			509	-357	509	-357	550	-400	550	-400
Primary membrane circumferential stress*			76	76	76	76	75	75	75	75
3C*	1.0278	0.0775	74	74	74	74	0	0	0	0
4C*	1.0775	0.0448	0	0	0	0	77	77	77	77
1C-1	0.2793	0.0571	553	-553	553	-553	0	0	0	0
2C	0.2475	0.0571	0	0	0	0	490	-490	490	-490
4A*	0.0276	0.0602	0	0	0	0	0	0	0	0
2A	0.0669	0.0638	0	0	0	0	0	0	0	0
4B*	0.0117	0.0392	0	0	0	0	0	0	0	0
2B-1	0.1113	0.0478	0	0	0	0	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total longitudinal stress			627	-479	627	-479	567	-413	567	-413
Primary membrane longitudinal stress*			74	74	74	74	77	77	77	77
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			0	0	0	0	0	0	0	0
Long shear from V_L			0	0	0	0	0	0	0	0
Total Shear stress			0	0	0	0	0	0	0	0
Combined stress (P_L+P_b+Q)			627	-479	627	-479	567	-413	567	-413

* denotes primary stress.

Channel Lifting Lug 2

Geometry Inputs	
	
Attached To	CHANNEL FLANGE 2
Material	SA-516 Gr.70
Orientation	Circumferential
Distance of Lift Point From Datum	47.0665"
Angular Position	°
Length, L	3.937"
Height, H	5"
Thickness, t	.6299"
Hole Diameter, d	1.1024"
Pin Diameter, Dp	.9843"
Load Eccentricity, a_1	"
Distance from Load to Shell or Pad, a_2	3.622"
Load Angle Normal to Vessel, β	°
Load Angle from Vertical, ϕ	°
Welds	
Size, t_w	.315"

Intermediate Values	
Load Factor	1.5000
Vessel Weight (new, incl. Load Factor), W	13,035.6 lb
Lug Weight (new), W_{lug}	3.5 lb
Distance from Center of Gravity to this lug, x_1	28.7244"
Distance from Center of Gravity to second lug, x_2	10.7631"
Allowable Stress, Tensile, σ_t	12,000 psi
Allowable Stress, Shear, σ_s	8,000 psi
Allowable Stress, Bearing, σ_p	18,000 psi
Allowable Stress, Bending, σ_b	13,334 psi
Allowable Stress, Weld Shear, $\tau_{allowable}$	8,000 psi
Allowable Stress set to 1/3 Sy per ASME B30.20	Yes

Summary Values	
Required Lift Pin Diameter, d_{reqd}	.5317"
Required Lug Thickness, t_{reqd}	.2228"
Lug Stress Ratio, σ_{ratio}	0.12
Weld Shear Stress Ratio, τ_{ratio}	0.22
Lug Design	Acceptable
Local Stresses WRC 537	Acceptable

Lift Forces

F_r = force on vessel at lug

F_r = $[W / \cos(\phi_1)]*(1 - x_1 / (x_1 + x_2))$

= (13,035.6) / cos()*(1 - 28.7244/ (28.7244 + 10.7631))

= 3,553 lb_f

where 'x_1' is the distance between this lug and the center of gravity

'x_2' is the distance between the second lift lug and the center of gravity

Lug Pin Diameter - Shear stress

d_{reqd} = $(2*F_r / (\pi*\sigma_s))^{.5}$

= $(2*3{,}553 / (\pi*8{,}000))^{.5}$ = .5317"

d_{reqd} / D_p = .5317 / .9843 = 0.54 Acceptable

σ = F_r / A

= $F_r / (2*(.25*\pi*D_p^2))$

= $3{,}553 / (2*(.25*\pi*.9843^2))$ = 2,335 psi

σ / σ_s = 2,335 / 8,000 = 0.29 Acceptable

Lug Thickness - Tensile stress

t_{reqd} = $F_r / ((L - d)*\sigma_t)$

= 3,553 / ((3.937 - 1.1024)*12,000) = .1045"

t_{reqd} / t = .1045 / .6299 = 0.17 Acceptable

σ = F_r / A

= $F_r / ((L - d)*t)$

= 3,553 / ((3.937 - 1.1024)*.6299) = 1,990 psi

σ / σ_t = 1,990 / 12,000 = 0.17 Acceptable

Lug Thickness - Bearing stress

t_{reqd} = $F_v / (D_p*\sigma_p)$

= 3,553 / (.9843*18,000) = .2006"

t_{reqd} / t = .2006 / .6299 = 0.32 Acceptable

σ = $F_v / A_{bearing}$

= $F_v / (D_p*(t))$

= 3,553 / (.9843*(.6299)) = 5,731 psi

σ / σ_p = 5,731 / 18,000 = 0.32 Acceptable

Lug Thickness - Shear stress

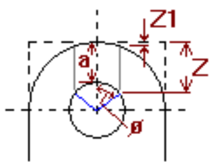
t_{reqd} = $[F_v / \sigma_s] / (2*L_{shear})$
= (3,553 / 8,000) / (2*.9967) = .2228"

t_{reqd} / t = .2228 / .6299 = 0.35 Acceptable

τ = F_v / A_{shear}
= $F_v / (2*t*L_{shear})$
= 3,553 / (2*.6299*.9967) = 2,830 psi

τ / σ_s = 2,830 / 8,000 = 0.35 Acceptable

Shear stress length (per Pressure Vessel and Stacks, A. Keith Escoe)



ϕ = $55*D_p / d$
= 55*.9843 / 1.1024
= 49.1071°

L_{shear} = $(H - a2 - 0.5*d) + 0.5*D_p*(1 - \cos(\phi))$
= (5 - 3.622 - 0.5*1.1024) + 0.5*.9843*(1 - cos(49.1071))
= .9967"

Lug Plate Stress

Lug stress tensile + bending during lift:

σ_{ratio} = $[F_{ten} / (A_{ten}*\sigma_t)] + [M_{bend} / (Z_{bend}*\sigma_b)] \le 1$
= $[(F_r*\cos(\beta)) / (t*L*\sigma_t)] + [(6*\mathrm{abs}(F_r*\sin(\beta)*Hght - F_r*\cos(\beta)*a_1)) / (t*L^2*\sigma_b)] \le 1$
= $3{,}553*\cos(0.0) / (.6299*3.937*12{,}000) + 6*\mathrm{abs}(3{,}553*\sin(0.0)*3.622 - 3{,}553*\cos(0.0)*) / (.6299*3.937^2*13{,}334)$
= 0.12 Acceptable

Weld Stress

Weld stress, tensile, bending and shear during lift:

Direct shear:

Shear stress at lift angle 0.00°; lift force = 3,553 lb_f

A_{weld} = $2*(.707)*t_w*(L + t)$

= 2*(.707)*.315*(3.937 + .6299) = 2.0339 in^2

τ_t = $F_{lug}*\cos(\beta) / A_{weld}$

= 3,553*cos(0.0) / 2.0339 = 1,747 psi

τ_s = $F_{lug}*\sin(\beta) / A_{weld}$

= 3,553*sin(0.0) / 2.0339 = 0 psi

τ_b = M * c / I
= $3*(F_{lug}*\sin(\beta)*Hght - F_{lug}*\cos(\beta)*a_1) / (.707*h*L*(3*t + L))$
= 3*abs(3,553*sin(0.0)*3.622 - 3,553*cos(0.0)*()) / (5.1082)

= 0 psi

τ_{ratio} = sqr($(\tau_t + \tau_b)^2 + \tau_s^2$) / $\tau_{allowable} \le 1$
= sqr ($(1{,}747 + 0)^2 + (0)^2$) / 8,000
= 0.22 Acceptable

WRC 537 Analysis

Geometry	
Height (radial)	5"
Width (circumferential)	3.937"
Length	.6299"
Fillet Weld Size:	.315"
Located On	CHANNEL FLANGE 2 (3.2085" from left end)
Location Angle	0.00°

Applied Loads	
Radial load, P_r	-3,553.13 lb_f
Circumferential moment, M_c	0 lb_f-in
Circumferential shear, V_c	0 lb_f
Longitudinal moment, M_L	0 lb_f-in
Longitudinal shear, V_L	0 lb_f
Torsion moment, M_t	0 lb_f-in
Internal pressure, P	0 psi
Mean shell radius, R_m	24.681"
Design factor	3

Maximum stresses due to the applied loads at the lug edge

$\gamma = R_m / T = 24.681 / 5.362 = 4.6029$

WRC 537: R_m / t < 5 (ratio not covered by WRC 537; R_m / t = 5 used)

$C_1 = 2.2835$, $C_2 = 0.6299$ in

Local circumferential pressure stress = $P*R_i / T$ =0 psi

Local longitudinal pressure stress = $P*R_i / (2*T)$ =0 psi

Maximum combined stress (P_L+P_b+Q) = 235 psi
Allowable combined stress (P_L+P_b+Q) = ±3*S = ±60,000 psi

The maximum combined stress (P_L+P_b+Q) is within allowable limits.

Maximum local primary membrane stress (P_L) = 29 psi
Allowable local primary membrane stress (P_L) = ±1.5*S = ±30,000 psi

The maximum local primary membrane stress (P_L) is within allowable limits.

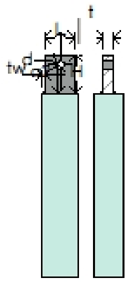
Stresses at the lug edge per WRC Bulletin 537										
Figure	Y	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	1.0469	0.0448	0	0	0	0	28	28	28	28
4C*	1.0617	0.0775	29	29	29	29	0	0	0	0
1C	0.2398	0.0809	0	0	0	0	178	-178	178	-178
2C-1	0.219	0.0809	162	-162	162	-162	0	0	0	0
3A*	0.021	0.0602	0	0	0	0	0	0	0	0
1A	0.1081	0.0855	0	0	0	0	0	0	0	0
3B*	0.0506	0.0392	0	0	0	0	0	0	0	0
1B-1	0.0671	0.0677	0	0	0	0	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total circumferential stress			191	-133	191	-133	206	-150	206	-150
Primary membrane circumferential stress*			29	29	29	29	28	28	28	28
3C*	1.0278	0.0775	28	28	28	28	0	0	0	0
4C*	1.0775	0.0448	0	0	0	0	29	29	29	29
1C-1	0.2793	0.0571	207	-207	207	-207	0	0	0	0
2C	0.2475	0.0571	0	0	0	0	184	-184	184	-184
4A*	0.0276	0.0602	0	0	0	0	0	0	0	0
2A	0.0669	0.0638	0	0	0	0	0	0	0	0
4B*	0.0117	0.0392	0	0	0	0	0	0	0	0
2B-1	0.1113	0.0478	0	0	0	0	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total longitudinal stress			235	-179	235	-179	213	-155	213	-155
Primary membrane longitudinal stress*			28	28	28	28	29	29	29	29
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			0	0	0	0	0	0	0	0
Long shear from V_L			0	0	0	0	0	0	0	0
Total Shear stress			0	0	0	0	0	0	0	0
Combined stress (P_L+P_b+Q)			235	-179	235	-179	213	-155	213	-155

* denotes primary stress.

9.Appendix 8：Cover Lifting Lug Calculation

Cover Lifting Lug

Geometry Inputs	



Attached To	CHANNEL COVER
Material	SA-516 Gr.70
Orientation	Circumferential
Distance of Lift Point From Datum	2.224"
Angular Position	°
Length, L	3.937"
Height, H	5"
Thickness, t	.6299"
Hole Diameter, d	1.1024"
Pin Diameter, Dp	.9843"
Load Eccentricity, a_1	"
Distance from Load to Shell or Pad, a_2	3.622"
Load Angle Normal to Vessel, β	°
Load Angle from Vertical, ϕ	°
Welds	
Size, t_w	.315"

Intermediate Values	
Load Factor	1.5000
Vessel Weight (new, incl. Load Factor), W	5,263.6 lb
Lug Weight (new), W_{lug}	3.5 lb
Allowable Stress, Tensile, σ_t	12,000 psi
Allowable Stress, Shear, σ_s	8,000 psi
Allowable Stress, Bearing, σ_p	18,000 psi
Allowable Stress, Bending, σ_b	13,334 psi
Allowable Stress, Weld Shear, $\tau_{allowable}$	8,000 psi
Allowable Stress set to 1/3 Sy per ASME B30.20	Yes

Summary Values	
Required Lift Pin Diameter, d_{reqd}	.6472"
Required Lug Thickness, t_{reqd}	.33"
Lug Stress Ratio, σ_{ratio}	0.18
Weld Shear Stress Ratio, τ_{ratio}	0.32
Lug Design	Acceptable
Local Stresses WRC 537	Acceptable

Lift Forces

F_r = force on vessel at lug

F_r = W*LoadFactor

= 5,264 lb_f

Lug Pin Diameter - Shear stress

d_{reqd} = $(2*F_r / (\pi*\sigma_s))^{.5}$

= $(2*5,264 / (\pi*8,000))^{.5}$ = .6472"

d_{reqd} / D_p = .6472 / .9843 = 0.66 Acceptable

σ = F_r / A

= $F_r / (2*(.25*\pi*D_p^2))$

= $5,264 / (2*(.25*\pi*.9843^2))$ = 3,459 psi

σ / σ_s = 3,459 / 8,000 = 0.43 Acceptable

Lug Thickness - Tensile stress

t_{reqd} = $F_r / ((L - d)*\sigma_t)$

= 5,264 / ((3.937 - 1.1024)*12,000) = .1547"

t_{reqd} / t = .1547 / .6299 = 0.25 Acceptable

σ = F_r / A

= F_r / ((L - d)*t)

= 5,264 / ((3.937 - 1.1024)*.6299) = 2,948 psi

σ / σ_t = 2,948 / 12,000 = 0.25 Acceptable

Lug Thickness - Bearing stress

t_{reqd} = $F_v / (D_p*\sigma_p)$

= 5,264 / (.9843*18,000) = .2971"

t_{reqd} / t = .2971 / .6299 = 0.47 Acceptable

σ = $F_v / A_{bearing}$

= $F_v / (D_p*(t))$

= 5,264 / (.9843*(.6299)) = 8,490 psi

σ / σ_p = 8,490 / 18,000 = 0.47 Acceptable

Lug Thickness - Shear stress

t_{reqd} = $[F_v / \sigma_s] / (2*L_{shear})$

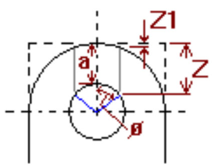
= (5,264 / 8,000) / (2*.9967) = .33"

t_{reqd} / t = .33 / .6299 = 0.52 Acceptable

τ = F_v / A_{shear}
= F_v / (2*t*L_{shear})
= 5,264 / (2*.6299*.9967) = 4,192 psi

τ / σ_s = 4,192 / 8,000 = 0.52 Acceptable

Shear stress length (per Pressure Vessel and Stacks, A. Keith Escoe)



ϕ = 55*D_p / d
= 55*.9843 / 1.1024
= 49.1071°

L_{shear} = (H - a2 - 0.5*d) + 0.5*D_p*(1 - cos(ϕ))
= (5 - 3.622 - 0.5*1.1024) + 0.5*.9843*(1 - cos(49.1071))
= .9967"

Lug Plate Stress

Lug stress tensile + bending during lift:

σ_{ratio} = [F_{ten} / (A_{ten}*σ_t)] + [M_{bend} / (Z_{bend}*σ_b)] ≤ 1
= [(F_r*cos(β)) / (t*L*σ_t)] + [(6*abs(F_r*sin(β)*Hght - F_r*cos(β)*a_1)) / (t*L^2*σ_b)] ≤ 1
= 5,264*cos(0.0) / (.6299*3.937*12,000) + 6*abs(5,264*sin(0.0)*3.622 - 5,264*cos(0.0)*) / (.6299*3.937^2*13,334)
= 0.18 Acceptable

Weld Stress

Weld stress, tensile, bending and shear during lift:

Direct shear:

Shear stress at lift angle 0.00°; lift force = 5,264 lb_f

A_{weld} = 2*(.707)*t_w*(L + t)
= 2*(.707)*.315*(3.937 + .6299) = 2.0339 in^2

τ_t = F_{lug}*cos(β) / A_{weld}
= 5,264*cos(0.0) / 2.0339 = 2,588 psi

τ_s = F_{lug}*sin(β) / A_{weld}
= 5,264*sin(0.0) / 2.0339 = 0 psi

τ_b = M * c / I
= 3*(F_{lug}*sin(β)*Hght - F_{lug}*cos(β)*a_1) / (.707*h*L*(3*t + L))
= 3*abs(5,264*sin(0.0)*3.622 - 5,264*cos(0.0)*()) / (5.1082)
= 0 psi

τ_{ratio} = sqr((τ_t + τ_b)^2 + τ_s^{2}) / $\tau_{allowable}$ ≤ 1
= sqr ((2,588 + 0)^2 + (0)^2) / 8,000

= 0.32 Acceptable

WRC 537 Analysis

Geometry	
Height (radial)	5"
Width (circumferential)	3.937"
Length	.6299"
Fillet Weld Size:	.315"
Located On	CHANNEL COVER (1.909" from right end)
Location Angle	0.00°

Applied Loads	
Radial load, P_r	-5,263.56 lb_f
Circumferential moment, M_c	0 lb_f-in
Circumferential shear, V_c	0 lb_f
Longitudinal moment, M_L	0 lb_f-in
Longitudinal shear, V_L	0 lb_f
Torsion moment, M_t	0 lb_f-in
Internal pressure, P	0 psi
Mean shell radius, R_m	15.5512"
Design factor	3

Maximum stresses due to the applied loads at the lug edge

$\gamma = R_m / T = 15.5512 / 23.622 = 0.6583$

WRC 537: $R_m / t < 5$ (ratio not covered by WRC 537; $R_m / t = 5$ used)

$C_1 = 2.2835$, $C_2 = 0.6299$ in

Local circumferential pressure stress = $P*R_i / T$ =0 psi

Local longitudinal pressure stress = $P*R_i / (2*T)$ =0 psi

Maximum combined stress (P_L+P_b+Q) = 27 psi
Allowable combined stress (P_L+P_b+Q) = ±3*S = ±60,000 psi

The maximum combined stress (P_L+P_b+Q) is within allowable limits.

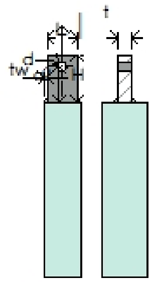
Maximum local primary membrane stress (P_L) = 15 psi
Allowable local primary membrane stress (P_L) = ±1.5*S = ±30,000 psi

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the lug edge per WRC Bulletin 537										
Figure	Y	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	1.0318	0.071	0	0	0	0	15	15	15	15
4C*	1.0318	0.123	15	15	15	15	0	0	0	0
1C	0.191	0.1284	0	0	0	0	11	-11	11	-11
2C-1	0.1683	0.1284	10	-10	10	-10	0	0	0	0
3A*	0.0446	0.0956	0	0	0	0	0	0	0	0
1A	0.1062	0.1357	0	0	0	0	0	0	0	0
3B*	0.1047	0.0622	0	0	0	0	0	0	0	0
1B-1	0.0651	0.1074	0	0	0	0	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total circumferential stress			25	5	25	5	26	4	26	4
Primary membrane circumferential stress*			15	15	15	15	15	15	15	15
3C*	0.996	0.123	14	14	14	14	0	0	0	0
4C*	1.0654	0.071	0	0	0	0	15	15	15	15
1C-1	0.2304	0.0906	13	-13	13	-13	0	0	0	0
2C	0.2022	0.0906	0	0	0	0	11	-11	11	-11
4A*	0.0575	0.0956	0	0	0	0	0	0	0	0
2A	0.0655	0.1013	0	0	0	0	0	0	0	0
4B*	0.0228	0.0622	0	0	0	0	0	0	0	0
2B-1	0.1083	0.0759	0	0	0	0	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total longitudinal stress			27	1	27	1	26	4	26	4
Primary membrane longitudinal stress*			14	14	14	14	15	15	15	15
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			0	0	0	0	0	0	0	0
Long shear from V_L			0	0	0	0	0	0	0	0
Total Shear stress			0	0	0	0	0	0	0	0
Combined stress (P_L+P_b+Q)			27	5	27	5	26	4	26	4

* denotes primary stress.

Tubesheet Lifting Lug

Geometry Inputs	
	
Attached To	TUBESHEET
Material	SA-240 316L
Orientation	Circumferential
Distance of Lift Point From Datum	2.7517"
Angular Position	°
Length, L	3.937"
Height, H	6.2992"
Thickness, t	1.0236"
Hole Diameter, d	1.2598"
Pin Diameter, Dp	1.1962"
Load Eccentricity, a_1	"
Distance from Load to Shell or Pad, a_2	4.7244"
Load Angle Normal to Vessel, β	°
Load Angle from Vertical, ϕ	°
Welds	
Size, t_w	.4724"

Intermediate Values	
Load Factor	1.5000
Vessel Weight (new, incl. Load Factor), W	12,488.1 lb
Lug Weight (new), W_{lug}	7.3 lb
Allowable Stress, Tensile, σ_t	8,333 psi
Allowable Stress, Shear, σ_s	5,556 psi
Allowable Stress, Bearing, σ_p	12,500 psi
Allowable Stress, Bending, σ_b	9,260 psi
Allowable Stress, Weld Shear, $\tau_{allowable}$	5,556 psi
Allowable Stress set to 1/3 Sy per ASME B30.20	Yes

Summary Values	
Required Lift Pin Diameter, d_{reqd}	1.1962"
Required Lug Thickness, t_{reqd}	.9552"
Lug Stress Ratio, σ_{ratio}	0.37
Weld Shear Stress Ratio, τ_{ratio}	0.68
Lug Design	Acceptable
Local Stresses WRC 537	Acceptable

Lift Forces

F_r = force on vessel at lug

F_r = W*LoadFactor

= 12,488 lb_f

Lug Pin Diameter - Shear stress

d_{reqd} = $(2*F_r / (\pi*\sigma_s))^{.5}$

= $(2*12{,}488 / (\pi*5{,}556))^{.5}$ = 1.1962"

d_{reqd} / D_p = 1.1962 / 1.1962 = 1.00 Acceptable

σ = F_r / A

= $F_r / (2*(.25*\pi*D_p^2))$

= $12{,}488 / (2*(.25*\pi*1.1962^2))$ = 5,556 psi

σ / σ_s = 5,556 / 5,556 = 1 Acceptable

Lug Thickness - Tensile stress

t_{reqd} = $F_r / ((L - d)*\sigma_t)$

= 12,488 / ((3.937 - 1.2598)*8,333) = .5598"

t_{reqd} / t = .5598 / 1.0236 = 0.55 Acceptable

σ = F_r / A

= F_r / ((L - d)*t)

= 12,488 / ((3.937 - 1.2598)*1.0236) = 4,557 psi

σ / σ_t = 4,557 / 8,333 = 0.55 Acceptable

Lug Thickness - Bearing stress

t_{reqd} = $F_v / (D_p*\sigma_p)$

= 12,488 / (1.1962*12,500) = .8352"

t_{reqd} / t = .8352 / 1.0236 = 0.82 Acceptable

σ = $F_v / A_{bearing}$

= $F_v / (D_p*(t))$

= 12,488 / (1.1962*(1.0236)) = 10,199 psi

σ / σ_p = 10,199 / 12,500 = 0.82 Acceptable

Lug Thickness - Shear stress

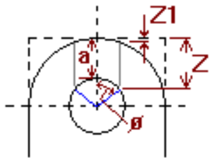
t_{reqd} = $[F_v / \sigma_s] / (2*L_{shear})$

	=	(12,488 / 5,556) / (2*1.1766)	=	.9552"
t_{reqd} / t	=	.9552 / 1.0236	=	0.93 Acceptable

τ = F_v / A_{shear}
= $F_v / (2*t*L_{shear})$
= 12,488 / (2*1.0236*1.1766) = 5,184 psi

τ / σ_s = 5,184 / 5,556 = 0.93 Acceptable

Shear stress length (per Pressure Vessel and Stacks, A. Keith Escoe)



ϕ = $55*D_p / d$
= 55*1.1962 / 1.2598
= 52.2228°

L_{shear} = $(H - a2 - 0.5*d) + 0.5*D_p*(1 - \cos(\phi))$
= (6.2992 - 4.7244 - 0.5*1.2598) + 0.5*1.1962*(1 - cos(52.2228))
= 1.1766"

Lug Plate Stress

Lug stress tensile + bending during lift:

σ_{ratio} = $[F_{ten} / (A_{ten}*\sigma_t)] + [M_{bend} / (Z_{bend}*\sigma_b)] \leq 1$
= $[(F_r*\cos(\beta)) / (t*L*\sigma_t)] + [(6*abs(F_r*\sin(\beta)*Hght - F_r*\cos(\beta)*a_1)) / (t*L^2*\sigma_b)] \leq 1$
= 12,488*cos(0.0) / (1.0236*3.937*8,333) + 6*abs(12,488*sin(0.0)*4.7244 - 12,488*cos(0.0)*) / (1.0236*3.937^2*9,260)
= 0.37 Acceptable

Weld Stress

Weld stress, tensile, bending and shear during lift:

Direct shear:

Shear stress at lift angle 0.00°; lift force = 12,488 lb_f

A_{weld} = $2*(.707)*t_w*(L + t)$
= 2*(.707)*.4724*(3.937 + 1.0236) = 3.3139 in^2

τ_t = $F_{lug}*\cos(\beta) / A_{weld}$
= 12,488*cos(0.0) / 3.3139 = 3,768 psi

τ_s = $F_{lug}*\sin(\beta) / A_{weld}$
= 12,488*sin(0.0) / 3.3139 = 0 psi

τ_b = M * c / I
= $3*(F_{lug}*\sin(\beta)*Hght - F_{lug}*\cos(\beta)*a_1) / (.707*h*L*(3*t + L))$
= 3*abs(12,488*sin(0.0)*4.7244 - 12,488*cos(0.0)*()) / (9.2155)
= 0 psi

τ_{ratio} = sqr($(\tau_t + \tau_b)^2 + \tau_s^2$) / $\tau_{allowable} \le 1$
= sqr ($(3{,}768 + 0)^2 + (0)^2$) / 5,556
= 0.68 Acceptable

WRC 537 Analysis

Geometry	
Height (radial)	6.2992"
Width (circumferential)	3.937"
Length	1.0236"
Fillet Weld Size:	.4724"
Located On	TUBESHEET (2.2399" from right end)
Location Angle	0.00°

Applied Loads	
Radial load, P_r	-12,488.1 lb_f
Circumferential moment, M_c	0 lb_f-in
Circumferential shear, V_c	0 lb_f
Longitudinal moment, M_L	0 lb_f-in
Longitudinal shear, V_L	0 lb_f
Torsion moment, M_t	0 lb_f-in
Internal pressure, P	0 psi
Mean shell radius, R_m	15.5512"
Design factor	3

Maximum stresses due to the applied loads at the lug edge

$\gamma = R_m / T = 15.5512 / 23.622 = 0.6583$

WRC 537: R_m / t < 5 (ratio not covered by WRC 537; R_m / t = 5 used)

$C_1 = 2.4409$, $C_2 = 0.9843$ in

Local circumferential pressure stress = $P*R_i / T$ =0 psi

Local longitudinal pressure stress = $P*R_i / (2*T)$ =0 psi

Maximum combined stress (P_L+P_b+Q) = 62 psi
Allowable combined stress (P_L+P_b+Q) = ±3*S = ±50,100 psi

Note: The allowable combined stress (P_L+P_b+Q) is based on the strain hardening characteristics of this material.

The maximum combined stress (P_L+P_b+Q) is within allowable limits.

Maximum local primary membrane stress (P_L) = 36 psi
Allowable local primary membrane stress (P_L) = ±1.5*S = ±25,050 psi

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the lug edge per WRC Bulletin 537										
Figure	Y	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	1.0161	0.0952	0	0	0	0	35	35	35	35
4C*	1.0247	0.1331	35	35	35	35	0	0	0	0
1C	0.1842	0.137	0	0	0	0	25	-25	25	-25
2C-1	0.1608	0.137	22	-22	22	-22	0	0	0	0
3A*	0.0601	0.116	0	0	0	0	0	0	0	0
1A	0.1057	0.1467	0	0	0	0	0	0	0	0
3B*	0.1621	0.0857	0	0	0	0	0	0	0	0
1B-1	0.0645	0.1164	0	0	0	0	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total circumferential stress			57	13	57	13	60	10	60	10
Primary membrane circumferential stress*			35	35	35	35	35	35	35	35
3C*	0.9881	0.1331	34	34	34	34	0	0	0	0
4C*	1.0507	0.0952	0	0	0	0	36	36	36	36
1C-1	0.2101	0.1095	28	-28	28	-28	0	0	0	0
2C	0.1824	0.1095	0	0	0	0	24	-24	24	-24
4A*	0.0788	0.116	0	0	0	0	0	0	0	0
2A	0.0648	0.1155	0	0	0	0	0	0	0	0
4B*	0.0364	0.0857	0	0	0	0	0	0	0	0
2B-1	0.1054	0.0957	0	0	0	0	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total longitudinal stress			62	6	62	6	60	12	60	12
Primary membrane longitudinal stress*			34	34	34	34	36	36	36	36
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			0	0	0	0	0	0	0	0
Long shear from V_L			0	0	0	0	0	0	0	0
Total Shear stress			0	0	0	0	0	0	0	0
Combined stress (P_L+P_b+Q)			62	13	62	13	60	12	60	12

* denotes primary stress.

Appendix 10：Equipment Lifting Lug Calculation

Table of Contents

```
PV Elite 24        Licensee: WCE
FileName : 18-X-262-LIFTING    -----------------------------
Lifting Lug Calcs: Left End          Step:   14   3:37pm   Sep 5,2022
```

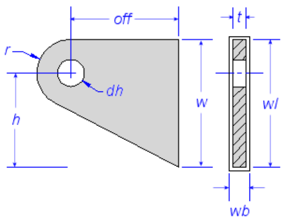
Lifting Lug Calculations: Lug(s) on Left End of Vessel

Input Values:

```
Lifting Lug Material                                   SA-516 70
Lifting Lug Yield Stress                            Yield   38000.00 psi

Total Height of Lifting Lug                              w     9.8425 in
Thickness of Lifting Lug                                 t     1.0236 in
Diameter of Hole in Lifting Lug                         dh     2.0866 in
Radius of Semi-Circular Arc of Lifting Lug               r     3.9370 in
Height of Lug from bottom to Center of Hole              h     4.9210 in
Offset from Vessel OD to Center of Hole                off     5.9055 in
Lug Fillet Weld Size                                    tw     0.4331 in
Length of weld along side of Lifting Lug                wl    10.4724 in
Length of Weld along Bottom of Lifting Lug              wb     1.8110 in
Thickness of Collar (if any)                            tc     0.0000 in
Diameter of Collar (if any)                             dc     0.0000 in
Impact Factor                                       Impfac       1.50
Sling Angle from Horizontal                                      90.0 deg
Number of Lugs in Group                                             1

Lifting Lug Orientation to Vessel: Perpendicular
Lift Orientation : Horizontal Lift
```



PV Elite does not compute weak axis bending forces on the lugs. It is assumed that a spreader bar is used.

Computed Results:

```
Total vessel weight (No Liquid)                              37735.88 lbf
Design Reaction force at the Left end lug                    46391.05 lbf
Design Reaction force at the Right end lug                   10212.77 lbf

Force Along Vessel Axis                                Fax       0.00 lbf
Force Normal to Vessel                                  Fn   46391.05 lbf
Force Tangential to Vessel                              Ft       0.00 lbf
```

Converting the weld leg dimension (tw) to the weld throat dimension.

Weld Group Inertia Calculations:

```
Weld Group Inertia about the Circumferential Axis     Ilc      90.828 in**4
Weld Group Centroid distance in the Long. Direction   Yll       5.542 in
Dist. of Weld Group Centroid from Lug bottom        Yll_b       5.236 in
Weld Group Inertia about the Longitudinal Axis        Ill       3.188 in**4
Weld Group Centroid Distance in the Circ. Direction   Ylc       0.818 in
```

Note: The Impact Factor is applied to the Forces acting on the Lug.

Primary Shear Stress in the Welds due to Shear Loads [Ssll]:

$= \mathrm{sqrt}(Fax^2 + Ft^2 + Fn^2)/((2 * (wl + wb)) * tw)$

= sqrt(0^2+0^2+46391^2)/((2*(10.472+1.811))*0.3062)
= 6167.46 psi

Shear Stress in the Welds due to Bending Loads [Sblf]:
= (Fn(h-Yll_b))Yll/Ilc + (Fax * off * Yll/Ilc) + (Ft * off * Ylc/Ill)
= (46391(4.921 -5.2362))5.5424/90.828 +
(0 * 5.9055 * 5.5424/90.828) +
(0 * 5.9055 * 0.818/3.1883)
= -892.27 psi

Total Shear Stress for Combined Loads [St]:
= Ssll + Sblf
= 6167.5 + -892.27
= 5275.19 psi

Allowable Shear Stress for Combined Loads [Sta]:
= 0.4 * Yield * Occfac (AISC Shear Allowable)
= 0.4 * 38000 * 1
= 15200.00 psi

Shear Stress in Lug above Hole [Shs]:
= sqrt(Pl^2 + Fax^2) / Sha
= sqrt(46391^2 + 0^2)/5.9241
= 7830.89 psi

Allowable Shear Stress in Lug above Hole [Sas]:
= 0.4 * Yield * Occfac
= 0.4 * 38000 * 1
= 15200.00 psi

Pin Hole Bearing Width [Pbw]:
= Lug Thickness + 2 * Collar Thickness
= 1.0236 + 2 * 0
= 1.024 in

Pin Hole Bearing Stress [Pbs]:
= sqrt(Pl^2 + $Faxial^2$) / (Pbw * dh)
= sqrt(46391^2 + 0^2)/(1.0236 * 2.0866)
= 21719.72 psi

Allowable Bearing Stress [Pba]:
= min(0.75 * Yield * Occfac, 0.9 * Yield) AISC Bearing All.
= min(0.75 * 38000 * 1, 34200)
= 28500.00 psi

Bending Stress at the Base of the Lug [Fbs]:
= Ft * off/(w * t^2/6) + Fax * off/(w^2 * t/6)
= 0 * 5.9055/(9.8425 * 1.0236^2/6) +
0 * 5.9055/(9.8425^2 * 1.0236/6)
= 0.00 psi

Tensile Stress at the Base of the Lug [Fa]:
= Fn / (w * t)
= 46391/(9.8425 * 1.0236)
= 4604.57 psi

Total Combined Stress at the Base of the Lug:
= Fbs + Fa
= 0 + 4604.6
= 4604.57 psi

Lug Allowable Stress for Bending and Tension:
= min(0.66 * Yield * Occfac, 0.75 * Yield)

= min(0.66 * 38000 * 1, 28500)
= 25080.00 psi

Required Shackle Pin Diameter [Spd]:
= $\mathrm{sqrt}((2(Fn^2 + Fax^2)^{0.5}/(\ pi * Sta)))$
= $\mathrm{sqrt}(2(46391^2 + 0^2)^{0.5}/(\ pi * 15200\ ))$
= 1.3939 in

WRC 107/537 Stress Analysis for the Lifting Lug to Shell Junction in the new and Cold Condition (no corrosion applied).

Note : The ratio Beta1/Beta2 for rectangular attachments was outside the range of values in tables 7 & 8 and was set to be an acceptable (maximum or minimum) value.

Note: Attachment dimensions (C11P, C22P etc.) may be modified accounting for attachment welds where applicable.

Input Echo, WRC107/537 Item 1, Description: Lift Lug

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	0.0000	in
Vessel Diameter	Dv	44.252	in
Vessel Thickness	Tv	0.630	in

Note: Lifting lug calculations are performed at ambient temperature conditions.

Attachment Type	Type	Rectangular	
Parameter C11	C11	1.81	in
Parameter C22	C22	7.24	in
Thickness of Reinforcing Pad	Tpad	0.630	in
Pad Parameter C11P	C11p	8.976	in
Pad Parameter C22P	C22p	16.299	in
Design Internal Pressure	Dp	0.000	psig
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	-46391.1	lbf
Longitudinal Shear	(SUS)	Vl	0.0	lbf
Circumferential Shear	(SUS)	Vc	0.0	lbf
Circumferential Moment	(SUS)	Mc	0.0	ft-lb
Longitudinal Moment	(SUS)	Ml	0.0	ft-lb
Torsional Moment	(SUS)	Mt	0.0	ft-lb

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

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".

```
PV Elite 24        Licensee: WCE
FileName : 18-X-262-LIFTING    ------------------------------
Lifting Lug Calcs: Left End          Step:    14    3:37pm    Sep 5,2022
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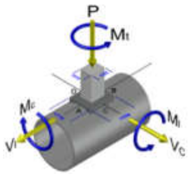


WRC 107/537 has dimensional limitations that can be found in the bulletin's Foreword and which can also be inferred by review of the non-dimensional curve limits.

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	-46391.1	lbf
Circumferential Shear	VC	0.0	lbf
Longitudinal Shear	VL	0.0	lbf
Circumferential Moment	MC	0.0	ft-lb
Longitudinal Moment	ML	0.0	ft-lb
Torsional Moment	MT	0.0	ft-lb

Dimensionless Parameters used :   Gamma = 18.06

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.118	4C	3.304	(A,B)
N(PHI) / (P/Rm)	0.118	3C	3.019	(C,D)
M(PHI) / (P)	0.070	2C1	0.159	(A,B)
M(PHI) / (P)	0.070	1C	0.193	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.063	3A	0.206	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.082	1A	0.103	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.100	3B	1.398	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.090	1B	0.056	(A,B,C,D)
N(x) / (P/Rm)	0.096	3C	3.217	(A,B)
N(x) / (P/Rm)	0.096	4C	3.417	(C,D)
M(x) / (P)	0.099	1C1	0.163	(A,B)
M(x) / (P)	0.099	2C	0.124	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.063	4A	0.263	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.115	2A	0.057	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.100	4B	0.367	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.124	2B	0.081	(A,B,C,D)

Stress Concentration Factors: Kn = 1.00,   Kb = 1.00

Stresses in the Vessel at the Attachment Junction (psi)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	5347	5347	5347	5347	4885	4885	4885	4885
Circ. Bend. P	27889	-27889	27889	-27889	33899	-33899	33899	-33899
Circ. Memb. MC	0	0	0	0	0	0	0	0
Circ. Bend. MC	0	0	0	0	0	0	0	0
Circ. Memb. ML	0	0	0	0	0	0	0	0
Circ. Bend. ML	0	0	0	0	0	0	0	0
Tot. Circ. Str.	33236	-22542	33236	-22542	38785	-29014	38785	-29014
Long. Memb. P	5205	5205	5205	5205	5528	5528	5528	5528
Long. Bend. P	28559	-28559	28559	-28559	21760	-21760	21760	-21760
Long. Memb. MC	0	0	0	0	0	0	0	0

Long. Bend. MC	0	0	0	0	0	0	0	0
Long. Memb. ML	0	0	0	0	0	0	0	0
Long. Bend. ML	0	0	0	0	0	0	0	0
Tot. Long. Str.	33764	-23354	33764	-23354	27288	-16231	27288	-16231
Shear VC	0	0	0	0	0	0	0	0
Shear VL	0	0	0	0	0	0	0	0
Shear MT	0	0	0	0	0	0	0	0
Tot. Shear	0	0	0	0	0	0	0	0
Str. Int.	33764	23354	33764	23354	38785	29014	38785	29014

Dimensionless Parameters used : Gamma = 35.62

Dimensionless Loads for Cylindrical Shells at Pad Edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.347	4C	3.667	(A,B)
N(PHI) / (P/Rm)	0.347	3C	1.691	(C,D)
M(PHI) / (P)	0.250	2C1	0.025	(A,B)
M(PHI) / (P)	0.250	1C !	0.061	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.244	3A	1.443	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.265	1A	0.072	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.298	3B	2.766	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.282	1B	0.016	(A,B,C,D)
N(x) / (P/Rm)	0.302	3C	2.037	(A,B)
N(x) / (P/Rm)	0.302	4C	4.089	(C,D)
M(x) / (P)	0.310	1C1	0.039	(A,B)
M(x) / (P)	0.310	2C !	0.032	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.244	4A	3.026	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.322	2A	0.028	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.298	4B	1.363	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.327	2B	0.020	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (psi)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	12033	12033	12033	12033	5549	5549	5549	5549
Circ. Bend. P	17464	-17464	17464	-17464	43057	-43057	43057	-43057
Circ. Memb. MC	0	0	0	0	0	0	0	0
Circ. Bend. MC	0	0	0	0	0	0	0	0
Circ. Memb. ML	0	0	0	0	0	0	0	0
Circ. Bend. ML	0	0	0	0	0	0	0	0
Tot. Circ. Str.	29497	-5430	29497	-5430	48607	-37508	48607	-37508
Long. Memb. P	6685	6685	6685	6685	13417	13417	13417	13417
Long. Bend. P	27126	-27126	27126	-27126	22201	-22201	22201	-22201
Long. Memb. MC	0	0	0	0	0	0	0	0
Long. Bend. MC	0	0	0	0	0	0	0	0
Long. Memb. ML	0	0	0	0	0	0	0	0

```
PV Elite 24        Licensee: WCE
FileName : 18-X-262-LIFTING    ------------------------------
Lifting Lug Calcs: Left End            Step:    14   3:37pm   Sep 5,2022
```

Long. Bend. ML	0	0	0	0	0	0	0	0
Tot. Long. Str.	33812	-20441	33812	-20441	35619	-8783	35619	-8783
Shear VC	0	0	0	0	0	0	0	0
Shear VL	0	0	0	0	0	0	0	0
Shear MT	0	0	0	0	0	0	0	0
Tot. Shear	0	0	0	0	0	0	0	0
Str. Int.	33812	20441	33812	20441	48607	37508	48607	37508

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (psi)

Type of Stress Load	Stress Intensity Values at							
	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	0	0	0	0	0	0	0	0
Circ. Pl (SUS)	5347	5347	5347	5347	4885	4885	4885	4885
Circ. Q (SUS)	27889	-27889	27889	-27889	33899	-33899	33899	-33899
Long. Pm (SUS)	0	0	0	0	0	0	0	0
Long. Pl (SUS)	5205	5205	5205	5205	5528	5528	5528	5528
Long. Q (SUS)	28559	-28559	28559	-28559	21760	-21760	21760	-21760
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	0	0	0	0	0	0	0	0
Shear Q (SUS)	0	0	0	0	0	0	0	0
Pm (SUS)	0	0	0	0	0	0	0	0
Pm+Pl (SUS)	5347	5347	5347	5347	5528	5528	5528	5528
Pm+Pl+Q (Total)	33764	23354	33764	23354	38785	29014	38785	29014

Vessel Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	0	20000	Passed
Pm+Pl (SUS)	5528	30000	Passed
Pm+Pl+Q (TOTAL)	38785	60000	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 (psi)

Type of Stress Load	Stress Intensity Values at							
	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	0	0	0	0	0	0	0	0
Circ. Pl (SUS)	12033	12033	12033	12033	5549	5549	5549	5549
Circ. Q (SUS)	17464	-17464	17464	-17464	43057	-43057	43057	-43057

```
PV Elite 24       Licensee: WCE
FileName : 18-X-262-LIFTING    ------------------------------
Lifting Lug Calcs: Left End           Step:   14   3:37pm   Sep 5,2022
```

Long. Pm (SUS)	0	0	0	0	0	0	0	0
Long. Pl (SUS)	6685	6685	6685	6685	13417	13417	13417	13417
Long. Q (SUS)	27126	-27126	27126	-27126	22201	-22201	22201	-22201
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	0	0	0	0	0	0	0	0
Shear Q (SUS)	0	0	0	0	0	0	0	0
Pm (SUS)	0	0	0	0	0	0	0	0
Pm+Pl (SUS)	12033	12033	12033	12033	13417	13417	13417	13417
Pm+Pl+Q (Total)	33812	20441	33812	20441	48607	37508	48607	37508

Vessel Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	0	20000	Passed
Pm+Pl (SUS)	13417	30000	Passed
Pm+Pl+Q (TOTAL)	48607	60000	Passed

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

```
PV Elite 24        Licensee: WCE
FileName : 18-X-262-LIFTING    -----------------------------
Lifting Lug Calcs: Right End          Step:   15   3:37pm   Sep 5,2022
```

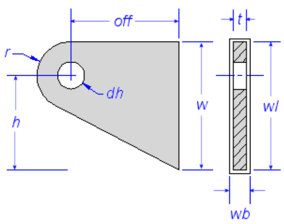
Lifting Lug Calculations: Lug(s) on Right End of Vessel

Input Values:

```
Lifting Lug Material                                   SA-516 70
 Lifting Lug Yield Stress                          Yield    38000.00 psi

 Total Height of Lifting Lug                           w      9.8425 in
 Thickness of Lifting Lug                              t      1.0236 in
 Diameter of Hole in Lifting Lug                      dh      2.0866 in
 Radius of Semi-Circular Arc of Lifting Lug            r      3.9370 in
 Height of Lug from bottom to Center of Hole           h      4.9210 in
 Offset from Vessel OD to Center of Hole             off      5.9055 in
 Lug Fillet Weld Size                                 tw      0.4331 in
 Length of weld along side of Lifting Lug             wl     10.4724 in
 Length of Weld along Bottom of Lifting Lug           wb      1.8110 in
 Thickness of Collar (if any)                         tc      0.0000 in
 Diameter of Collar (if any)                          dc      0.0000 in
 Impact Factor                                    Impfac        1.50
 Number of Lugs in Group                                          1

 Lifting Lug Orientation to Vessel: Perpendicular
 Lift Orientation : Horizontal Lift
```



PV Elite does not compute weak axis bending forces on the lugs. It is assumed that a spreader bar is used.

Computed Results:

```
 Total vessel weight (No Liquid)                             37735.88 lbf
 Design Reaction force at the Left end lug                   46391.05 lbf
 Design Reaction force at the Right end lug                  10212.77 lbf

 Force Along Vessel Axis                            Fax          0.00 lbf
 Force Normal to Vessel                              Fn      10212.77 lbf
 Force Tangential to Vessel                          Ft          0.00 lbf

 Sling Angle from Horizontal                                      0.0 deg
```

Converting the weld leg dimension (tw) to the weld throat dimension.

Weld Group Inertia Calculations:

```
 Weld Group Inertia about the Circumferential Axis     Ilc      90.828 in**4
 Weld Group Centroid distance in the Long. Direction  Yll       5.542 in
 Dist. of Weld Group Centroid from Lug bottom       Yll_b       5.236 in
 Weld Group Inertia about the Longitudinal Axis        Ill       3.188 in**4
 Weld Group Centroid Distance in the Circ. Direction  Ylc       0.818 in
```

Note: The Impact Factor is applied to the Forces acting on the Lug.

Primary Shear Stress in the Welds due to Shear Loads [Ssll]:

```
  = sqrt( Fax^2 + Ft^2 + Fn^2 )/(( 2 * (wl + wb) ) * tw )
  = sqrt(0^2+0^2+10213^2)/((2*(10.472+1.811))*0.3062)
  = 1357.74 psi
```

Shear Stress in the Welds due to Bending Loads [Sblf]:

```
  = (Fn(h-Yll_b))Yll/Ilc + (Fax * off * Yll/Ilc) + (Ft * off * Ylc/Ill)
  = (10213(4.921 -5.2362 ))5.5424/90.828 +
    (0 * 5.9055 * 5.5424/90.828 ) +
    (0 * 5.9055 * 0.818/3.1883 )
  = -196.43 psi
```

Total Shear Stress for Combined Loads [St]:

```
  = Ssll + Sblf
  = 1357.7 + -196.43
  = 1161.31 psi
```

Allowable Shear Stress for Combined Loads [Sta]:

```
  = 0.4 * Yield * Occfac (AISC Shear Allowable)
  = 0.4 * 38000 * 1
  = 15200.00 psi
```

Shear Stress in Lug above Hole [Shs]:

```
  = sqrt( Pl^2 + Fax^2 ) / Sha
  = sqrt( 10213^2 + 0^2 )/5.9241
  = 1723.93 psi
```

Allowable Shear Stress in Lug above Hole [Sas]:

```
  = 0.4 * Yield * Occfac
  = 0.4 * 38000 * 1
  = 15200.00 psi
```

Pin Hole Bearing Width [Pbw]:

```
  = Lug Thickness + 2 * Collar Thickness
  = 1.0236 + 2 * 0
  = 1.024 in
```

Pin Hole Bearing Stress [Pbs]:

```
  = sqrt( Pl^2 + Faxial^2 ) / ( Pbw * dh )
  = sqrt( 10213^2 + 0^2 )/( 1.0236 * 2.0866 )
  = 4781.49 psi
```

Allowable Bearing Stress [Pba]:

```
  = min( 0.75 * Yield * Occfac, 0.9 * Yield ) AISC Bearing All.
  = min( 0.75 * 38000 * 1, 34200 )
  = 28500.00 psi
```

Bending Stress at the Base of the Lug [Fbs]:

```
  = Ft * off/(w * t^2/6) + Fax * off/(w^2 * t/6)
  = 0 * 5.9055/(9.8425 * 1.0236^2/6) +
    0 * 5.9055/(9.8425^2 * 1.0236/6)
  = 0.00 psi
```

Tensile Stress at the Base of the Lug [Fa]:

```
  = Fn / (w * t)
  = 10213/(9.8425 * 1.0236 )
  = 1013.67 psi
```

Total Combined Stress at the Base of the Lug:

```
  = Fbs + Fa
  = 0 + 1013.7
  = 1013.67 psi
```

Lug Allowable Stress for Bending and Tension:

```
  = min( 0.66 * Yield * Occfac, 0.75 * Yield )
  = min( 0.66 * 38000 * 1, 28500 )
  = 25080.00 psi
```

Required Shackle Pin Diameter [Spd]:

$= \text{sqrt}((2(Fn^2 + Fax^2)^{0.5}/(\text{ pi } * \text{ Sta})))$
$= \text{sqrt}(2(10213^2 + 0^2)^{0.5}/(\text{ pi } * 15200))$
$= 0.6540$ in

WRC 107/537 Stress Analysis for the Lifting Lug to Shell Junction in the new and Cold Condition (no corrosion applied).

Note : The ratio Beta1/Beta2 for rectangular attachments was outside the range of values in tables 7 & 8 and was set to be an acceptable (maximum or minimum) value.

Note: Attachment dimensions (C11P, C22P etc.) may be modified accounting for attachment welds where applicable.

Input Echo, WRC107/537 Item 1, Description: Lift Lug

```
 Diameter Basis for Vessel                  Vbasis      ID
 Cylindrical or Spherical Vessel            Cylsph      Cylindrical
 Internal Corrosion Allowance                  Cas      0.0000  in
 Vessel Diameter                                Dv      44.252  in
 Vessel Thickness                               Tv       0.630  in
```

Note: Lifting lug calculations are performed at ambient temperature conditions.

```
 Attachment Type                              Type      Rectangular
 Parameter C11                                 C11        1.81  in
 Parameter C22                                 C22        7.24  in

 Thickness of Reinforcing Pad                 Tpad       0.630  in
 Pad Parameter C11P                           C11p       8.976  in
 Pad Parameter C22P                           C22p      16.299  in

 Design Internal Pressure                       Dp       0.000  psig
 Include Pressure Thrust                                    No
```

External Forces and Moments in WRC 107/537 Convention:

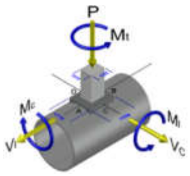
```
 Radial Load            (SUS)                    P    -10212.8  lbf
 Longitudinal Shear     (SUS)                   Vl         0.0  lbf
 Circumferential Shear  (SUS)                   Vc         0.0  lbf
 Circumferential Moment (SUS)                   Mc         0.0  ft-lb
 Longitudinal Moment    (SUS)                   Ml         0.0  ft-lb
 Torsional Moment       (SUS)                   Mt         0.0  ft-lb


 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
```

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".

```
PV Elite 24        Licensee: WCE
FileName : 18-X-262-LIFTING    -----------------------------
Lifting Lug Calcs: Right End          Step:   15   3:37pm   Sep 5,2022
```



WRC 107/537 has dimensional limitations that can be found in the bulletin's Foreword and which can also be inferred by review of the non-dimensional curve limits.

WRC 107 Stress Calculation for SUStained loads:

```
 Radial Load                                   P     -10212.8  lbf
 Circumferential Shear                        VC          0.0  lbf
 Longitudinal Shear                           VL          0.0  lbf
 Circumferential Moment                       MC          0.0  ft-lb
 Longitudinal Moment                          ML          0.0  ft-lb
 Torsional Moment                             MT          0.0  ft-lb

 Dimensionless Parameters used :   Gamma = 18.06
```

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

```
 -------------------------------------------------------------------
 Curves read for 1979              Beta  Figure    Value   Location
 -------------------------------------------------------------------
 N(PHI) / ( P/Rm )                0.118   4C        3.304   (A,B)
 N(PHI) / ( P/Rm )                0.118   3C        3.019   (C,D)
 M(PHI) / ( P )                   0.070   2C1       0.159   (A,B)
 M(PHI) / ( P )                   0.070   1C        0.193   (C,D)
 N(PHI) / ( MC/(Rm**2 * Beta) )   0.063   3A        0.206   (A,B,C,D)
 M(PHI) / ( MC/(Rm    * Beta) )   0.082   1A        0.103   (A,B,C,D)
 N(PHI) / ( ML/(Rm**2 * Beta) )   0.100   3B        1.398   (A,B,C,D)
 M(PHI) / ( ML/(Rm    * Beta) )   0.090   1B        0.056   (A,B,C,D)

 N(x)   / ( P/Rm )                0.096   3C        3.217   (A,B)
 N(x)   / ( P/Rm )                0.096   4C        3.417   (C,D)
 M(x)   / ( P )                   0.099   1C1       0.163   (A,B)
 M(x)   / ( P )                   0.099   2C        0.124   (C,D)
 N(x)   / ( MC/(Rm**2 * Beta) )   0.063   4A        0.263   (A,B,C,D)
 M(x)   / ( MC/(Rm    * Beta) )   0.115   2A        0.057   (A,B,C,D)
 N(x)   / ( ML/(Rm**2 * Beta) )   0.100   4B        0.367   (A,B,C,D)
 M(x)   / ( ML/(Rm    * Beta) )   0.124   2B        0.081   (A,B,C,D)
```

Stress Concentration Factors: Kn = 1.00,   Kb = 1.00

Stresses in the Vessel at the Attachment Junction (psi)

Type of Stress Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	1177	1177	1177	1177	1075	1075	1075	1075
Circ. Bend. P	6139	-6139	6139	-6139	7462	-7462	7462	-7462
Circ. Memb. MC	0	0	0	0	0	0	0	0
Circ. Bend. MC	0	0	0	0	0	0	0	0
Circ. Memb. ML	0	0	0	0	0	0	0	0
Circ. Bend. ML	0	0	0	0	0	0	0	0
Tot. Circ. Str.	7316	-4962	7316	-4962	8538	-6387	8538	-6387
Long. Memb. P	1145	1145	1145	1145	1217	1217	1217	1217
Long. Bend. P	6287	-6287	6287	-6287	4790	-4790	4790	-4790
Long. Memb. MC	0	0	0	0	0	0	0	0

Long. Bend. MC	0	0	0	0	0	0	0	0
Long. Memb. ML	0	0	0	0	0	0	0	0
Long. Bend. ML	0	0	0	0	0	0	0	0
Tot. Long. Str.	7433	-5141	7433	-5141	6007	-3573	6007	-3573
Shear VC	0	0	0	0	0	0	0	0
Shear VL	0	0	0	0	0	0	0	0
Shear MT	0	0	0	0	0	0	0	0
Tot. Shear	0	0	0	0	0	0	0	0
Str. Int.	7433	5141	7433	5141	8538	6387	8538	6387

Dimensionless Parameters used : Gamma = 35.62

Dimensionless Loads for Cylindrical Shells at Pad Edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.347	4C	3.667	(A,B)
N(PHI) / (P/Rm)	0.347	3C	1.691	(C,D)
M(PHI) / (P)	0.250	2C1	0.025	(A,B)
M(PHI) / (P)	0.250	1C !	0.061	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.244	3A	1.443	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.265	1A	0.072	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.298	3B	2.766	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.282	1B	0.016	(A,B,C,D)
N(x) / (P/Rm)	0.302	3C	2.037	(A,B)
N(x) / (P/Rm)	0.302	4C	4.089	(C,D)
M(x) / (P)	0.310	1C1	0.039	(A,B)
M(x) / (P)	0.310	2C !	0.032	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.244	4A	3.026	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.322	2A	0.028	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.298	4B	1.363	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.327	2B	0.020	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (psi)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	2649	2649	2649	2649	1221	1221	1221	1221
Circ. Bend. P	3844	-3844	3844	-3844	9479	-9479	9479	-9479
Circ. Memb. MC	0	0	0	0	0	0	0	0
Circ. Bend. MC	0	0	0	0	0	0	0	0
Circ. Memb. ML	0	0	0	0	0	0	0	0
Circ. Bend. ML	0	0	0	0	0	0	0	0
Tot. Circ. Str.	6493	-1195	6493	-1195	10700	-8257	10700	-8257
Long. Memb. P	1471	1471	1471	1471	2953	2953	2953	2953
Long. Bend. P	5971	-5971	5971	-5971	4887	-4887	4887	-4887
Long. Memb. MC	0	0	0	0	0	0	0	0
Long. Bend. MC	0	0	0	0	0	0	0	0
Long. Memb. ML	0	0	0	0	0	0	0	0

Long. Bend. ML	0	0	0	0	0	0	0	0
Tot. Long. Str.	7443	-4500	7443	-4500	7841	-1933	7841	-1933
Shear VC	0	0	0	0	0	0	0	0
Shear VL	0	0	0	0	0	0	0	0
Shear MT	0	0	0	0	0	0	0	0
Tot. Shear	0	0	0	0	0	0	0	0
Str. Int.	7443	4500	7443	4500	10700	8257	10700	8257

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction (psi)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	0	0	0	0	0	0	0	0
Circ. Pl (SUS)	1177	1177	1177	1177	1075	1075	1075	1075
Circ. Q (SUS)	6139	-6139	6139	-6139	7462	-7462	7462	-7462
Long. Pm (SUS)	0	0	0	0	0	0	0	0
Long. Pl (SUS)	1145	1145	1145	1145	1217	1217	1217	1217
Long. Q (SUS)	6287	-6287	6287	-6287	4790	-4790	4790	-4790
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	0	0	0	0	0	0	0	0
Shear Q (SUS)	0	0	0	0	0	0	0	0
Pm (SUS)	0	0	0	0	0	0	0	0
Pm+Pl (SUS)	1177	1177	1177	1177	1217	1217	1217	1217
Pm+Pl+Q (Total)	7433	5141	7433	5141	8538	6387	8538	6387

Vessel Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	0	20000	Passed
Pm+Pl (SUS)	1217	30000	Passed
Pm+Pl+Q (TOTAL)	8538	60000	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 (psi)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	0	0	0	0	0	0	0	0
Circ. Pl (SUS)	2649	2649	2649	2649	1221	1221	1221	1221
Circ. Q (SUS)	3844	-3844	3844	-3844	9479	-9479	9479	-9479

```
PV Elite 24        Licensee: WCE
FileName : 18-X-262-LIFTING    ------------------------------
Lifting Lug Calcs: Right End          Step:    15    3:37pm    Sep 5,2022
```

Long. Pm (SUS)	0	0	0	0	0	0	0	0
Long. Pl (SUS)	1471	1471	1471	1471	2953	2953	2953	2953
Long. Q (SUS)	5971	-5971	5971	-5971	4887	-4887	4887	-4887
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	0	0	0	0	0	0	0	0
Shear Q (SUS)	0	0	0	0	0	0	0	0
Pm (SUS)	0	0	0	0	0	0	0	0
Pm+Pl (SUS)	2649	2649	2649	2649	2953	2953	2953	2953
Pm+Pl+Q (Total)	7443	4500	7443	4500	10700	8257	10700	8257

Vessel Stress Summation Comparison (psi):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	0	20000	Passed
Pm+Pl (SUS)	2953	30000	Passed
Pm+Pl+Q (TOTAL)	10700	60000	Passed

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

```
PV Elite 24        Licensee: WCE
FileName : 18-X-262-04 empty    -----------------------------
Saddle Calcs: Operating Case:          Step:   20   9:54am  Jan 17,2023
```

ASME VIII Division 2 Horizontal Vessel Analysis, Left Saddle:

Horizontal Vessel Stress Calculations : Operating Case

Note:
Wear Pad Width (9.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

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

```
  = min( b + 1.56*sqrt( Rm * t ), 2a )
  = min( 7.4252 + 1.56*sqrt( 22.441 * 0.63 ), 2 * 20.354 )
  = 13.2908 in
```

Input and Calculated Values:

```
 Vessel Mean Radius                              Rm        22.44  in
 Shell Thickness used in this Case                t        0.630  in
 Stiffened Vessel Length per 4.15.6               L       217.75  in
 Distance from Saddle to Vessel tangent      a1 or a       20.35  in

 Saddle Width                                b1 or b        7.43  in
 Saddle Bearing Angle                 delta or theta      120.00  degrees

 Shell Allowable Stress used in Calculation         20000.00  psi
 Head Allowable Stress used in Calculation          20000.00  psi
 Circumferential Efficiency in Plane of Saddle          1.00
 Circumferential Efficiency at Mid-Span                 1.00

 Distance from Saddle Base to Centerline         B     40.00  in
 Coefficient of Friction                        mu      0.40

 Saddle Force Q, Operating Case                     52872.53  lbf

 Pressure used in Analysis                       P   150.000  psig

 Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                             psi |          psi |
 ---------------------------------------------------------------
 Long. Stress at Top    of Midspan        802.22 |     20000.00 |
 Long. Stress at Bottom of Midspan       4540.87 |     20000.00 |
 Long. Stress at Top    of Saddles       3042.84 |     20000.00 |
 Long. Stress at Bottom of Saddles       2465.75 |     20000.00 |
 ---------------------------------------------------------------
 Tangential Shear in Shell               3559.66 |     16000.00 |
 Circ. Stress at Horn of Saddle         10666.26 |     25000.00 |
 Circ. Compressive Stress in Shell        480.06 |     20000.00 |
 ---------------------------------------------------------------
```

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( 1224.1/2 + 0 ) * 40/40
  = 1836.1 lbf
```

Saddle Reaction Force due to Wind Fl [Fwl]:

```
  = max( Fl, Sum of X Forces) * B / Ls
  = max( 462.44, 0 ) * 40/139
  = 133.1 lbf
```

Saddle Reaction Force due to Earthquake Fl [Fsl]:

```
  = max( Fl, Sum of X Forces ) * B / Ls
  = max( 18752, 0 ) * 40/139
```

```
  = 5396.2 lbf
```

Saddle Reaction Force due to Earthquake Ft [Fst]:

```
  = Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3( 18752/2 + 0 ) * 40/40
  = 28127.5 lbf
```

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

```
  = Saddle Load + max( Fwl, Fwt, Fsl, Fst )
  = 24745 + max( 133.08, 1836.1, 5396.2, 28127 )
  = 52872.5 lbf
```

Longitudinal Wind Force [Fl]:

$$= WindScalar * WindPress(Platform Area + (pi/4(OD * WindDiaMult)^2))$$
$$= 0.6 * 31.992(0 + pi/4(4.0427 * 1.37)^2)$$
$$= 462.443 lbf$$

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	53361.06	lbf
Transverse Shear Load Saddle	9375.83	lbf
Longitudinal Shear Load Saddle	18751.65	lbf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:

```
  = Baseplate Length
  = 40.000 in
```

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 = 0.0455	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	

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

Moment per Equation 4.15.1 [M1]:

$$= -Q*a [1 - (1- a/L + (Rm^2-h2^2)/(2a*L))/(1+(4h2)/3L)]$$
$$= -52873*20.354[1-(1-20.354/217.75+(22.441^2-0^2)/(2*20.354*217.75))/(1+(4*0)/(3*217.75))]$$
$$= -3287.8 ft-lb$$

Moment per Equation 4.15.4 [M2]:

$$= Q*L/4(1+2(Rm^2-h2^2)/(L^2))/(1+(4h2)/(3L))-4a/L$$
$$= 52873*217.75/4(1+2(22.441^2-0^2)/(217.75^2))/(1+(4*0)/(3*217.75))-4*20.354/217.75$$
$$= 155266.7 ft-lb$$

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:

$$= P * Rm/(2t) - M2/(pi*Rm^2t)$$
$$= 150 * 22.441/(2*0.63) - 1863200/(pi*22.441^2*0.63)$$
$$= 802.22 psi$$

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:

$$= P * Rm/(2t) + M2/(pi * Rm^2 * t)$$
$$= 150 * 22.441/(2 * 0.63) + 1863200/(pi * 22.441^2 * 0.63)$$
$$= 4540.87 psi$$

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma✱3]:

$$= P * Rm/(2t) - M1/(K1*pi*Rm^2t)$$
$$= 150*22.441/(2*0.63)--39454/(0.1066*pi*22.441^2*0.63)$$
$$= 3042.84 psi$$

```
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```

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma✱4]:
```
  = P * Rm/(2t) + M1/(K1✱ * pi * Rm² * t)
  = 150*22.441/(2*0.63)+-39454/(0.1923*pi*22.441²*0.63)
  = 2465.75 psi
```

Maximum Shear Force in the Saddle (4.15.3) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 52873( 217.75 - 2 * 20.354 )/(217.75 +( 4 * 0/3))
  = 42988.0 lbf
```

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 42988/( 22.441 * 0.63 )
  = 3559.66 psi
```

Decay Length (4.15.20) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 22.441 * 0.63 )
  = 2.933 in
```

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:
```
  = -K5 * Q * k / ( t( b + X1 + X2 ) )
  = -0.7603 * 52873 * 0.1/( 0.63( 7.4252 + 2.9328 + 2.9328 ) )
  = -480.06 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:
```
  = -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -52873/(4 * 0.63(7.4252 + 2.9328 + 2.9328 )) -
     3 * 0.04548 * 52873/(2*0.63²)
  = -10666.26 psi
```

Effective reinforcing plate width (4.15.24) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 7.4252 + 1.56 * sqrt( 22.441 * 0.63 ), 2 * 20.354 )
  = 13.29 in
```

Distance between Saddle Supports [Ls]:
```
  = 139.0 in
```

Free Un-Restrained Thermal Expansion between the Saddles [Exp]:
```
  = Alpha * Ls( Design Temperature - Ambient Temperature )
  = 0.69600E-05 * 139( 330 - 70 )
  = 0.252 in
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	40.0000	in
Baseplate Thickness	Bpthk	1.2598	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	0.5510	in
Web Thickness	Webtk	0.5510	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	33270.0	psi
Height of Web at Center	Hw,c	17.0	in
Friction Coefficient	mu	0.400	

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

Inertia of Shell [ShellInertia]:
```
  = (( 1.56 * sqrt( R * t ) + WearPlateWidth )t³ )/12
  = (( 1.56 * sqrt( 22.126 * 0.63 ) + 9 )0.63³ )/12
  = 0.309 in**4
```

Resolved Inertia for the Shell [I,shell]:

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$= ShellInertia + AShell(C1 - Y)^2$
$= 0.3089 + 9.3393(8.0278 - 0.315)^2$
= 555.882 in**4

	B in	D in	Y in	A in^2	AY in^3	$I + AD^2$ in**4
Shell	14.8243	0.6300	0.3150	9.3393	2.9419	555.8818
Wearplate	9.0000	0.6300	0.9450	5.6700	5.3582	284.6299
Web	0.5510	15.3542	8.9371	8.4601	75.6091	173.2018
BasePlate	9.0000	1.2598	17.2441	11.3386	195.5232	964.5957
Totals	...	...	...	34.8080	279.4323	1978.3096

Distance to Centroid [C1]:
= AY / A
= 279.43/34.808
= 8.028 in

Angle [beta]:
= 180 - Saddle Angle/2
= 180 - 120/2
= 120.0

Saddle Splitting Coefficient [K1]:
$= (1 + cos(beta) - 0.5*sin(beta)^2)/(pi - beta + sin(beta)cos(beta))$
$= (1 + cos(120) - 0.5*sin(120)^2)/(pi - 2.0944 + sin(120)cos(120))$
= 0.2035

Saddle Splitting Force [Fh]:
= K1 * Q
= 0.2035 * 52873
= 10760.7070 lbf

Tension Stress, St = (Fh/As) = 422.5070 psi
Allowed Stress, Sa = 0.6 * Yield Str = 19962.0000 psi

Saddle Splitting Dimension [d]:
= B - R * sin(theta/2)/(theta/2 in radians)
= 40 - 22.126 * sin(120/2)/1.0472
= 21.702 in

Bending Moment, M = Fh * d = 19460.7012 ft-lb

Bending Stress, Sb = (M * C1 / I) = 947.6383 psi
Allowed Stress, Sa = 2/3 * Yield Str = 22180.0000 psi

Minimum Thickness of Baseplate per Moss:
= sqrt(3(Q + Saddle_Wt)BasePlateWidth / (2 * BasePlateLength * AllStress))
= sqrt(3(52873 + 488.53)9/(2 * 40 * 22180))
= 0.901 in

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 - 120/2)(22.126 + 0.63 + 0.63)
= 40.506 in

Distance between Ribs [e]:
= Web Length / (Nribs - 1)
= 40.506/(3 - 1)
= 20.253 in

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 20.253 * 9/2
  = 91.138 in^2
```

Bearing Pressure [Bp]:

```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 52873/( 40 * 9 )
  = 146.868 lbf/in^2
```

Axial Load [P]:

```
  = Ap * Bp
  = 91.138 * 146.87
  = 13385.247 lbf
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 3.7877 + 5.5797
  = 9.367 in^2
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 13385/9.3673
  = 1428.926 psi
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	33.4385
Web	10.1264	0.5510	0.2755	5.5797	1.5372	12.7153
Totals	...	...	...	9.3673	16.6429	46.1538

Rib dimension [D]:

```
  = Saddle Width - Web Thickness
  = 7.4252 - 0.551
  = 6.874 in
```

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 16.643/9.3673
  = 1.777 in
```

Distance to Centroid [C1]:

```
  = max( ytot, Saddle Width - ytot )
  = max( 1.7767, 7.4252 - 1.7767 )
  = 5.649 in
```

Radius of Gyration [r]:

```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 46.154/9.3673 )
  = 2.220 in
```

Length of Outer Rib, step 1, [Lw]:

```
  = 2 * sin( saddle bearing angle / 2 )( radius + shlthk + wpdthk )
  = 2 * sin( 120/2 )( 22.126 + 0.63 + 0.63 )
  = 40.506 in
```

Length of Outer Rib, step 2, [Bd]:

```
  = Baseplate length - clearance
  = 40 - 2
  = 38.000 in
```

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Length of Outer Rib, step 3, [Dd]:
```
  = ( Lw - Bd )/2
  = ( 40.506 - 38 )/2
  = 1.253 in
```

Length of Outer Rib [L]:
  $= sqrt(Rl^2 + Dd^2)$
  $= sqrt(27.076^2 + 1.2529^2)$
  = 27.076 in

Intermediate Term [Cc]:
  $= sqrt(2 * pi^2 * Elastic Modulus / Yield Stress)$
  $= sqrt(2 * pi^2 * 28999900/33270)$
  = 131.171

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 27.076/2.2197
  = 12.198
```

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 18752/( 2 * 40 ) * 20.253 * 27.076/2
  = 5355.645 ft-lb
```

Compressive Allowable, KL/r < Cc(12.198 < 131.17) per AISC E2-1 [Sca]:
  $= (1-(Klr)^2/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)$
  $= (1-(12.198)^2/(2 * 131.17^2))33270/$
  $(5/3+3*(12.198)/(8* 131.17)-(12.198^3)/(8*131.17^3)$
  = 19469 psi

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 1428.9/19469 +( 64268 * 5.6485/46.154 )/22180
  = 0.428
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	44.0158
Web	20.2529	0.5510	0.2755	11.1593	3.0744	10.1595
Totals	...	...	...	14.9470	18.1801	54.1753

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 18.18/14.947
  = 1.216 in
```

Distance to Centroid [C1]:
```
  = max( ytot, abs( Saddle Width - ytot ) )
  = max( 1.2163, abs( 7.4252 - 1.2163 ) )
  = 6.209 in
```

Length of Inner Rib [L]:
```
  = Saddle Height - Outside Radius - Bpthk
  = 40 - cos( 23.386/2 )( 1.2598 + 0 + 0 ) - 0
  = 15.354 in
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 54.175/14.947 )
  = 1.904 in
```

```
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```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 15.354/1.9038
  = 8.065
```

Unit Force [Force,u]:
```
  = Fl / ( 2 * Baseplate Length )
  = 18752/( 2 * 40 )
  = 234.396 lbf/in
```

Moment at base of inner Rib [Mbase,c]:
```
  = Unit Force * e * L
  = 234.4 * 20.253 * 15.354
  = 72889.062 in.lbs
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
  = Bending Moment / Section Modulus
  = 72889/8.7254
  = 8353.644 psi
```

Compressive Allowable, KL/r < Cc(8.065 < 131.17) per AISC E2-1 [Sca]:

$$= (1-(Klr)^2/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)$$
$$= (1-(8.065)^2/(2 * 131.17^2))33270/$$
$$(5/3+3*(8.065)/(8* 131.17)-(8.065^3)/(8*131.17^3)$$
$$= 19653 \text{ psi}$$

AISC Unity Check of Inside Ribs (must be <= 1)
```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 1753.9/19653 +( 72889 * 6.2089/54.175 )/22180
  = 0.466
```

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

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-36	
Bolt Allowable Stress	Stba	21754.90	psi
Bolt Corrosion Allowance	Bca	0.0630	in
Distance from Bolts to Edge	Edgedis	4.0000	in
Nominal Bolt Diameter	Bnd	1.7500	in
Thread Series	Series	TEMA	
BasePlate Allowable Stress	S	20000.00	psi
Area Available in a Single Bolt	BltArea	1.6782	in^2
Saddle Load QO (Weight)	QO	25233.6	lbf
Saddle Load QL (Wind/Seismic contribution)	QL	5396.2	lbf
Maximum Transverse Force	Ft	9375.8	lbf
Maximum Longitudinal Force	Fl	18751.7	lbf
Saddle Bolted to Steel Foundation		No	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:
```
  = Fl / ( Bolt Area * Number of Bolts )
  = 18752/( 1.6782 * 2 )
  = 5586.8 psi.  Must be less than 13052.9 psi.
```

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:
```
  = Ft / ( Bolt Area * Number of Bolts )
  = 9375.8/( 1.6782 * 2 )
  = 2793.4 psi.  Must be less than 13052.9 psi.
```

<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)
```

```
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```

Bolt Area due to Shear Load [Bltarears]:

```
  = Fl / ( BoltShearAllowable * Nbolts )
  = 18752/(13053 * 2 )
  = 0.7183 in^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
  = B * Ft + Sum of X Moments
  = 3.3333 * 9375.8 + 0
  = 31252.75 ft-lb
```

Eccentricity (e):

```
  = Rmom / QO
  = 375033/25234
  = 14.86 in > Bplen/6 --> Uplift in Transverse direction

 f = Bplen / 2 - Edgedis
   = 40/2 - 4
   = 16.00 in
```

Modular Ratio Of Steel/Concrete (n1):

```
  = ES / EC
  = 29500000/3122018
  = 9.45

 K1 = 3 (e - 0.5 * Bplen)
    = 3(14.862 - 0.5*40 )
    = -15.41 in

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 9.449 * 1.6782/9 *(16 + 14.862 )
    = 326.27 in ²

 K3 = -K2 * (0.5 * Bplen + f)
    = -326.27 *(0.5 * 40 + 16 )
    = -11745.63 in ³
```

Iteratively Solving for the Effective Bearing Length:

```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + -15.413 * Y² + 326.27 * Y + -11746 = 0
 Y  = 23.19 in

 Num = (Bplen / 2 - Y / 3 - e)
     = (40/2 - 23.188/3 - 14.862 )
     = -2.59

 Denom = (Bplen / 2 - Y / 3 + f)
       = (40/2 - 23.188/3 + 16 )
       = 28.27
```

Total Bolt Tension Force [Tforce]:

```
  = - QO * Num / Denom
  = - 25234 * -2.5916/28.271
  = 2313.21 lbf
```

Bolt Area Required due to Transverse Load [Bltareart]:

```
  = Tforce / (Stba * Nbt)
  = 2313.2/( 21755 * 1 )
  = 0.1063 in^2
```

Required Area of a Single Bolt [Bltarear]:

```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0, 0.7183, 0.1063 ]
  = 0.7183 in^2
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)
```
  = 2(QO + Tforce) / (Y * Bpwid)
  = 2(25234 + 2313.2 )/(23.188 * 9 )
  = 264.00 psig
```

Distance from Baseplate Edge to the Web [ADIST]:
```
  = (Bplen - Weblngth) / 2
  = (40 - 38 )/2
  = 1.0000 in
```

Overturning Moment due To Bolt Tension [Mt]:
```
  = Tforce * Adist
  = 2313.2 * 1
  = 192.77 ft-lb
```

Equivalent Bearing Pressure (f1):
```
  = fc * (Y - Adist) / Y
  = 264 *(23.188 - 1 )/23.188
  = 252.61 psig
```

Overturning Moment due to Bearing Pressure [Mc]:
```
  = (Adist² * Bpwid / 6) * (f1 + 2 * fc)
  = (0.08333² * 0.75/6) *(36376 + 2 * 38016 )
  = 97.58 ft-lb
```

Baseplate Required Thickness [Treq]:
```
  = sqrt(6 * max(Mt,Mc) / (Bpwid * Sba))
  = sqrt(6 * max(2313.2,1170.9 )/(9 * 30000 ))
  = 0.2267 in
```

MDMT Calculations for: Fixed Saddle, Saddle to Wearplate Junction, Curve: D

Govrn. thk, tg = 0.63, tr = 0.3125, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.4961, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve D             -50 F
```

ASME VIII Division 2 Horizontal Vessel Analysis, Right Saddle:

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

Note:
Wear Pad Width (9.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

Minimum Wear Plate Width to be considered in analysis [b1]:
```
  = min( b + 1.56*sqrt( Rm * t ), 2a )
  = min( 7.4252 + 1.56*sqrt( 22.441 * 0.63 ), 2 * 58.638 )
  = 13.2908 in
```

Input and Calculated Values:

Vessel Mean Radius	Rm	22.44	in
Shell Thickness used in this Case	t	0.630	in
Stiffened Vessel Length per 4.15.6	L	217.75	in

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```
 Distance from Saddle to Vessel tangent   a1 or a       58.64  in

 Saddle Width                            b1 or b        7.43  in
 Saddle Bearing Angle             delta or theta      120.00  degrees

 Inside Depth of Head                    Hi or h2       11.06  in

 Shell Allowable Stress used in Calculation         20000.00  psi
 Head Allowable Stress used in Calculation          20000.00  psi
 Circumferential Efficiency in Plane of Saddle          1.00
 Circumferential Efficiency at Mid-Span                 1.00

 Distance from Saddle Base to Centerline        B      40.00  in
 Coefficient of Friction                       mu       0.00

 Saddle Force Q, Operating Case                     36951.01  lbf

 Pressure used in Analysis                      P     150.000  psig

 Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                             psi |          psi |
 ---------------------------------------------------------------
 Long. Stress at Top    of Midspan       2924.94 |     20000.00 |
 Long. Stress at Bottom of Midspan       2418.16 |     20000.00 |
 Long. Stress at Top    of Saddles       8822.81 |     20000.00 |
 Long. Stress at Bottom of Saddles       -737.87 |    -29943.00 |
 Long. Stress at Bottom of Saddles        737.87 |     20000.00 |
 ---------------------------------------------------------------
 Tangential Shear in Shell               1322.24 |     16000.00 |
 Circ. Stress at Horn of Saddle          8483.92 |     25000.00 |
 Circ. Compressive Stress in Shell        335.50 |     20000.00 |
 ---------------------------------------------------------------
```

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( 1224.1/2 + 0 ) * 40/40
  = 1836.1 lbf
```

Saddle Reaction Force due to Wind Fl [Fwl]:
```
  = max( Fl, Sum of X Forces) * B / Ls
  = max( 462.44, 0 ) * 40/139
  = 133.1 lbf
```

Saddle Reaction Force due to Earthquake Fl [Fsl]:
```
  = max( Fl, Sum of X Forces ) * B / Ls
  = max( 18752, 0 ) * 40/139
  = 5396.2 lbf
```

Saddle Reaction Force due to Earthquake Ft [Fst]:
```
  = Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3( 18752/2 + 0 ) * 40/40
  = 28127.5 lbf
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
  = Saddle Load + max( Fwl, Fwt, Fsl, Fst )
  = 8823.5 + max( 133.08, 1836.1, 5396.2, 28127 )
  = 36951.0 lbf
```

Longitudinal Wind Force [Fl]:

$= WindScalar * WindPress(Platform Area + (pi/4(OD * WindDiaMult)^2))$

$= 0.6 * 31.992(0 + pi/4(4.0427 * 1.37)^2)$

$= 462.443$ lbf

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	37439.54	lbf
Transverse Shear Load Saddle	9375.83	lbf
Longitudinal Shear Load Saddle	18751.65	lbf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:
```
  = Baseplate Length
  = 40.000 in
```

The Computed K values from Table 4.15.1:

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

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

Moment per Equation 4.15.1 [M1]:
```
  = -Q*a [1 - (1- a/L + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -36951*58.638[1-(1-58.638/217.75+(22.441²-11.063²)/
    (2*58.638*217.75))/(1+(4*11.063)/(3*217.75))]
  = -54470.3 ft-lb
```

Moment per Equation 4.15.4 [M2]:
```
  = Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 36951*217.75/4(1+2(22.441²-11.063²)/(217.75²))/(1+(4*11.063)/
    (3*217.75))-4*58.638/217.75
  = -21046.7 ft-lb
```

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:
```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 150 * 22.441/(2*0.63 ) - -252560/(pi*22.441²*0.63 )
  = 2924.94 psi
```

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:
```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 150 * 22.441/(2 * 0.63 ) + -252560/(pi * 22.441² * 0.63 )
  = 2418.16 psi
```

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma✱3]:
```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 150*22.441/(2*0.63)--653644/(0.1066*pi*22.441²*0.63)
  = 8822.81 psi
```

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma✱4]:
```
  = P * Rm/(2t) + M1/(K1✱ * pi * Rm² * t)
  = 150*22.441/(2*0.63)+-653644/(0.1923*pi*22.441²*0.63)
  = -737.87 psi
```

Maximum Shear Force in the Saddle (4.15.3) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 36951( 217.75 - 2 * 58.638 )/(217.75 +( 4 * 11.063/3))
  = 15968.0 lbf
```

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 15968/( 22.441 * 0.63 )
  = 1322.24 psi
```

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Decay Length (4.15.20) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 22.441 * 0.63 )
  = 2.933 in
```

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:
```
  = -K5 * Q * k / ( t( b + X1 + X2 ) )
  = -0.7603 * 36951 * 0.1/( 0.63( 7.4252 + 2.9328 + 2.9328 ) )
  = -335.50 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:
```
  = -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -36951/(4 * 0.63(7.4252 + 2.9328 + 2.9328 )) -
     3 * 0.05285 * 36951/(2*0.63²)
  = -8483.92 psi
```

Effective reinforcing plate width (4.15.24) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 7.4252 + 1.56 * sqrt( 22.441 * 0.63 ), 2 * 58.638 )
  = 13.29 in
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	40.0000	in
Baseplate Thickness	Bpthk	1.2598	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	0.5510	in
Web Thickness	Webtk	0.5510	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	38000.0	psi
Height of Web at Center	Hw,c	17.0	in
Friction Coefficient	mu	0.000	

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

Inertia of Shell [ShellInertia]:
```
  = (( 1.56 * sqrt( R * t ) + WearPlateWidth )t³ )/12
  = (( 1.56 * sqrt( 22.126 * 0.63 ) + 9 )0.63³ )/12
  = 0.309 in**4
```

Resolved Inertia for the Shell [I,shell]:
```
  = ShellInertia + AShell( C1 - Y )²
  = 0.3089 + 9.3393( 8.0278 - 0.315 )²
  = 555.882 in**4
```

	B in	D in	Y in	A in^2	AY in^3	I + AD^2 in**4
Shell	14.8243	0.6300	0.3150	9.3393	2.9419	555.8818
Wearplate	9.0000	0.6300	0.9450	5.6700	5.3582	284.6299
Web	0.5510	15.3542	8.9371	8.4601	75.6091	173.2018
BasePlate	9.0000	1.2598	17.2441	11.3386	195.5232	964.5957
Totals	...	...	...	34.8080	279.4323	1978.3096

Distance to Centroid [C1]:
```
  = AY / A
  = 279.43/34.808
  = 8.028 in
```

Angle [beta]:
```
  = 180 - Saddle Angle/2
  = 180 - 120/2
  = 120.0
```

```
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```

Saddle Splitting Coefficient [K1]:

```
  = ( 1 + cos(beta) - 0.5*sin(beta)² )/(pi - beta + sin(beta)cos(beta) )
  = ( 1 + cos(120 ) - 0.5*sin(120 )² )/(pi - 2.0944 + sin(120 )cos(120 ) )
  = 0.2035
```

Saddle Splitting Force [Fh]:

```
  = K1 * Q
  = 0.2035 * 36951
  = 7520.3315 lbf

 Tension Stress, St = ( Fh/As )       =        295.2773  psi
 Allowed Stress, Sa = 0.6 * Yield Str =      22800.0000  psi
```

Saddle Splitting Dimension [d]:

```
  = B - R * sin(theta/2)/(theta/2 in radians)
  = 40 - 22.126 * sin(120/2)/1.0472
  = 21.702 in

 Bending Moment, M  = Fh * d          =      13600.4932  ft-lb

 Bending Stress, Sb = ( M * C1 / I  ) =        662.2756  psi
 Allowed Stress, Sa = 2/3 * Yield Str =      25333.3340  psi
```

Minimum Thickness of Baseplate per Moss:

```
  = sqrt( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))
  = sqrt( 3(36951 + 488.53 )9/( 2 * 40 * 25333 ))
  = 0.706 in
```

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 - 120/2 )( 22.126 + 0.63 + 0.63 )
  = 40.506 in
```

Distance between Ribs [e]:

```
  = Web Length / ( Nribs - 1 )
  = 40.506/( 3 - 1 )
  = 20.253 in
```

Baseplate Pressure Area [Ap]:

```
  = e * Bpwid / 2
  = 20.253 * 9/2
  = 91.138 in^2
```

Bearing Pressure [Bp]:

```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 36951/( 40 * 9 )
  = 102.642 lbf/in^2
```

Axial Load [P]:

```
  = Ap * Bp
  = 91.138 * 102.64
  = 9354.542 lbf
```

Area of the Rib and Web [Ar]:

```
  = Rib Area + Web Area
  = 3.7877 + 5.5797
  = 9.367 in^2
```

Compressive Stress [Sc]:

```
  = P/Ar
  = 9354.5/9.3673
```

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= 998.633 psi

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	33.4385
Web	10.1264	0.5510	0.2755	5.5797	1.5372	12.7153
Totals	...	...	...	9.3673	16.6429	46.1538

Rib dimension [D]:
= Saddle Width - Web Thickness
= 7.4252 - 0.551
= 6.874 in

Distance to Centroid from Datum [ytot]:
= AY / A
= 16.643/9.3673
= 1.777 in

Distance to Centroid [C1]:
= max(ytot, Saddle Width - ytot)
= max(1.7767, 7.4252 - 1.7767)
= 5.649 in

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(46.154/9.3673)
= 2.220 in

Length of Outer Rib, step 1, [Lw]:
= 2 * sin(saddle bearing angle / 2)(radius + shlthk + wpdthk)
= 2 * sin(120/2)(22.126 + 0.63 + 0.63)
= 40.506 in

Length of Outer Rib, step 2, [Bd]:
= Baseplate length - clearance
= 40 - 2
= 38.000 in

Length of Outer Rib, step 3, [Dd]:
= (Lw - Bd)/2
= (40.506 - 38)/2
= 1.253 in

Length of Outer Rib [L]:
= sqrt(Rl^2 + Dd^2)
= sqrt(27.076^2 + 1.2529^2)
= 27.076 in

Intermediate Term [Cc]:
= sqrt(2 * pi^2 * Elastic Modulus / Yield Stress)
= sqrt(2 * pi^2 * 28999900/38000)
= 122.736

Slenderness ratio [KL/r]:
= KL/r
= 1 * 27.076/2.2197
= 12.198

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

```
  = 18752/( 2 * 40 ) * 20.253 * 27.076/2
  = 5355.645 ft-lb
```

Compressive Allowable, KL/r < Cc(12.198 < 122.74) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.198 )²/(2 * 122.74² ))38000/
    ( 5/3+3*(12.198 )/(8* 122.74 )-( 12.198³)/(8*122.74³)
  = 22193 psi
```

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

```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 998.63/22193 +( 64268 * 5.6485/46.154 )/25333
  = 0.355
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	44.0158
Web	20.2529	0.5510	0.2755	11.1593	3.0744	10.1595
Totals	...	...	...	14.9470	18.1801	54.1753

Distance to Centroid from Datum [ytot]:

```
  = AY / A
  = 18.18/14.947
  = 1.216 in
```

Distance to Centroid [C1]:

```
  = max( ytot, abs( Saddle Width - ytot ) )
  = max( 1.2163, abs( 7.4252 - 1.2163 ) )
  = 6.209 in
```

Length of Inner Rib [L]:

```
  = Saddle Height - Outside Radius - Bpthk
  = 40 - cos( 23.386/2 )( 1.2598 + 0 + 0 ) - 0
  = 15.354 in
```

Radius of Gyration [r]:

```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 54.175/14.947 )
  = 1.904 in
```

Slenderness ratio [KL/r]:

```
  = KL/r
  = 1 * 15.354/1.9038
  = 8.065
```

Unit Force [Force,u]:

```
  = Fl / ( 2 * Baseplate Length )
  = 18752/( 2 * 40 )
  = 234.396 lbf/in
```

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

```
  = Unit Force * e * L
  = 234.4 * 20.253 * 15.354
  = 72889.062 in.lbs
```

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

```
  = Bending Moment / Section Modulus
  = 72889/8.7254
  = 8353.644 psi
```

Compressive Allowable, KL/r < Cc(8.065 < 122.74) per AISC E2-1 [Sca]:

```
= ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= ( 1-( 8.065 )²/(2 * 122.74² ))38000/
  ( 5/3+3*(8.065 )/(8* 122.74 )-( 8.065³)/(8*122.74³)
= 22420 psi
```

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

```
= Sc/Sca + ( Mbase,c * C1/I )/Sba
= 1225.7/22420 +( 72889 * 6.2089/54.175 )/25333
= 0.384
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-36	
Bolt Allowable Stress	Stba	21754.90	psi
Bolt Corrosion Allowance	Bca	0.0630	in
Distance from Bolts to Edge	Edgedis	4.0000	in
Nominal Bolt Diameter	Bnd	1.7500	in
Thread Series	Series	TEMA	
BasePlate Allowable Stress	S	20000.00	psi
Area Available in a Single Bolt	BltArea	1.6782	in^2
Saddle Load QO (Weight)	QO	9312.1	lbf
Saddle Load QL (Wind/Seismic contribution)	QL	5396.2	lbf
Maximum Transverse Force	Ft	9375.8	lbf
Maximum Longitudinal Force	Fl	18751.7	lbf
Saddle Bolted to Steel Foundation		No	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:

```
= Fl / ( Bolt Area * Number of Bolts )
= 18752/( 1.6782 * 2 )
= 5586.8 psi.  Must be less than 13052.9 psi.
```

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:

```
= Ft / ( Bolt Area * Number of Bolts )
= 9375.8/( 1.6782 * 2 )
= 2793.4 psi.  Must be less than 13052.9 psi.
```

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 / ( BoltShearAllowable * Nbolts )
= 18752/(13053 * 2 )
= 0.7183 in^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
= B * Ft + Sum of X Moments
= 3.3333 * 9375.8 + 0
= 31252.75 ft-lb
```

Eccentricity (e):

```
= Rmom / QO
= 375033/9312.1
= 40.27 in > Bplen/6 --> Uplift in Transverse direction
```

```
f = Bplen / 2 - Edgedis
  = 40/2 - 4
  = 16.00 in
```

```
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```

Modular Ratio Of Steel/Concrete (n1):
```
  = ES / EC
  = 29500000/3122018
  = 9.45

 K1 = 3 (e - 0.5 * Bplen)
    = 3(40.274 - 0.5*40 )
    = 60.82 in

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 9.449 * 1.6782/9 *(16 + 40.274 )
    = 594.91 in ²

 K3 = -K2 * (0.5 * Bplen + f)
    = -594.91 *(0.5 * 40 + 16 )
    = -21416.72 in ³
```

Iteratively Solving for the Effective Bearing Length:
```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + 60.822 * Y² + 594.91 * Y + -21417 = 0
 Y  = 13.44 in

 Num = (Bplen / 2 - Y / 3 - e)
     = (40/2 - 13.443/3 - 40.274 )
     = -24.75

 Denom = (Bplen / 2 - Y / 3 + f)
       = (40/2 - 13.443/3 + 16 )
       = 31.52
```

Total Bolt Tension Force [Tforce]:
```
  = - QO * Num / Denom
  = - 9312.1 * -24.755/31.519
  = 7313.57 lbf
```

Bolt Area Required due to Transverse Load [Bltareart]:
```
  = Tforce / (Stba * Nbt)
  = 7313.6/( 21755 * 1 )
  = 0.3362 in^2
```

Required Area of a Single Bolt [Bltarear]:
```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0, 0.7183, 0.3362 ]
  = 0.7183 in^2
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)
```
  = 2(QO + Tforce) / (Y * Bpwid)
  = 2(9312.1 + 7313.6 )/(13.443 * 9 )
  = 274.84 psig
```

Distance from Baseplate Edge to the Web [ADIST]:
```
  = (Bplen - Weblngth) / 2
  = (40 - 38 )/2
  = 1.0000 in
```

Overturning Moment due To Bolt Tension [Mt]:
```
  = Tforce * Adist
  = 7313.6 * 1
  = 609.46 ft-lb
```

```
PV Elite 24        Licensee: WCE
FileName : 18-X-262-04 empty     -----------------------------
Saddle Calcs: Operating Case:          Step:   20   9:54am  Jan 17,2023
```

Equivalent Bearing Pressure (f1):
```
  = fc * (Y - Adist) / Y
  = 274.84 *(13.443 - 1 )/13.443
  = 254.40 psig
```

Overturning Moment due to Bearing Pressure [Mc]:
```
  = (Adist² * Bpwid / 6) * (f1 + 2 * fc)
  = (0.08333² * 0.75/6) *(36633 + 2 * 39577 )
  = 100.51 ft-lb
```

Baseplate Required Thickness [Treq]:
```
  = sqrt(6 * max(Mt,Mc) / (Bpwid * Sba))
  = sqrt(6 * max(7313.6,1206.1 )/(9 * 30000 ))
  = 0.4031 in
```

MDMT Calculations for: Fixed Saddle, Saddle to Wearplate Junction, Curve: D

Govrn. thk, tg = 0.63, tr = 0.3125, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.4961, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve D             -50 F
```

```
PV Elite 24        Licensee: WCE
FileName : 18-X-262-04 uncorroded    ------------------------
Saddle Calcs: Operating Case:         Step:   20   1:00pm  Jan 17,2023
```

ASME VIII Division 2 Horizontal Vessel Analysis, Left Saddle:

Horizontal Vessel Stress Calculations : Operating Case

Note:
Wear Pad Width (9.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

Minimum Wear Plate Width to be considered in analysis [b1]:
```
  = min( b + 1.56*sqrt( Rm * t ), 2a )
  = min( 7.4252 + 1.56*sqrt( 22.441 * 0.63 ), 2 * 20.354 )
  = 13.2908 in
```

Input and Calculated Values:

```
 Vessel Mean Radius                              Rm        22.44  in
 Shell Thickness used in this Case                t        0.630  in
 Stiffened Vessel Length per 4.15.6               L       217.75  in
 Distance from Saddle to Vessel tangent     a1 or a        20.35  in

 Saddle Width                               b1 or b         7.43  in
 Saddle Bearing Angle                delta or theta       120.00  degrees

 Shell Allowable Stress used in Calculation            20000.00  psi
 Head Allowable Stress used in Calculation             20000.00  psi
 Circumferential Efficiency in Plane of Saddle             1.00
 Circumferential Efficiency at Mid-Span                    1.00

 Distance from Saddle Base to Centerline          B        40.00  in
 Coefficient of Friction                         mu         0.40

 Saddle Force Q, Operating Case                         72561.55  lbf

 Pressure used in Analysis                        P      150.777  psig

 Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                             psi |          psi |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan        119.94 |     20000.00 |
 Long. Stress at Bottom of Midspan       5250.82 |     20000.00 |
 Long. Stress at Top    of Saddles       3194.94 |     20000.00 |
 Long. Stress at Bottom of Saddles       2402.95 |     20000.00 |
 ----------------------------------------------------------------
 Tangential Shear in Shell               4885.23 |     16000.00 |
 Circ. Stress at Horn of Saddle         14638.23 |     25000.00 |
 Circ. Compressive Stress in Shell        658.83 |     20000.00 |
 ----------------------------------------------------------------
```

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( 1224.1/2 + 0 ) * 40/40
  = 1836.1 lbf
```

Saddle Reaction Force due to Wind Fl [Fwl]:
```
  = max( Fl, Sum of X Forces) * B / Ls
  = max( 462.44, 0 ) * 40/139
  = 133.1 lbf
```

Saddle Reaction Force due to Earthquake Fl [Fsl]:
```
  = max( Fl, Sum of X Forces ) * B / Ls
  = max( 26443, 0 ) * 40/139
```

= 7609.5 lbf

Saddle Reaction Force due to Earthquake Ft [Fst]:
= Ftr(Ft/Num of Saddles + Z Force Load) * B / E
= 3(26443/2 + 0) * 40/40
= 39664.6 lbf

Load Combination Results for Q + Wind or Seismic [Q]:
= Saddle Load + max(Fwl, Fwt, Fsl, Fst)
= 32897 + max(133.08, 1836.1, 7609.5, 39665)
= 72561.5 lbf

Longitudinal Wind Force [Fl]:
= WindScalar * WindPress(Platform Area + (pi/4(OD * WindDiaMult)^2))
= 0.6 * 31.992(0 + pi/4(4.0427 * 1.37)^2)
= 462.443 lbf

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	73050.08	lbf
Transverse Shear Load Saddle	13221.54	lbf
Longitudinal Shear Load Saddle	26443.08	lbf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:
= Baseplate Length
= 40.000 in

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 = 0.0455	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	

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

Moment per Equation 4.15.1 [M1]:
= -Q*a [1 - (1- a/L + (Rm^2-h2^2)/(2a*L))/(1+(4h2)/3L)]
= -72562*20.354[1-(1-20.354/217.75+(22.441^2-0^2)/
(2*20.354*217.75))/(1+(4*0)/(3*217.75))]
= -4512.2 ft-lb

Moment per Equation 4.15.4 [M2]:
= Q*L/4(1+2(Rm^2-h2^2)/(L^2))/(1+(4h2)/(3L))-4a/L
= 72562*217.75/4(1+2(22.441^2-0^2)/(217.75^2))/(1+(4*0)/
(3*217.75))-4*20.354/217.75
= 213086.0 ft-lb

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:
= P * Rm/(2t) - M2/(pi*Rm^{2}t)
= 150.78 * 22.441/(2*0.63) - 2557031/(pi*22.441^2*0.63)
= 119.94 psi

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:
= P * Rm/(2t) + M2/(pi * Rm^2 * t)
= 150.78 * 22.441/(2 * 0.63) + 2557031/(pi * 22.441^2 * 0.63)
= 5250.82 psi

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma✱3]:
= P * Rm/(2t) - M1/(K1*pi*Rm^{2}t)
= 150.78*22.441/(2*0.63)--54146/(0.1066*pi*22.441^2*0.63)
= 3194.94 psi

```
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```

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma✱4]:
```
  = P * Rm/(2t) + M1/(K1✱ * pi * Rm² * t)
  = 150.78*22.441/(2*0.63)+-54146/(0.1923*pi*22.441²*0.63)
  = 2402.95 psi
```

Maximum Shear Force in the Saddle (4.15.3) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 72562( 217.75 - 2 * 20.354 )/(217.75 +( 4 * 0/3))
  = 58996.2 lbf
```

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 58996/( 22.441 * 0.63 )
  = 4885.23 psi
```

Decay Length (4.15.20) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 22.441 * 0.63 )
  = 2.933 in
```

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:
```
  = -K5 * Q * k / ( t( b + X1 + X2 ) )
  = -0.7603 * 72562 * 0.1/( 0.63( 7.4252 + 2.9328 + 2.9328 ) )
  = -658.83 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:
```
  = -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -72562/(4 * 0.63(7.4252 + 2.9328 + 2.9328 )) -
     3 * 0.04548 * 72562/(2*0.63²)
  = -14638.23 psi
```

Effective reinforcing plate width (4.15.24) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 7.4252 + 1.56 * sqrt( 22.441 * 0.63 ), 2 * 20.354 )
  = 13.29 in
```

Distance between Saddle Supports [Ls]:
```
  = 139.0 in
```

Free Un-Restrained Thermal Expansion between the Saddles [Exp]:
```
  = Alpha * Ls( Design Temperature - Ambient Temperature )
  = 0.69600E-05 * 139( 330 - 70 )
  = 0.252 in
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	40.0000	in
Baseplate Thickness	Bpthk	1.2598	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	0.5510	in
Web Thickness	Webtk	0.5510	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	33270.0	psi
Height of Web at Center	Hw,c	17.0	in
Friction Coefficient	mu	0.400	

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

Inertia of Shell [ShellInertia]:
```
  = (( 1.56 * sqrt( R * t ) + WearPlateWidth )t³ )/12
  = (( 1.56 * sqrt( 22.126 * 0.63 ) + 9 )0.63³ )/12
  = 0.309 in**4
```

Resolved Inertia for the Shell [I,shell]:

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= ShellInertia + AShell(C1 - Y)^2
= 0.3089 + 9.3393(8.0278 - 0.315)^2
= 555.882 in**4

	B	D	Y	A	AY	I + AD^2
	in	in	in	in^2	in^3	in**4
Shell	14.8243	0.6300	0.3150	9.3393	2.9419	555.8818
Wearplate	9.0000	0.6300	0.9450	5.6700	5.3582	284.6299
Web	0.5510	15.3542	8.9371	8.4601	75.6091	173.2018
BasePlate	9.0000	1.2598	17.2441	11.3386	195.5232	964.5957
Totals	...	...	...	34.8080	279.4323	1978.3096

Distance to Centroid [C1]:
= AY / A
= 279.43/34.808
= 8.028 in

Angle [beta]:
= 180 - Saddle Angle/2
= 180 - 120/2
= 120.0

Saddle Splitting Coefficient [K1]:
= (1 + cos(beta) - 0.5*sin(beta)^2)/(pi - beta + sin(beta)cos(beta))
= (1 + cos(120) - 0.5*sin(120)^2)/(pi - 2.0944 + sin(120)cos(120))
= 0.2035

Saddle Splitting Force [Fh]:
= K1 * Q
= 0.2035 * 72562
= 14767.8486 lbf

Tension Stress, St = (Fh/As) = 579.8428 psi
Allowed Stress, Sa = 0.6 * Yield Str = 19962.0000 psi

Saddle Splitting Dimension [d]:
= B - R * sin(theta/2)/(theta/2 in radians)
= 40 - 22.126 * sin(120/2)/1.0472
= 21.702 in

Bending Moment, M = Fh * d = 26707.6016 ft-lb

Bending Stress, Sb = (M * C1 / I) = 1300.5260 psi
Allowed Stress, Sa = 2/3 * Yield Str = 22180.0000 psi

Minimum Thickness of Baseplate per Moss:
= sqrt(3(Q + Saddle_Wt)BasePlateWidth / (2 * BasePlateLength * AllStress))
= sqrt(3(72562 + 488.53)9/(2 * 40 * 22180))
= 1.054 in

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 - 120/2)(22.126 + 0.63 + 0.63)
= 40.506 in

Distance between Ribs [e]:
= Web Length / (Nribs - 1)
= 40.506/(3 - 1)
= 20.253 in

Baseplate Pressure Area [Ap]:

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Saddle Calcs: Operating Case: Step: 20 1:00pm Jan 17,2023

```
  = e * Bpwid / 2
  = 20.253 * 9/2
  = 91.138 in^2
```

Bearing Pressure [Bp]:
```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 72562/( 40 * 9 )
  = 201.560 lbf/in^2
```

Axial Load [P]:
```
  = Ap * Bp
  = 91.138 * 201.56
  = 18369.730 lbf
```

Area of the Rib and Web [Ar]:
```
  = Rib Area + Web Area
  = 3.7877 + 5.5797
  = 9.367 in^2
```

Compressive Stress [Sc]:
```
  = P/Ar
  = 18370/9.3673
  = 1961.039 psi
```

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	33.4385
Web	10.1264	0.5510	0.2755	5.5797	1.5372	12.7153
Totals	...	...	...	9.3673	16.6429	46.1538

Rib dimension [D]:
```
  = Saddle Width - Web Thickness
  = 7.4252 - 0.551
  = 6.874 in
```

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 16.643/9.3673
  = 1.777 in
```

Distance to Centroid [C1]:
```
  = max( ytot, Saddle Width - ytot )
  = max( 1.7767, 7.4252 - 1.7767 )
  = 5.649 in
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 46.154/9.3673 )
  = 2.220 in
```

Length of Outer Rib, step 1, [Lw]:
```
  = 2 * sin( saddle bearing angle / 2 )( radius + shlthk + wpdthk )
  = 2 * sin( 120/2 )( 22.126 + 0.63 + 0.63 )
  = 40.506 in
```

Length of Outer Rib, step 2, [Bd]:
```
  = Baseplate length - clearance
  = 40 - 2
  = 38.000 in
```

```
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Saddle Calcs: Operating Case:         Step:   20   1:00pm  Jan 17,2023
```

Length of Outer Rib, step 3, [Dd]:
```
  = ( Lw - Bd )/2
  = ( 40.506 - 38 )/2
  = 1.253 in
```

Length of Outer Rib [L]:
```
  = sqrt( Rl² + Dd² )
  = sqrt( 27.076² + 1.2529² )
  = 27.076 in
```

Intermediate Term [Cc]:
```
  = sqrt( 2 * pi² * Elastic Modulus / Yield Stress )
  = sqrt( 2 * pi² * 28999900/33270 )
  = 131.171
```

Slenderness ratio [KL/r]:
```
  = KL/r
  = 1 * 27.076/2.2197
  = 12.198
```

Bending Moment [Rm]:
```
  = Fl /( 2 * Bplen ) * e * L / 2
  = 26443/( 2 * 40 ) * 20.253 * 27.076/2
  = 7552.389 ft-lb
```

Compressive Allowable, KL/r < Cc(12.198 < 131.17) per AISC E2-1 [Sca]:
```
  = ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
  = ( 1-( 12.198 )²/(2 * 131.17² ))33270/
    ( 5/3+3*(12.198 )/(8* 131.17 )-( 12.198³)/(8*131.17³)
  = 19469 psi
```

AISC Unity Check of Outside Ribs (must be <= 1)
```
  = Sc/Sca + ( Rm * C1 / I )/Sba
  = 1961/19469 +( 90629 * 5.6485/46.154 )/22180
  = 0.601
```

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	44.0158
Web	20.2529	0.5510	0.2755	11.1593	3.0744	10.1595
Totals	...	...	...	14.9470	18.1801	54.1753

Distance to Centroid from Datum [ytot]:
```
  = AY / A
  = 18.18/14.947
  = 1.216 in
```

Distance to Centroid [C1]:
```
  = max( ytot, abs( Saddle Width - ytot ) )
  = max( 1.2163, abs( 7.4252 - 1.2163 ) )
  = 6.209 in
```

Length of Inner Rib [L]:
```
  = Saddle Height - Outside Radius - Bpthk
  = 40 - cos( 23.386/2 )( 1.2598 + 0 + 0 ) - 0
  = 15.354 in
```

Radius of Gyration [r]:
```
  = sqrt( Total Inertia / Total Area )
  = sqrt( 54.175/14.947 )
  = 1.904 in
```

```
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```

Slenderness ratio [KL/r]:
```
= KL/r
= 1 * 15.354/1.9038
= 8.065
```

Unit Force [Force,u]:
```
= Fl / ( 2 * Baseplate Length )
= 26443/( 2 * 40 )
= 330.539 lbf/in
```

Moment at base of inner Rib [Mbase,c]:
```
= Unit Force * e * L
= 330.54 * 20.253 * 15.354
= 102786.219 in.lbs
```

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
```
= Bending Moment / Section Modulus
= 102786/8.7254
= 11780.086 psi
```

Compressive Allowable, KL/r < Cc(8.065 < 131.17) per AISC E2-1 [Sca]:
```
= ( 1-(Klr)²/(2*Cc²))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr³)/(8*Cc³)
= ( 1-( 8.065 )²/(2 * 131.17² ))33270/
  ( 5/3+3*(8.065 )/(8* 131.17 )-( 8.065³)/(8*131.17³)
= 19653 psi
```

AISC Unity Check of Inside Ribs (must be <= 1)
```
= Sc/Sca + ( Mbase,c * C1/I )/Sba
= 2407/19653 +( 102786 * 6.2089/54.175 )/22180
= 0.654
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-36	
Bolt Allowable Stress	Stba	21754.90	psi
Bolt Corrosion Allowance	Bca	0.0630	in
Distance from Bolts to Edge	Edgedis	4.0000	in
Nominal Bolt Diameter	Bnd	1.7500	in
Thread Series	Series	TEMA	
BasePlate Allowable Stress	S	20000.00	psi
Area Available in a Single Bolt	BltArea	1.6782	in^2
Saddle Load QO (Weight)	QO	33385.5	lbf
Saddle Load QL (Wind/Seismic contribution)	QL	7609.5	lbf
Maximum Transverse Force	Ft	13221.5	lbf
Maximum Longitudinal Force	Fl	26443.1	lbf
Saddle Bolted to Steel Foundation		No	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:
```
= Fl / ( Bolt Area * Number of Bolts )
= 26443/( 1.6782 * 2 )
= 7878.3 psi.  Must be less than 13052.9 psi.
```

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:
```
= Ft / ( Bolt Area * Number of Bolts )
= 13222/( 1.6782 * 2 )
= 3939.2 psi.  Must be less than 13052.9 psi.
```

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 / ( BoltShearAllowable * Nbolts )
  = 26443/(13053 * 2 )
  = 1.0129 in^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:
```
  = B * Ft + Sum of X Moments
  = 3.3333 * 13222 + 0
  = 44071.80 ft-lb
```

Eccentricity (e):
```
  = Rmom / QO
  = 528862/33385
  = 15.84 in > Bplen/6 --> Uplift in Transverse direction

 f = Bplen / 2 - Edgedis
   = 40/2 - 4
   = 16.00 in
```

Modular Ratio Of Steel/Concrete (n1):
```
  = ES / EC
  = 29500000/3122018
  = 9.45

 K1 = 3 (e - 0.5 * Bplen)
    = 3(15.841 - 0.5*40 )
    = -12.48 in

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 9.449 * 1.6782/9 *(16 + 15.841 )
    = 336.61 in ²

 K3 = -K2 * (0.5 * Bplen + f)
    = -336.61 *(0.5 * 40 + 16 )
    = -12118.08 in ³
```

Iteratively Solving for the Effective Bearing Length:
```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + -12.477 * Y² + 336.61 * Y + -12118 = 0
 Y  = 22.08 in

 Num = (Bplen / 2 - Y / 3 - e)
     = (40/2 - 22.083/3 - 15.841 )
     = -3.20

 Denom = (Bplen / 2 - Y / 3 + f)
       = (40/2 - 22.083/3 + 16 )
       = 28.64
```

Total Bolt Tension Force [Tforce]:
```
  = - QO * Num / Denom
  = - 33385 * -3.2021/28.639
  = 3732.80 lbf
```

Bolt Area Required due to Transverse Load [Bltareart]:
```
  = Tforce / (Stba * Nbt)
  = 3732.8/( 21755 * 1 )
  = 0.1716 in^2
```

Required Area of a Single Bolt [Bltarear]:

```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0, 1.0129, 0.1716 ]
  = 1.0129 in^2
```

Baseplate Thickness Calculation per D. Moss:

Bearing Pressure (fc)
```
  = 2(QO + Tforce) / (Y * Bpwid)
  = 2(33385 + 3732.8 )/(22.083 * 9 )
  = 373.52 psig
```

Distance from Baseplate Edge to the Web [ADIST]:
```
  = (Bplen - Weblngth) / 2
  = (40 - 38 )/2
  = 1.0000 in
```

Overturning Moment due To Bolt Tension [Mt]:
```
  = Tforce * Adist
  = 3732.8 * 1
  = 311.07 ft-lb
```

Equivalent Bearing Pressure (f1):
```
  = fc * (Y - Adist) / Y
  = 373.52 *(22.083 - 1 )/22.083
  = 356.61 psig
```

Overturning Moment due to Bearing Pressure [Mc]:
```
  = (Adist² * Bpwid / 6) * (f1 + 2 * fc)
  = (0.08333² * 0.75/6) *(51351 + 2 * 53787 )
  = 137.96 ft-lb
```

Baseplate Required Thickness [Treq]:
```
  = sqrt(6 * max(Mt,Mc) / (Bpwid * Sba))
  = sqrt(6 * max(3732.8,1655.5 )/(9 * 30000 ))
  = 0.2880 in
```

MDMT Calculations for: Fixed Saddle, Saddle to Wearplate Junction, Curve: D

Govrn. thk, tg = 0.63, tr = 0.3125, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.4961, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve D             -50 F
```

ASME VIII Division 2 Horizontal Vessel Analysis, Right Saddle:

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

Note:
Wear Pad Width (9.00) is less than 1.56*sqrt(rm*t)
and less than 2a. The wear plate will be ignored.

Minimum Wear Plate Width to be considered in analysis [b1]:
```
  = min( b + 1.56*sqrt( Rm * t ), 2a )
  = min( 7.4252 + 1.56*sqrt( 22.441 * 0.63 ), 2 * 58.638 )
  = 13.2908 in
```

Input and Calculated Values:

```
 Vessel Mean Radius                          Rm       22.44  in
 Shell Thickness used in this Case            t       0.630  in
 Stiffened Vessel Length per 4.15.6           L      217.75  in
```

```
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 Distance from Saddle to Vessel tangent   a1 or a       58.64  in

 Saddle Width                             b1 or b        7.43  in
 Saddle Bearing Angle              delta or theta      120.00  degrees

 Inside Depth of Head                    Hi or h2       11.06  in

 Shell Allowable Stress used in Calculation         20000.00  psi
 Head Allowable Stress used in Calculation          20000.00  psi
 Circumferential Efficiency in Plane of Saddle          1.00
 Circumferential Efficiency at Mid-Span                 1.00

 Distance from Saddle Base to Centerline        B       40.00  in
 Coefficient of Friction                       mu        0.00

 Saddle Force Q, Operating Case                     54505.98  lbf

 Pressure used in Analysis                      P     150.777  psig

 Horizontal Vessel Analysis Results:      Actual |    Allowable |
                                             psi |          psi |
 ----------------------------------------------------------------
 Long. Stress at Top    of Midspan       3059.15 |     20000.00 |
 Long. Stress at Bottom of Midspan       2311.61 |     20000.00 |
 Long. Stress at Top    of Saddles      11759.04 |     20000.00 |
 Long. Stress at Bottom of Saddles      -2343.80 |    -29943.00 |
 Long. Stress at Bottom of Saddles       2343.80 |     20000.00 |
 ----------------------------------------------------------------
 Tangential Shear in Shell               1950.42 |     16000.00 |
 Circ. Stress at Horn of Saddle         12514.52 |     25000.00 |
 Circ. Compressive Stress in Shell        494.89 |     20000.00 |
 ----------------------------------------------------------------
```

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( 1224.1/2 + 0 ) * 40/40
  = 1836.1 lbf
```

Saddle Reaction Force due to Wind Fl [Fwl]:
```
  = max( Fl, Sum of X Forces) * B / Ls
  = max( 462.44, 0 ) * 40/139
  = 133.1 lbf
```

Saddle Reaction Force due to Earthquake Fl [Fsl]:
```
  = max( Fl, Sum of X Forces ) * B / Ls
  = max( 26443, 0 ) * 40/139
  = 7609.5 lbf
```

Saddle Reaction Force due to Earthquake Ft [Fst]:
```
  = Ftr( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3( 26443/2 + 0 ) * 40/40
  = 39664.6 lbf
```

Load Combination Results for Q + Wind or Seismic [Q]:
```
  = Saddle Load + max( Fwl, Fwt, Fsl, Fst )
  = 14841 + max( 133.08, 1836.1, 7609.5, 39665 )
  = 54506.0 lbf
```

Longitudinal Wind Force [Fl]:

$= WindScalar * WindPress(Platform Area + (pi/4(OD * WindDiaMult)^2))$

$= 0.6 * 31.992(0 + pi/4(4.0427 * 1.37)^2)$

$= 462.443$ lbf

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	54994.52	lbf
Transverse Shear Load Saddle	13221.54	lbf
Longitudinal Shear Load Saddle	26443.08	lbf

Formulas and Substitutions for Horizontal Vessel Analysis:

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

Saddle Dimension [E]:
```
  = Baseplate Length
  = 40.000 in
```

The Computed K values from Table 4.15.1:

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

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

Moment per Equation 4.15.1 [M1]:
```
  = -Q*a [1 - (1- a/L + (Rm²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -54506*58.638[1-(1-58.638/217.75+(22.441²-11.063²)/
    (2*58.638*217.75))/(1+(4*11.063)/(3*217.75))]
  = -80348.5 ft-lb
```

Moment per Equation 4.15.4 [M2]:
```
  = Q*L/4(1+2(Rm²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 54506*217.75/4(1+2(22.441²-11.063²)/(217.75²))/(1+(4*11.063)/
    (3*217.75))-4*58.638/217.75
  = -31045.7 ft-lb
```

Longitudinal Stress at Top of Shell (4.15.4) [sigma1]:
```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 150.78 * 22.441/(2*0.63 ) - -372548/(pi*22.441²*0.63 )
  = 3059.15 psi
```

Longitudinal Stress at Bottom of Shell (4.15.5) [sigma2]:
```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 150.78 * 22.441/(2 * 0.63 ) + -372548/(pi * 22.441² * 0.63 )
  = 2311.61 psi
```

Longitudinal Stress at Top of Shell at Support (4.15.8) [sigma✱3]:
```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 150.78*22.441/(2*0.63)--964182/(0.1066*pi*22.441²*0.63)
  = 11759.04 psi
```

Longitudinal Stress at Bottom of Shell at Support (4.15.9) [sigma✱4]:
```
  = P * Rm/(2t) + M1/(K1✱ * pi * Rm² * t)
  = 150.78*22.441/(2*0.63)+-964182/(0.1923*pi*22.441²*0.63)
  = -2343.80 psi
```

Maximum Shear Force in the Saddle (4.15.3) [T]:
```
  = Q(L-2a)/(L+(4*h2/3))
  = 54506( 217.75 - 2 * 58.638 )/(217.75 +( 4 * 11.063/3))
  = 23554.2 lbf
```

Shear Stress in the shell no rings, not stiffened (4.15.12) [tau2]:
```
  = K2 * T / ( Rm * t )
  = 1.1707 * 23554/( 22.441 * 0.63 )
  = 1950.42 psi
```

```
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```

Decay Length (4.15.20) [x1,x2]:
```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 22.441 * 0.63 )
  = 2.933 in
```

Circumferential Stress in shell, no rings (4.15.21) [sigma6]:
```
  = -K5 * Q * k / ( t( b + X1 + X2 ) )
  = -0.7603 * 54506 * 0.1/( 0.63( 7.4252 + 2.9328 + 2.9328 ) )
  = -494.89 psi
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.22) [sigma7]:
```
  = -Q/(4*t(b+X1+X2)) - 3*K7*Q/(2*t²)
  = -54506/(4 * 0.63(7.4252 + 2.9328 + 2.9328 )) -
     3 * 0.05285 * 54506/(2*0.63²)
  = -12514.52 psi
```

Effective reinforcing plate width (4.15.24) [B1]:
```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 7.4252 + 1.56 * sqrt( 22.441 * 0.63 ), 2 * 58.638 )
  = 13.29 in
```

Results for Vessel Ribs, Web and Base:

Baseplate Length	Bplen	40.0000	in
Baseplate Thickness	Bpthk	1.2598	in
Baseplate Width	Bpwid	9.0000	in
Number of Ribs (inc. outside ribs)	Nribs	3	
Rib Thickness	Ribtk	0.5510	in
Web Thickness	Webtk	0.5510	in
Web Location	Webloc	Side	
Saddle Yield Stress	Sy	38000.0	psi
Height of Web at Center	Hw,c	17.0	in
Friction Coefficient	mu	0.000	

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

Inertia of Shell [ShellInertia]:
```
  = (( 1.56 * sqrt( R * t ) + WearPlateWidth )t³ )/12
  = (( 1.56 * sqrt( 22.126 * 0.63 ) + 9 )0.63³ )/12
  = 0.309 in**4
```

Resolved Inertia for the Shell [I,shell]:
```
  = ShellInertia + AShell( C1 - Y )²
  = 0.3089 + 9.3393( 8.0278 - 0.315 )²
  = 555.882 in**4
```

	B in	D in	Y in	A in^2	AY in^3	$I + AD^2$ in**4
Shell	14.8243	0.6300	0.3150	9.3393	2.9419	555.8818
Wearplate	9.0000	0.6300	0.9450	5.6700	5.3582	284.6299
Web	0.5510	15.3542	8.9371	8.4601	75.6091	173.2018
BasePlate	9.0000	1.2598	17.2441	11.3386	195.5232	964.5957
Totals	...	...	...	34.8080	279.4323	1978.3096

Distance to Centroid [C1]:
```
  = AY / A
  = 279.43/34.808
  = 8.028 in
```

Angle [beta]:
```
  = 180 - Saddle Angle/2
  = 180 - 120/2
  = 120.0
```

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```

Saddle Splitting Coefficient [K1]:
```
  = ( 1 + cos(beta) - 0.5*sin(beta)² )/(pi - beta + sin(beta)cos(beta) )
  = ( 1 + cos(120 ) - 0.5*sin(120 )² )/(pi - 2.0944 + sin(120 )cos(120 ) )
  = 0.2035
```

Saddle Splitting Force [Fh]:
```
  = K1 * Q
  = 0.2035 * 54506
  = 11093.1494 lbf

 Tension Stress, St = ( Fh/As )       =        435.5600  psi
 Allowed Stress, Sa = 0.6 * Yield Str =      22800.0000  psi
```

Saddle Splitting Dimension [d]:
```
  = B - R * sin(theta/2)/(theta/2 in radians)
  = 40 - 22.126 * sin(120/2)/1.0472
  = 21.702 in

 Bending Moment, M  = Fh * d          =      20061.9219  ft-lb

 Bending Stress, Sb = ( M * C1 / I  ) =        976.9148  psi
 Allowed Stress, Sa = 2/3 * Yield Str =      25333.3340  psi
```

Minimum Thickness of Baseplate per Moss:
```
  = sqrt( 3( Q + Saddle_Wt )BasePlateWidth / ( 2 * BasePlateLength * AllStress ))
  = sqrt( 3(54506 + 488.53 )9/( 2 * 40 * 25333 ))
  = 0.856 in
```

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 - 120/2 )( 22.126 + 0.63 + 0.63 )
  = 40.506 in
```

Distance between Ribs [e]:
```
  = Web Length / ( Nribs - 1 )
  = 40.506/( 3 - 1 )
  = 20.253 in
```

Baseplate Pressure Area [Ap]:
```
  = e * Bpwid / 2
  = 20.253 * 9/2
  = 91.138 in^2
```

Bearing Pressure [Bp]:
```
  = Q / ( BasePlateLength * BasePlateWidth )
  = 54506/( 40 * 9 )
  = 151.406 lbf/in^2
```

Axial Load [P]:
```
  = Ap * Bp
  = 91.138 * 151.41
  = 13798.773 lbf
```

Area of the Rib and Web [Ar]:
```
  = Rib Area + Web Area
  = 3.7877 + 5.5797
  = 9.367 in^2
```

Compressive Stress [Sc]:
```
  = P/Ar
  = 13799/9.3673
```

= 1473.072 psi

Check of Outside Ribs:

Inertia of Saddle, Outer Ribs - Longitudinal Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	33.4385
Web	10.1264	0.5510	0.2755	5.5797	1.5372	12.7153
Totals	...	...	...	9.3673	16.6429	46.1538

Rib dimension [D]:
= Saddle Width - Web Thickness
= 7.4252 - 0.551
= 6.874 in

Distance to Centroid from Datum [ytot]:
= AY / A
= 16.643/9.3673
= 1.777 in

Distance to Centroid [C1]:
= max(ytot, Saddle Width - ytot)
= max(1.7767, 7.4252 - 1.7767)
= 5.649 in

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(46.154/9.3673)
= 2.220 in

Length of Outer Rib, step 1, [Lw]:
= 2 * sin(saddle bearing angle / 2)(radius + shlthk + wpdthk)
= 2 * sin(120/2)(22.126 + 0.63 + 0.63)
= 40.506 in

Length of Outer Rib, step 2, [Bd]:
= Baseplate length - clearance
= 40 - 2
= 38.000 in

Length of Outer Rib, step 3, [Dd]:
= (Lw - Bd)/2
= (40.506 - 38)/2
= 1.253 in

Length of Outer Rib [L]:
= sqrt(Rl^2 + Dd^2)
= sqrt(27.076^2 + 1.2529^2)
= 27.076 in

Intermediate Term [Cc]:
= sqrt(2 * pi^2 * Elastic Modulus / Yield Stress)
= sqrt(2 * pi^2 * 28999900/38000)
= 122.736

Slenderness ratio [KL/r]:
= KL/r
= 1 * 27.076/2.2197
= 12.198

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

= 26443/(2 * 40) * 20.253 * 27.076/2
= 7552.389 ft-lb

Compressive Allowable, KL/r < Cc(12.198 < 122.74) per AISC E2-1 [Sca]:
= $(1-(Klr)^2/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)$
= $(1-(12.198)^2/(2 * 122.74^2))38000/$
$(5/3+3*(12.198)/(8* 122.74)-(12.198^3)/(8*122.74^3)$
= 22193 psi

AISC Unity Check of Outside Ribs (must be <= 1)
= Sc/Sca + (Rm * C1 / I)/Sba
= 1473.1/22193 +(90629 * 5.6485/46.154)/25333
= 0.504

Check of Inside Ribs:

Inertia of Saddle, Inner Ribs - Axial Direction

	B	D	Y	A	AY	Io
Rib	0.5510	6.8742	3.9881	3.7877	15.1057	44.0158
Web	20.2529	0.5510	0.2755	11.1593	3.0744	10.1595
Totals	...	...	...	14.9470	18.1801	54.1753

Distance to Centroid from Datum [ytot]:
= AY / A
= 18.18/14.947
= 1.216 in

Distance to Centroid [C1]:
= max(ytot, abs(Saddle Width - ytot))
= max(1.2163, abs(7.4252 - 1.2163))
= 6.209 in

Length of Inner Rib [L]:
= Saddle Height - Outside Radius - Bpthk
= 40 - cos(23.386/2)(1.2598 + 0 + 0) - 0
= 15.354 in

Radius of Gyration [r]:
= sqrt(Total Inertia / Total Area)
= sqrt(54.175/14.947)
= 1.904 in

Slenderness ratio [KL/r]:
= KL/r
= 1 * 15.354/1.9038
= 8.065

Unit Force [Force,u]:
= Fl / (2 * Baseplate Length)
= 26443/(2 * 40)
= 330.539 lbf/in

Moment at base of inner Rib [Mbase,c]:
= Unit Force * e * L
= 330.54 * 20.253 * 15.354
= 102786.219 in.lbs

Bending Stress due to Transverse Force and Weight Load [SigmaB,base,c]:
= Bending Moment / Section Modulus
= 102786/8.7254
= 11780.086 psi

Compressive Allowable, KL/r < Cc(8.065 < 122.74) per AISC E2-1 [Sca]:

```
  = ( 1-(Klr)^2/(2*Cc^2))Fy/(5/3+3*(Klr)/(8*Cc)-(Klr^3)/(8*Cc^3)
  = ( 1-( 8.065 )^2/(2 * 122.74^2 ))38000/
    ( 5/3+3*(8.065 )/(8* 122.74 )-( 8.065^3)/(8*122.74^3)
  = 22420 psi
```

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

```
  = Sc/Sca + ( Mbase,c * C1/I )/Sba
  = 1808/22420 +( 102786 * 6.2089/54.175 )/25333
  = 0.546
```

Input Data for Base Plate Bolting Calculations:

Total Number of Bolts per BasePlate	Nbolts	2	
Total Number of Bolts in Tension/Baseplate	Nbt	1	
Bolt Material Specification		SA-36	
Bolt Allowable Stress	Stba	21754.90	psi
Bolt Corrosion Allowance	Bca	0.0630	in
Distance from Bolts to Edge	Edgedis	4.0000	in
Nominal Bolt Diameter	Bnd	1.7500	in
Thread Series	Series	TEMA	
BasePlate Allowable Stress	S	20000.00	psi
Area Available in a Single Bolt	BltArea	1.6782	in^2
Saddle Load QO (Weight)	QO	15329.9	lbf
Saddle Load QL (Wind/Seismic contribution)	QL	7609.5	lbf
Maximum Transverse Force	Ft	13221.5	lbf
Maximum Longitudinal Force	Fl	26443.1	lbf
Saddle Bolted to Steel Foundation		No	

Shear Stress in a Single Bolt, Longitudinal Direction [taub,l]:

```
  = Fl / ( Bolt Area * Number of Bolts )
  = 26443/( 1.6782 * 2 )
  = 7878.3 psi.  Must be less than 13052.9 psi.
```

Shear Stress in a Single Bolt, Transverse Direction [taub,t]:

```
  = Ft / ( Bolt Area * Number of Bolts )
  = 13222/( 1.6782 * 2 )
  = 3939.2 psi.  Must be less than 13052.9 psi.
```

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 / ( BoltShearAllowable * Nbolts )
  = 26443/(13053 * 2 )
  = 1.0129 in^2
```

Bolt Area due to Transverse Load:

Moment on Baseplate Due to Transverse Load [Rmom]:

```
  = B * Ft + Sum of X Moments
  = 3.3333 * 13222 + 0
  = 44071.80 ft-lb
```

Eccentricity (e):

```
  = Rmom / QO
  = 528862/15330
  = 34.50 in > Bplen/6 --> Uplift in Transverse direction

 f = Bplen / 2 - Edgedis
   = 40/2 - 4
   = 16.00 in
```

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```

Modular Ratio Of Steel/Concrete (n1):
```
  = ES / EC
  = 29500000/3122018
  = 9.45

 K1 = 3 (e - 0.5 * Bplen)
    = 3(34.499 - 0.5*40 )
    = 43.50 in

 K2 = 6 * n1 * At / Bpwid * (f + e)
    = 6 * 9.449 * 1.6782/9 *(16 + 34.499 )
    = 533.86 in ²

 K3 = -K2 * (0.5 * Bplen + f)
    = -533.86 *(0.5 * 40 + 16 )
    = -19218.80 in ³
```

Iteratively Solving for the Effective Bearing Length:
```
 Y³ + K1 * Y² + K2 * Y + K3 = 0
 Y³ + 43.496 * Y² + 533.86 * Y + -19219 = 0
 Y  = 14.20 in

 Num = (Bplen / 2 - Y / 3 - e)
     = (40/2 - 14.202/3 - 34.499 )
     = -19.23

 Denom = (Bplen / 2 - Y / 3 + f)
       = (40/2 - 14.202/3 + 16 )
       = 31.27
```

Total Bolt Tension Force [Tforce]:
```
  = - QO * Num / Denom
  = - 15330 * -19.233/31.266
  = 9429.85 lbf
```

Bolt Area Required due to Transverse Load [Bltareart]:
```
  = Tforce / (Stba * Nbt)
  = 9429.8/( 21755 * 1 )
  = 0.4335 in^2
```

Required Area of a Single Bolt [Bltarear]:
```
  = max[Bltarearl, Bltarears, Bltareart]
  = max[0, 1.0129, 0.4335 ]
  = 1.0129 in^2
```

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

Bearing Pressure (fc)
```
  = 2(QO + Tforce) / (Y * Bpwid)
  = 2(15330 + 9429.8 )/(14.202 * 9 )
  = 387.43 psig
```

Distance from Baseplate Edge to the Web [ADIST]:
```
  = (Bplen - Weblngth) / 2
  = (40 - 38 )/2
  = 1.0000 in
```

Overturning Moment due To Bolt Tension [Mt]:
```
  = Tforce * Adist
  = 9429.8 * 1
  = 785.82 ft-lb
```

```
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```

Equivalent Bearing Pressure (f1):
```
  = fc * (Y - Adist) / Y
  = 387.43 *(14.202 - 1 )/14.202
  = 360.15 psig
```

Overturning Moment due to Bearing Pressure [Mc]:
```
  = (Adist² * Bpwid / 6) * (f1 + 2 * fc)
  = (0.08333² * 0.75/6) *(51861 + 2 * 55790 )
  = 141.88 ft-lb
```

Baseplate Required Thickness [Treq]:
```
  = sqrt(6 * max(Mt,Mc) / (Bpwid * Sba))
  = sqrt(6 * max(9429.8,1702.5 )/(9 * 30000 ))
  = 0.4578 in
```

MDMT Calculations for: Fixed Saddle, Saddle to Wearplate Junction, Curve: D

Govrn. thk, tg = 0.63, tr = 0.3125, c = 0 in, E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.4961, Temp. Reduction = 0 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve D            -50 F
```

Warning:
Please note that nozzle loadings, if included, are assumed to be local in nature and will not contribute to or create a net section bending moment. Therefore, the addition of nozzle loads will not affect the support load calculation. If you wish to create a load on the legs/lugs etc. from forces or moments, use the Force/Moment dialog and add the appropriate forces and moments at the correct locations in the model. Ensure that all supports are designed to take into account all possible loading conditions.

Appendix 13：Test Ring Calculation

TEST RING CALCULATION FOR FRONT TUBESHEET END

Bolt material	SA-193 Gr.B7M	
Bolt yield stress	551.6	Mpa
Bolt tensile stress	689.5	Mpa
Bolt allowable stress when test	137.9	Mpa
Applied bolt tension stress coefficient	90	%
Bolt stress when test	124.11	Mpa
Bolt diameter	1 1/2"	
Bolt root area	910.02	mm^2
Bolt number	44	
Total bolt load when test	4969465.43	N
Test ring OD	1390	mm
Test ring ID	1117.6	mm
Bolt circle diameter	1295	mm
Test ring yield stress	248.2	Mpa
Test ring allowable stress	223.38	Mpa
Value H	88.7	mm
Value K	1.24	
Value Y	9.03	
Required test ring thickness as per TEMA RCB-5.14 $T=\left[\frac{2(W)(H)(Y)}{(B)(S)}\right]^{1/2} x\,10^3$	126.25	mm
Test ring thickness in drawing	135	mm