Table of Contents

DESIGN CALCULATION

In Accordance with ASME Section VIII Division 1

```
ASME Code Version     : 2023

Analysis Performed by : Kedkep Consulting Inc

Job File              : D:\Jobs 2008 to today\Business\web\Tower Analysis.pvdb

Date of Analysis      : Jun 10,2025   9:37pm
```

PV Elite 27, January 2025

Vessel Design Summary:

ASME Code, Section VIII Division 1, 2023

Diameter Spec : 40.000 x 28.000 in. ID		
Vessel Design Length, Tangent to Tangent	41.33	ft.
Distance of Bottom Tangent above Grade	3.00	ft.
Distance of Base above Grade	0.00	ft.
Specified Datum Line Distance	0.00	ft.
Internal Design Temperature	200	F
Internal Design Pressure	100.000	psig
External Design Temperature	200	F
External Design Pressure	15.000	psig
Maximum Allowable Working Pressure	105.2	psig
External Max. Allowable Working Pressure	21.32	psig
Shop Test Pressure	130.000	psig
Required Minimum Design Metal Temperature	-20.0	F
Warmest Computed Minimum Design Metal Temperature	-39.0	F
Wind Design Code	NBC-2005	
Earthquake Design Code	NBC 2005	

Materials of Construction:

Component Type	Material	Class	Thickness	UNS #	Normal ized	Impact Tested
Shell	SA-516 70	...	...	K02700	No	No
Head	SA-516 70	...	...	K02700	No	No
Cone	SA-516 70	...	...	K02700	No	No
Skirt	SA-516 70	...	...	K02700	No	No
Nozzle	SA-106 B	...	...	K03006	No	No
Nozzle Flg	SA-105	...	...	K03504	Yes	No
Rings	SA-516 70	...	...	K02700	No	No
Basering	SA-516 70	...	...	K02700	No	No
Base Bolting	SA-193 B7	...	<= 2 1/2	G41400	No	No

'Normalized is determined based on the UCS-66 material curve selection and Figure UCS-66.
'Impact Tested is based on material selection and material data properties.

Element Pressures and MAWP (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
Skirt	...	...	...	...	N/A	No
Btm Head	100.000	15.00	105.200	0.1250	Yes	No
Shell 1	100.000	15.00	518.300	0.1250	N/A	No
shell 2	100.000	15.00	518.300	0.1250	N/A	No
Cone	100.000	15.00	503.000	0.1250	N/A	No
Shell 3	100.000	15.00	732.800	0.1250	N/A	No
Top Head	100.000	15.00	297.700	0.1250	Yes	No

Stiffener Ring Specifications:

Elevation ft.	Selected Type	Ring Description
31.97	Bar 1.75 x 1.00	Ring:[1 of 1]

Element Types and Properties:

Element Type	"To" Elev ft.	Element Length ft.	Nominal Thickness in.	Finished Thickness in.	Reqd Thk Internal in.	Reqd Thk External in.	Long Eff	Circ Eff
Skirt	3.00	3.000	0.500	0.500	...	...	0.70	0.70
Ellipse	3.17	0.167	...	0.250	0.243	...	0.85	0.70
Cylinder	17.67	14.500	...	0.750	0.244	...	0.85	0.70
Cylinder	32.17	14.500	...	0.750	0.244	...	0.85	0.70
Conical	34.17	2.000	...	0.750	0.247	...	0.85	0.70
Cylinder	44.17	10.000	...	0.750	0.219	...	0.85	0.70
Ellipse	44.33	0.167	...	0.375	0.219	...	0.85	0.70

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	...	No Calc	...	No Calc
20	30	0.25	0.22986	15	21.32
30	40	0.75	0.4401	15	83.27
40	Ring	0.75	0.4401	15	83.27
Ring	50	0.75	0.16469	15	357.4
50	60	0.75	0.22772	15	338.3
60	70	0.75	0.2943	15	345.1
70	80	0.375	0.19944	15	127.4

External Pressure Calculations:

From	To	Actual Length Bet. Stiffeners ft.	Allowable Length Bet. Stiffeners ft.	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	29.2444	734.35	No Calc	No Calc
40	Ring	29.2444	734.35	No Calc	No Calc
Ring	50	0.2	4.76572	0.89879	2.20599
50	60	1.71084	1.71084	No Calc	No Calc
60	70	10.3611	670.073	No Calc	No Calc
70	80	No Calc	No Calc	No Calc	No Calc

Local Stress Analysis Results:

Description	Analysis Type	Max Stress Ratio	High Stress Location	Pass Fail
Local Skirt	Jawad & Farr	0.048	n/a	Passed

Wind/Earthquake Shear, Bending:

		Distance to	Cumulative	Earthquake	Wind	Earthquake

Vessel Design Summary: Step: 36 9:37pm Jun 10,2025

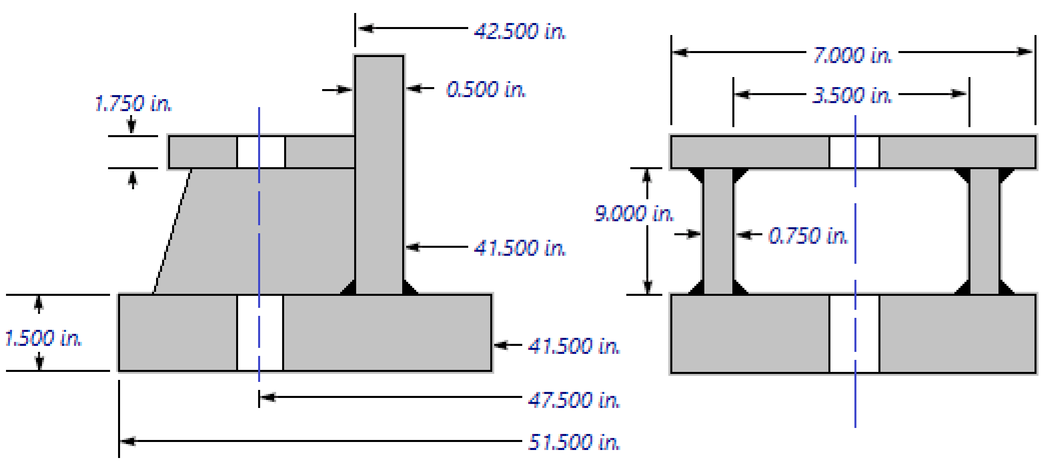
From	To	Support ft.	Wind Shear lb.	Shear lb.	Bending ft.lb.	Bending ft.lb.
10	20	1.5	2123.47	568.95	44666	15705.5
20	30	3.08333	1966.34	565.297	38531.3	14004.1
30	40	10.4167	1958.03	564.251	38204.3	13910
40	50	24.9167	1216.46	463.911	15189.2	6455.82
50	60	33.1667	474.905	228.264	2926.79	1437.55
60	70	39.1667	387.408	191.041	2064.48	1018.25
70	80	44.25	23.8683	11.8075	8.09539	4.00475

Abs Max of the all of the Stress Ratio's : 0.5947

Basering Data : Basering W/Gussets & Chair Cap

Thickness of Basering	1.5000	in.
Inside Diameter of Basering	41.5000	in.
Outside Diameter of Basering	51.5000	in.
Nominal Diameter of Bolts	2.0000	in.
Diameter of Bolt Circle	47.5000	in.
Number of Bolts	8	
Thickness of Gusset Plates	0.7500	in.
Average Width of Gusset Plates	4.5000	in.
Height of Gussets	9.0000	in.
Distance between Gussets	3.5000	in.
Thickness of Top Plate or Ring	1.7500	in.
Circumferential Width of the Top Plate	7.0000	in.
Radial Width of the Top Plate	4.5000	in.

Basering Sketch for Cylindrical Skirts:



Basering Cross Section View

Loads for Foundation/Support Design:

Total Wind Shear on Support	2123.	lb.
Total Earthquake Shear on Support	569.	lb.
Wind Moment on Support	44666.	ft.lb.
Earthquake Moment on Support	15705.	ft.lb.
Maximum Initial Bolt Load	3508.	lb.

The Wind and Seismic loads were not load factored in this analysis.

Wind and Earthquake moments include the effects of user defined forces and moments if any exist in the job and were specified to act (compute loads and stresses) during these cases. Also included are moment effects due to eccentric weights if any are present in the input.

Weights:

Fabricated	- Bare w/o removable internals	17068.5	lbm
Shop Test	- Fabricated + water (full)	36865.0	lbm
Shipping	- Fab. + rem. intls.+ shipping app.	17068.5	lbm
Erected	- Fab. + rem. intls.+ insul. (etc)	17068.5	lbm
Empty	- Fab. + intls. + details + wghts.	17068.5	lbm
Operating	- Empty + operating liquid (no ca)	17068.5	lbm

Nozzle Calculation Summary (psig & in.):

Description	MAWP	Ext	MAPNC	UG-45	[tr]	Weld Path	Areas or Stresses
Drain	105.2	...	...	OK	0.226	OK	No Calc[*]
Manway	308.2	OK	...	OK	0.226	OK	Passed
Inlet	118.9	OK	...	OK	0.226	OK	Passed
Outlet	169.1	OK	...	OK	0.219	OK	Passed
Vent	297.7	...	...	OK	0.219	OK	No Calc[*]

Nozzle MAWP Summary:

```
Minimum MAWP Nozzles          :          105.2 Nozzle  : Drain
Minimum MAWP Shells/Flanges   :          105.2 Element : Btm Head
Minimum MAPnc Shells/Flanges  :          212.2 Element : Btm Head
-----------------------------------------------------------------
Computed Vessel M.A.W.P.      :          105.2 psig
```

[*] - This was a small opening and the areas were not computed or
the MAWP of this connection could not be computed because
the longitudinal bending stress was greater than the hoop stress.

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

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	Y Coordinate in.	Layout Angle deg	Dia. Limit in.
20	Drain	0.000	0.000	6.300
30	Manway	38.000	0.000	30.500
40	Inlet	204.000	0.000	12.630
60	Outlet	470.000	0.000	12.630
70	Vent	0.000	0.000	5.146

The nozzle spacing is computed by the following:

= sqrt(ll² + lc²) 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!

Nozzle Schedule:

Description	Nominal or Actual Size	Schd or FVC Type	Flg Type	Nozzle O/Dia in	Wall Thk in	Reinforcing Pad Diameter	Reinforcing Pad Thk in	Cut Length in	Flg Class
Vent	2.500 in	80	WNF	2.875	0.276	...	...	6.42	150
Drain	3.000 in	80	WNF	3.500	0.300	...	...	6.29	150
Inlet	6.000 in	40	WNF	6.625	0.280	...	...	7.03	150
Outlet	6.000 in	40	WNF	6.625	0.280	...	...	7.15	150
Manway	16.000 in	40	WNF	16.000	0.500	...	...	8.42	150

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
Vent	SA-106 B	0.375	0.375	...	...	...
Drain	SA-106 B	0.250	0.375	...	...	...
Inlet	SA-106 B	0.750	0.375	...	...	...
Outlet	SA-106 B	0.750	0.375	...	...	...
Manway	SA-106 B	0.750	0.375	...	...	...

Note: The Outside projections below do not include the flange thickness.

Nozzle Miscellaneous Data:

Description	Elev/Distance From Datum ft.	Layout Angle deg	Proj Outside in.	Proj Inside in.	Installed in Component
Vent	...	0.0	6.00	0.00	Top Head
Drain	...	0.0	6.00	0.00	Btm Head
Inlet	20.000	0.0	6.00	0.00	shell 2
Outlet	42.167	0.0	6.00	0.00	Shell 3
Manway	6.167	0.0	6.00	0.00	Shell 1

Bill of Materials:

QTY	DESCRIPTION	MATERIAL
1	SKIRT: 0.500" THK X 41.500" ID X 3'	SA-516 70
1	ELLIPTICAL HEAD: 2.0 X 1, 0.250" THK X 40.000" ID X 2.00"	SA-516 70
2	CYLINDER: 0.750" THK X 40.000" ID X 14'-6"	SA-516 70
1	CONE: 0.750" THK X 40.000" ID X 2'	SA-516 70
1	CYLINDER: 0.750" THK X 28.000" ID X 10'	SA-516 70
1	ELLIPTICAL HEAD: 2.0 X 1, 0.375" THK X 28.000" ID X 2.00"	SA-516 70
1	BAR RING STIFFENER: 41.500" ID X 45.000" OD X 1.000"	SA-516 70
1	BASERING: 51.500" OD X 41.500 ID X 1.500"	SA-516 70
8	BASERING BOLTS: 2.000" DIA	SA-193 B7
8	BASERING BOLT NUTS: 2.000" DIA	...
16	BASERING GUSSET PLATES: 4.500" X 4.500" X 9.000" X 0.750"	...
8	BASERING TOP PLATES: 7.000" X 4.500" X 1.750"	...
1	NAMEPLATE	...

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
Btm Head	[10]	B	-20	-39	-20	0.805	0.250	0.85	No
Btm Head	[7]	B	-20	-39	-20	0.808	0.250	0.85	No
Shell 1	[8]	B	16	-155	-20	0.162	0.750	0.85	No
shell 2	[8]	B	16	-155	-20	0.162	0.750	0.85	No
Cone	[8]	B	16	-155	-20	0.167	0.750	0.85	No
Shell 3	[8]	B	16	-155	-20	0.128	0.750	0.85	No
Top Head	[10]	B	-20	-155	-20	0.319	0.375	0.85	No
Top Head	[7]	B	-20	-155	-20	0.319	0.375	0.85	No
Ring:[1 of 1]	[23]	B	16	-155	-20	0.162	0.750	0.85	No
Drain	[1]	B	-20	-48	-20	0.725	0.250	1.00	No
Nozzle Flg	[5]	B	0	-55					
Manway	[1]	B	-14	-155	-20	0.143	0.438	1.00	No
Nozzle Flg	[5]	B	0	-55					
Inlet	[1]	B	-20	-155		0.154	0.245	1.00	No
Nozzle Flg	[5]	B	0	-55					
Outlet	[1]	B	-20	-155		0.154	0.245	1.00	No
Nozzle Flg	[5]	B	0	-55					
Vent	[1]	B	-20	-155		0.065	0.241	1.00	No
Nozzle Flg	[5]	B	0	-55					
Warmest MDMT:			16	-39					

Required Minimum Design Metal Temperature -20.0 F
Warmest Computed Minimum Design Metal Temperature -39.0 F

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.

Class From To : Basic Element Checks.

Class From To: Check of Additional Element Data

There were no geometry errors or warnings.

The ASME Code Section VIII Division 1 does not explicitly require stresses on elements to be computed under test conditions. Please see interpretation VIII-1-10-12 for more information.
PV Elite also computes weight due to test fluid and uses the weight in various calculations such as saddle and leg loads. PV Elite also computes static pressure due to operating and test liquids. The static pressure is used in conjunction with the design and test pressures to determine a total pressure in the determination of required thickness, MAWP etc. This ensures compliance with UG-22 requirements.

Units used in this Analysis (ENGLISH):

Name	System Unit	Constant	User Unit
Length	Feet	1.0000	ft.
Force	Pounds	1.0000	lb.
Mass	Pounds	1.0000	lbm
Area	sq. inches	1.0000	sq.in.
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	lb./cu.in.
Ins. Density	lbs./cu.ft.	1.0000	lb./cu.ft.
Fluid Density	lbs./cu.ft.	1.0000	lb./cu.ft.
Wind Speed	miles/hr	1.0000	mile/hr
Tray Weight	lbs./sq.ft.	1.0000	lb./sq.ft.
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	1.0000	ft.
Volume	in.^3	1.0000	in3
Diameter	inches	1.0000	in.
Thickness	inches	1.0000	in.

PV Elite Vessel Analysis Program: Input Data

Design Internal Pressure (for Hydrotest)	100	psig
Design Internal Temperature	200.0	F
Projection of Nozzle from Vessel Top	0	in.
Projection of Nozzle from Vessel Bottom	0	in.
Minimum Design Metal Temperature	-20.0	F
Type of Construction	Welded	
Special Service	Air/Water/Steam	
Degree of Radiography	RT-4	
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(b) Note [35]
Pressure Test Position	Horizontal
Test Performed in Corroded Condition	No

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                                NBC-2005
 Design Wind Speed                                     70  mile/hr
 Exposure Category                        B, Rough Terrain
 Importance Factor                                    1.0
 Roughness Classification                Moderately smooth
 Base Elevation                                         0  ft.
 Percent Wind for Hydrotest                          33.0
 Using User defined Wind Press. Vs Elev.                N
 Damping Factor (Beta) for Wind (Ope)              0.0080
 Damping Factor (Beta) for Wind (Empty)            0.0000
 Damping Factor (Beta) for Wind (Filled)           0.0000
 Height of Hill or Escarpment     H or Hh               0  ft.
 Distance Upwind of Crest              Lh               0  ft.
 Distance from Crest to the Vessel      x               0  ft.
 Type of Terrain ( Hill, Escarpment )                Flat

 Seismic Design Code                             NBC-2005
 Importance Factor                                  1.000
 Overstrength Factor                               1.0000
 Ductility Factor                                  3.0000
 Height Ratio (hx/hn)                              0.0000
 Component Amplification factor [Rp]               2.5000
 Element or Component factor [Cp]                  1.0000
 Component Force factor [Ar]                       2.5000
 Site Class                                             C
 Acceleration Sa(0.2)                              0.1500
 Acceleration Sa(0.5)                              0.0840
 Acceleration Sa(1.0)                              0.0410
 Acceleration Sa(2.0)                              0.0230

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

 Perform Blast Load Analysis                           No
 Material Database Year        Current w/Addenda or Code Year
```

Configuration Directives:

```
  g0 is taken as min( g0, attached shell thk )             Yes


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

  Using Metric Material Databases, ASME II D                No
  Calculate B31.3 type stress for Nozzles with Loads       Yes
```

```
  Reduce the MDMT due to lower membrane stress            Yes
  Consider Longitudinal Stress in MDMT Calculations       Yes
```

Complete Listing of Vessel Elements and Details:

```
 Element#                                              1/7
 Element From Node                                      10
 Element To Node                                        20
 Element Type                                Skirt Support
 Description                                         Skirt
 Distance "FROM" to "TO"                                 3  ft.
 Skirt Inside Diameter                                41.5  in.
 Diameter of Skirt at Base                            41.5  in.
 Skirt Thickness                                       0.5  in.
 Internal Corrosion Allowance                            0  in.
 Nominal Thickness                                     0.5  in.
 External Corrosion Allowance                            0  in.
 Design Temperature Internal Pressure                  200  F
 Design Temperature External Pressure                  200  F
 Effective Diameter Multiplier                         1.2
 Material Name                                   SA-516 70
     Allowable Stress, Ambient                       20000  psi
     Allowable Stress, Operating                     20000  psi
     Allowable Stress, Hydrotest                     26000  psi
     Material Density                                0.283  lb./cu.in.
     P Number Thickness                               1.25  in.
     Yield Stress, Operating                         34800  psi
     UCS-66 Chart Curve Designation                      B
     External Pressure Chart Name                     CS-2
     UNS Number                                     K02700
     Product Form                                    Plate
 Efficiency, Longitudinal Seam                         0.7
 Efficiency, Head-to-Skirt or Circ. Seam               0.7
 Weld is pre-Heated                                     No

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

 Element#                                              2/7
 Element From Node                                      20
 Element To Node                                        30
 Element Type                                   Elliptical
 Description                                      Btm Head
 Distance "FROM" to "TO"                            0.1667  ft.
 Inside Diameter                                        40  in.
 Element Thickness                                    0.25  in.
 Internal Corrosion Allowance                        0.125  in.
 Nominal Thickness                                       0  in.
 External Corrosion Allowance                            0  in.
 Design Internal Pressure                              100  psig
 Design Temperature Internal Pressure                  200  F
 Design External Pressure                               15  psig
 Design Temperature External Pressure                  200  F
 Effective Diameter Multiplier                         1.2
 Material Name                                   SA-516 70
 Efficiency, Longitudinal Seam                        0.85
 Efficiency, Circumferential Seam                      0.7
 Elliptical Head Factor                                2.0
 Weld is pre-Heated                                     No

     Element From Node                                  20
     Detail Type                                    Nozzle
     Detail ID                                       Drain
```

```
    Dist. from "FROM" Node / Offset dist              0  in.
    Nozzle Diameter                                   3  in.
    Nozzle Schedule                                  80
    Nozzle Class                                    150
    Layout Angle                                    0.0
    Blind Flange (Y/N)                                N
    Weight of Nozzle ( Used if > 0 )                  0  lb.
    Grade of Attached Flange                     GR 1.1
    Nozzle Matl                                SA-106 B

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

Element#                                            3/7
Element From Node                                    30
Element To Node                                      40
Element Type                                   Cylinder
Description                                     Shell 1
Distance "FROM" to "TO"                            14.5  ft.
Inside Diameter                                      40  in.
Element Thickness                                  0.75  in.
Internal Corrosion Allowance                      0.125  in.
Nominal Thickness                                     0  in.
External Corrosion Allowance                          0  in.
Design Internal Pressure                            100  psig
Design Temperature Internal Pressure                200  F
Design External Pressure                             15  psig
Design Temperature External Pressure                200  F
Effective Diameter Multiplier                       1.2
Material Name                                 SA-516 70
Efficiency, Longitudinal Seam                      0.85
Efficiency, Circumferential Seam                    0.7
Weld is pre-Heated                                   No

    Element From Node                                30
    Detail Type                                  Nozzle
    Detail ID                                    Manway
    Dist. from "FROM" Node / Offset dist              3  ft.
    Nozzle Diameter                                  16  in.
    Nozzle Schedule                                  40
    Nozzle Class                                    150
    Layout Angle                                    0.0
    Blind Flange (Y/N)                                N
    Weight of Nozzle ( Used if > 0 )                  0  lb.
    Grade of Attached Flange                     GR 1.1
    Nozzle Matl                                SA-106 B

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

Element#                                            4/7
Element From Node                                    40
Element To Node                                      50
Element Type                                   Cylinder
Description                                     shell 2
Distance "FROM" to "TO"                            14.5  ft.
Inside Diameter                                      40  in.
Element Thickness                                  0.75  in.
Internal Corrosion Allowance                      0.125  in.
Nominal Thickness                                     0  in.
External Corrosion Allowance                          0  in.
Design Internal Pressure                            100  psig
Design Temperature Internal Pressure                200  F
Design External Pressure                             15  psig
```

Design Temperature External Pressure	200	F
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	
Efficiency, Longitudinal Seam	0.85	
Efficiency, Circumferential Seam	0.7	
Weld is pre-Heated	No	

Element From Node	40	
Detail Type	Ring	
Detail ID	Ring:[1 of 1]	
Dist. from "FROM" Node / Offset dist	14.3	ft.
Inside Diameter of Ring	41.5	in.
Thickness of Ring	1	in.
Outside Diameter of Ring	45	in.
Material Name	SA-516 70	
Height of Section Ring	0	in.
Using Custom Stiffener Section	No	

Element From Node	40	
Detail Type	Nozzle	
Detail ID	Inlet	
Dist. from "FROM" Node / Offset dist	2.3333	ft.
Nozzle Diameter	6	in.
Nozzle Schedule	40	
Nozzle Class	150	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0	lb.
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	

Element#	5/7	
Element From Node	50	
Element To Node	60	
Element Type	Conical	
Description	Cone	
Distance "FROM" to "TO"	2	ft.
Inside Diameter	40	in.
Element Thickness	0.75	in.
Internal Corrosion Allowance	0.125	in.
Nominal Thickness	0	in.
External Corrosion Allowance	0	in.
Design Internal Pressure	100	psig
Design Temperature Internal Pressure	200	F
Design External Pressure	15	psig
Design Temperature External Pressure	200	F
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	
Efficiency, Longitudinal Seam	0.85	
Efficiency, Circumferential Seam	0.7	
Cone Diameter at "To" End	28	in.
Design Length of Cone	24	in.
Half Apex Angle of Cone	14.036243	degrees
Toriconical (Y/N)	N	
Weld is pre-Heated	No	

Element#	6/7	
Element From Node	60	

Element To Node	70	
Element Type	Cylinder	
Description	Shell 3	
Distance "FROM" to "TO"	10	ft.
Inside Diameter	28	in.
Element Thickness	0.75	in.
Internal Corrosion Allowance	0.125	in.
Nominal Thickness	0	in.
External Corrosion Allowance	0	in.
Design Internal Pressure	100	psig
Design Temperature Internal Pressure	200	F
Design External Pressure	15	psig
Design Temperature External Pressure	200	F
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	
Efficiency, Longitudinal Seam	0.85	
Efficiency, Circumferential Seam	0.7	
Weld is pre-Heated	No	

Element From Node	60	
Detail Type	Nozzle	
Detail ID	Outlet	
Dist. from "FROM" Node / Offset dist	8	ft.
Nozzle Diameter	6	in.
Nozzle Schedule	40	
Nozzle Class	150	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0	lb.
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	

Element#	7/7	
Element From Node	70	
Element To Node	80	
Element Type	Elliptical	
Description	Top Head	
Distance "FROM" to "TO"	0.1667	ft.
Inside Diameter	28	in.
Element Thickness	0.375	in.
Internal Corrosion Allowance	0.125	in.
Nominal Thickness	0	in.
External Corrosion Allowance	0	in.
Design Internal Pressure	100	psig
Design Temperature Internal Pressure	200	F
Design External Pressure	15	psig
Design Temperature External Pressure	200	F
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	
Efficiency, Longitudinal Seam	0.85	
Efficiency, Circumferential Seam	0.7	
Elliptical Head Factor	2.0	
Weld is pre-Heated	No	

Element From Node	70	
Detail Type	Nozzle	
Detail ID	Vent	
Dist. from "FROM" Node / Offset dist	0	in.
Nozzle Diameter	2.5	in.
Nozzle Schedule	80	

Nozzle Class	150	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0	lb.
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	

XY Coordinate Calculations:

From	To	X (Horiz.) ft.	Y (Vert.) ft.	DX (Horiz.) ft.	DY (Vert.) ft.
Skirt		...	3	...	3
Btm Head		...	3.16667	...	0.16667
Shell 1		...	17.6667	...	14.5
shell 2		...	32.1667	...	14.5
Cone		...	34.1667	...	2
Shell 3		...	44.1667	...	10
Top Head		...	44.3333	...	0.16667

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.

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	Element#
Skirt		...	0.5	...	41.5	...	1
Btm Head		100	...	0.125	40	17000	2
Shell 1		100	...	0.125	40	17000	3
shell 2		100	...	0.125	40	17000	4
Cone		100	...	0.125	40	17000	5
Shell 3		100	...	0.125	28	17000	6
Top Head		100	...	0.125	28	17000	7

Element Required Thickness and MAWP :

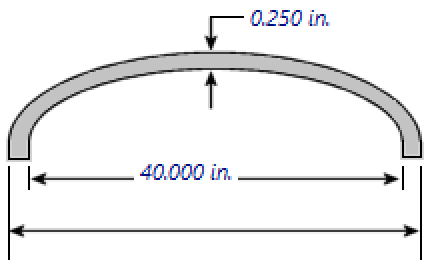
From	To	Design Pressure psig	M.A.W.P. Corroded psig	M.A.P. New & Cold psig	Minimum Thickness in.	Required Thickness in.	Element#
Skirt		...	No Calc	No Calc	0.5	No Calc	1
Btm Head		100	105.2	212.2	0.25	0.24345	2
Shell 1		100	518.3	623.5	0.75	0.2438	3
shell 2		100	518.3	623.5	0.75	0.2438	4
Cone		100	503	605.3	0.75	0.24748	5
Shell 3		100	732.8	882.4	0.75	0.21875	6
Top Head		100	297.7	454.1	0.375	0.21875	7
Minimum			105.2	212.2			

MAWP: 105.2 psig, limited by: Btm Head , Straight Flange Governing

Elements Suitable for Design Internal Pressure.

Internal Pressure Calculation Results:

ASME Code, Section VIII Division 1, 2023



Internal Pressure Results for: Btm Head

Elliptical Head Design Information:				
Design Pressure P	100.000 psig	Int. Design Temperature	200 F
Material	SA-516 70	Ext. Design Temperature	200 F
Length	0.167 ft.	External Pressure Chart	CS-2
		UNS Number	K02700
Int. Corr. All. c	0.1250 in.	Allowable Stress (ope) S	20000.0 psi
Ext. Corr. All. ce	0.0000 in.	Allowable Stress (amb) Sa	20000.0 psi
Inside Diameter Di	40.000 in.	Actual Stress	18952.9 psi
Spec. Min. Thk t,e, or sa	0.2500 in.	Spec. Nominal Thk.	... in.
Surface Area	2032.5 sq.in.	SG of Contents	0.000
Element Volume	10890.9 in3	Weight of Contents	0.0 lb.
Empty Weight	155.1 lb.	Operating Weight	155.1 lb.
		Comp. All. Ope. Stress	13388.6 psi
		Aspect Ratio	2.00

Radiography Information:			
User Defined Circ. Joint Efficiency	70 %	User Defined Long. Joint Efficiency E	85 %

Tolerance for Formed Heads per UG-81(a):

Head inner surface maximum deviation outside the specified shape, 1.25% of D: 0.500 in.
Head inner surface maximum deviation inside the specified shape, 0.625% of D: 0.250 in.

Required Thickness due to Internal Pressure [tr]:

```
= (P*D*K)/(2*S*E-0.2*P) Appendix 1-4(c)
= (100*40.25*1)/(2*20000*0.85-0.2*100)
= 0.1185 + 0.1250 = 0.2435 in.
```

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

```
= (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
= (2*20000*0.85*0.125)/(1*40.25+0.2*0.125)
= 105.5 psig
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
= (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
= (2*20000*0.85*0.25)/(1*40+0.2*0.25)
= 212.2 psig
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
= (P*(K*D+0.2*t))/(2*E*t)
= (100*(1*40.25+0.2*0.125))/(2*0.85*0.125)
= 18952.941 psi
```

Straight Flange Required Thickness:
```
= (P*R)/(S*E-0.6*P) + c    per UG-27 (c)(1)
= (100*20.12)/(20000*0.85-0.6*100)+0.125
= 0.244 in.
```

Straight Flange Maximum Allowable Working Pressure:
```
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (20000 * 0.85 * 0.125 )/(20.12 + 0.6 * 0.125 )
= 105.2 psig
```

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 2.708 %

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 0.25, tr = 0.118, c = 0.125 in., E✱ = 0.85
Thickness Ratio = tr * E✱/(tg - c) = 0.805, Temp. Reduction = 19 F

```
Min Metal Temp. w/o impact per UCS-66, Curve B           -20 F
Min Metal Temp. at Required thickness (UCS 66.1)         -39 F
```

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 0.25, tr = 0.119, c = 0.125 in., E✱ = 0.85
Thickness Ratio = tr * E✱/(tg - c) = 0.808, Temp. Reduction = 19 F

```
Min Metal Temp. w/o impact per UCS-66, Curve B           -20 F
Min Metal Temp. at Required thickness (UCS 66.1)         -39 F
```

MDMT Design Information:			
MDMT Curve	B	Press. at MDMT	100.000 psig
UCS-66(b) red.	Yes	Min. Des. Mtl. Temp.	-20 F
Governing Thk.	0.250 in.	Basic MDMT	-20 F
Stress/Thk. Ratio	0.808	Temperature Difference	19 F
UCS-66(c) red.	No	Computed Min. Temp.	-39 F
		MDMT per UG-20(f)	-20 F
		Joint Efficiency E*	85 %

Note: Temperature values displayed above are for the location with the highest basic MDMT

Tolerance for Formed Heads per UG-81(a):
```
Head inner surface maximum deviation outside the specified shape,  1.25% of D: 0.500 in.
Head inner surface maximum deviation inside the specified shape,  0.625% of D: 0.250 in.
```

EXTERNAL PRESSURE RESULTS for: Btm Head

<u>Elliptical Head From 20 to 30 Ext. Chart: CS-2 at 200 F</u>

Elastic Modulus from Chart: CS-2 at 200 F: 29000000 psi

Results for Maximum Allowable Ext. Pressure	MAEP

Tca	Outer Dia	Do/t	Factor A	Factor B
0.125	40.50	324.00	0.0004287	6215.71

MAEP = B/(K0*Do/t) = 6216/(0.9 *324) = 21.32 psig

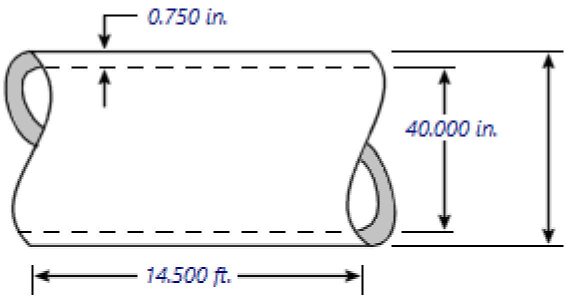
Results for Required Thickness	Tca

Tca	Outer Dia	Do/t	Factor A	Factor B
0.105	40.50	386.22	0.0003596	5214.37

MAEP = B/(K0*Do/t) = 5214/(0.9 *386.2) = 15 psig

Internal Pressure Calculation Results:

ASME Code, Section VIII Division 1, 2023



Internal Pressure Results for: Shell 1

Cylindrical Shell Design Information:

Design Pressure P	100.000 psig	Int. Design Temperature	200 F
Material	SA-516 70	Ext. Design Temperature	200 F
Length	14.500 ft.	External Pressure Chart	CS-2
		UNS Number	K02700
Int. Corr. All. c	0.1250 in.	Allowable Stress (ope) S	20000.0 psi
Ext. Corr. All. ce	0.0000 in.	Allowable Stress (amb) Sa	20000.0 psi
Inside Diameter Di	40.000 in.	Actual Stress	3858.8 psi
Spec. Min. Thk t,e, or sa	0.7500 in.	Spec. Nominal Thk.	... in.
Surface Area	22685.4 sq.in.	SG of Contents	0.000
Element Volume	218654.9 in3	Weight of Contents	0.0 lb.
Empty Weight	4728.0 lb.	Operating Weight	4728.0 lb.
		Comp. All. Ope. Stress	20122.0 psi

Radiography Information:

User Defined Circ. Joint Efficiency	70 %	User Defined Long. Joint Efficiency E	85 %

Required Thickness due to Internal Pressure [tr]:
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
= (100*20.12)/(20000*0.85-0.6*100)
= 0.1188 + 0.1250 = 0.2438 in.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (20000*0.85*0.625)/(20.12+0.6*0.625)
= 518.3 psig

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (20000*0.85*0.75)/(20+0.6*0.75)
= 623.5 psig

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(R+0.6*t))/(E*t)
= (100*(20.12+0.6*0.625))/(0.85*0.625)
= 3858.823 psi

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.840 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 0.75, tr = 0.119, c = 0.125 in., E∗ = 0.85
Thickness Ratio = tr * E∗/(tg - c) = 0.162, Temp. Reduction = 140 F

```
Min Metal Temp. w/o impact per UCS-66, Curve B            16 F
Min Metal Temp. at Required thickness (UCS 66.1)        -155 F
Min Metal Temp. w/o impact per UG-20(f)                  -20 F
```

MDMT Design Information:

MDMT Curve	B	Press. at MDMT	100.000 psig
UCS-66(b) red.	Yes	Min. Des. Mtl. Temp.	-20 F
Governing Thk.	0.750 in.	Basic MDMT	16 F
Stress/Thk. Ratio	0.162	Temperature Difference	171 F
UCS-66(c) red.	No	Computed Min. Temp.	-155 F
		MDMT per UG-20(f)	-20 F
		Joint Efficiency E*	85 %

EXTERNAL PRESSURE RESULTS for: Shell 1

Cylindrical Shell From 30 to 40 Ext. Chart: CS-2 at 200 F

Elastic Modulus from Chart: CS-2 at 200 F: 29000000 psi

Results for Maximum Allowable Ext. Pressure — MAEP

Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
0.625	41.50	350.93	66.40	8.4562	0.0002860	4146.94

MAEP = (4*B)/(3*(Do/t)) = (4*4147)/(3*66.4) = 83.27 psig

Results for Required Thickness — Tca

Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
0.315	41.50	350.93	131.70	8.4562	0.0001022	1481.70

MAEP = (4*B)/(3*(Do/t)) = (4*1482)/(3*131.7) = 15 psig

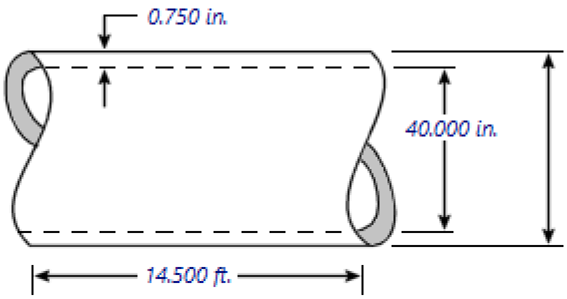
Results for Maximum Stiffened Length — Slen

Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
0.625	41.50	8812.20	66.40	50.0000	0.0002495	3617.63

MAEP = (4*B)/(3*(Do/t)) = (4*3618)/(3*66.4) = 72.64 psig

Internal Pressure Calculation Results:

ASME Code, Section VIII Division 1, 2023



Internal Pressure Results for: shell 2

```
                                                     |                                                |
 Cylindrical Shell Design Information:               |                                                |
------------------------------------------------------------------------------------------------------
   Design Pressure    P             100.000 psig    | Int. Design Temperature          200 F          |
          Material                  SA-516 70       | Ext. Design Temperature          200 F          |
            Length                   14.500 ft.     | External Pressure Chart         CS-2            |
                                                    |              UNS Number        K02700           |
   Int. Corr. All.    c              0.1250 in.     |  Allowable Stress (ope)  S    20000.0 psi       |
   Ext. Corr. All.   ce              0.0000 in.     |  Allowable Stress (amb) Sa    20000.0 psi       |
   Inside Diameter   Di              40.000 in.     |           Actual Stress        3858.8 psi       |
 Spec. Min. Thk t,e, or sa           0.7500 in.     |      Spec. Nominal Thk.           ... in.       |
      Surface Area                  22685.4 sq.in.  |        SG of Contents         0.000             |
    Element Volume                 218654.9 in3     |      Weight of Contents           0.0 lb.       |
      Empty Weight                   4728.0 lb.     |        Operating Weight        4728.0 lb.       |
                                                    |  Comp. All. Ope. Stress       20122.0 psi       |

                                                    |                                                 |
  Radiography Information:                          |                                                 |
------------------------------------------------------------------------------------------------------
  User Defined                                      | User Defined                                    |
  Circ. Joint Efficiency              70 %          | Long. Joint Efficiency    E         85 %        |
------------------------------------------------------------------------------------------------------
```

Required Thickness due to Internal Pressure [tr]:
```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (100*20.12)/(20000*0.85-0.6*100)
  = 0.1188 + 0.1250 = 0.2438 in.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (20000*0.85*0.625)/(20.12+0.6*0.625)
  = 518.3 psig
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (20000*0.85*0.75)/(20+0.6*0.75)
  = 623.5 psig
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(R+0.6*t))/(E*t)
  = (100*(20.12+0.6*0.625))/(0.85*0.625)
  = 3858.823 psi
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 1.840 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 0.75, tr = 0.119, c = 0.125 in., E∗ = 0.85
Thickness Ratio = tr * E∗/(tg - c) = 0.162, Temp. Reduction = 140 F

```
Min Metal Temp. w/o impact per UCS-66, Curve B            16 F
Min Metal Temp. at Required thickness (UCS 66.1)        -155 F
Min Metal Temp. w/o impact per UG-20(f)                  -20 F
```

MDMT Design Information:

MDMT Curve	B	Press. at MDMT	100.000 psig
UCS-66(b) red.	Yes	Min. Des. Mtl. Temp.	-20 F
Governing Thk.	0.750 in.	Basic MDMT	16 F
Stress/Thk. Ratio	0.162	Temperature Difference	171 F
UCS-66(c) red.	No	Computed Min. Temp.	-155 F
		MDMT per UG-20(f)	-20 F
		Joint Efficiency E*	85 %

EXTERNAL PRESSURE RESULTS for: shell 2

Cylindrical Shell From 40 to Ring:[1 of 1] Ext. Chart: CS-2 at 200 F

Elastic Modulus from Chart: CS-2 at 200 F: 29000000 psi

Results for Maximum Allowable Ext. Pressure — MAEP

Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
0.625	41.50	350.93	66.40	8.4562	0.0002860	4146.94

MAEP = (4*B)/(3*(Do/t)) = (4*4147)/(3*66.4) = 83.27 psig

Results for Required Thickness — Tca

Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
0.315	41.50	350.93	131.70	8.4562	0.0001022	1481.70

MAEP = (4*B)/(3*(Do/t)) = (4*1482)/(3*131.7) = 15 psig

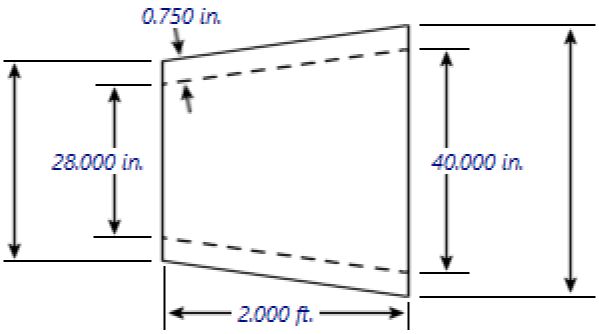
Results for Maximum Stiffened Length — Slen

Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
0.625	41.50	8812.20	66.40	50.0000	0.0002495	3617.63

MAEP = (4*B)/(3*(Do/t)) = (4*3618)/(3*66.4) = 72.64 psig

Internal Pressure Calculation Results:

ASME Code, Section VIII Division 1, 2023



Internal Pressure Results for: Cone

Conical Head/Section Design Information:			
Design Pressure P	100.000 psig	Int. Design Temperature	200 F
Material	SA-516 70	Ext. Design Temperature	200 F
Length	2.000 ft.	External Pressure Chart	CS-2
		UNS Number	K02700
Int. Corr. All. c	0.1250 in.	Allowable Stress (ope) S	20000.0 psi
Ext. Corr. All. ce	0.0000 in.	Allowable Stress (amb) Sa	20000.0 psi
Inside Diameter Di	40.000 in.	Actual Stress	3976.2 psi
Spec. Min. Thk t,e, or sa	0.7500 in.	Spec. Nominal Thk.	... in.
Surface Area	2762.6 sq.in.	SG of Contents	0.000
Element Volume	22016.3 in3	Weight of Contents	0.0 lb.
Empty Weight	573.6 lb.	Operating Weight	573.6 lb.
		Comp. All. Ope. Stress	20197.3 psi
		To End Diameter	28.000 in.
Line of Support	Both Ends		

Radiography Information:			
User Defined Circ. Joint Efficiency	70 %	User Defined Long. Joint Efficiency E	85 %

Required Thickness due to Internal Pressure [tr]:
```
= (P*D)/(2*cos(a)*(S*E-0.6*P)) per Appendix 1-4 (e)
= (100*40.26)/(2*0.97*(20000*0.85-0.6*100))
= 0.1225 + 0.1250 = 0.2475 in.
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
```
= (2*S*E*t*cos(a))/(D+1.2*t*cos(a)) per App 1-4(e)
= (2*20000*0.85*0.625*0.97)/(40.26+1.2*0.625*0.97)
= 503 psig
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
= (2*S*E*t*cos(a))/(D+1.2*t*cos(a)) per App 1-4(e)
= (2*20000*0.85*0.75*0.97)/(40+1.2*0.75*0.97)
= 605.3 psig
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
= (P*(D+1.2*t*cos(a)))/(2*E*t*cos(a))
```

```
= (100*(40.26+1.2*0.625*0.97))/(2*0.85*0.625*0.97)
= 3976.158 psi
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 2.607 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 0.75, tr = 0.122, c = 0.125 in., E✱ = 0.85
Thickness Ratio = tr * E✱/(tg - c) = 0.167, Temp. Reduction = 140 F

```
Min Metal Temp. w/o impact per UCS-66, Curve B          16 F
Min Metal Temp. at Required thickness (UCS 66.1)      -155 F
Min Metal Temp. w/o impact per UG-20(f)                -20 F
```

MDMT Design Information:

MDMT Curve	B	Press. at MDMT	100.000 psig
UCS-66(b) red.	Yes	Min. Des. Mtl. Temp.	-20 F
Governing Thk.	0.750 in.	Basic MDMT	16 F
Stress/Thk. Ratio	0.167	Temperature Difference	171 F
UCS-66(c) red.	No	Computed Min. Temp.	-155 F
		MDMT per UG-20(f)	-20 F
		Joint Efficiency E*	85 %

EXTERNAL PRESSURE RESULTS for: Cone

<u>Cone From 50 to 60 Ext. Chart: CS-2 at 200 F</u>

Elastic Modulus from Chart: CS-2 at 200 F: 29000000 psi

Results for Maximum Allowable Ext. Pressure — MAEP

Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
0.606	41.55	20.53	68.52	0.4942	0.0052117	17384.15

```
MAEP = (4*B)/(3*(Do/t)) = (4*17384 )/(3*68.52 ) = 338.3 psig
```

Note:
The cone thickness used in the calculation has been modified
per UG-33(f), te = t * cos(alpha).

Results for Required Thickness — Tca

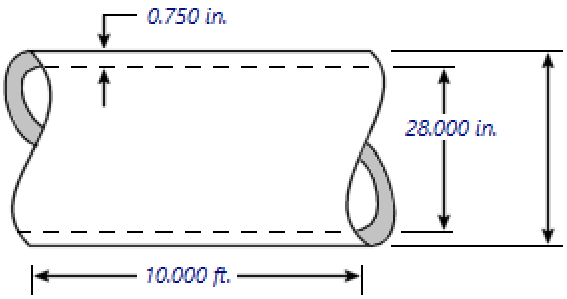
Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
0.100	41.55	20.53	416.90	0.4942	0.0003235	4690.47

```
MAEP = (4*B)/(3*(Do/t)) = (4*4690 )/(3*416.9 ) = 15 psig
```

Note:
The cone thickness used in the calculation has been modified
per UG-33(f), te = t * cos(alpha).

Internal Pressure Calculation Results:

ASME Code, Section VIII Division 1, 2023



Internal Pressure Results for: Shell 3

Cylindrical Shell Design Information:

Design Pressure P	100.000 psig	Int. Design Temperature	200 F
Material	SA-516 70	Ext. Design Temperature	200 F
Length	10.000 ft.	External Pressure Chart	CS-2
		UNS Number	K02700
Int. Corr. All. c	0.1250 in.	Allowable Stress (ope) S	20000.0 psi
Ext. Corr. All. ce	0.0000 in.	Allowable Stress (amb) Sa	20000.0 psi
Inside Diameter Di	28.000 in.	Actual Stress	2729.4 psi
Spec. Min. Thk t,e, or sa	0.7500 in.	Spec. Nominal Thk.	... in.
Surface Area	11121.2 sq.in.	SG of Contents	0.000
Element Volume	73890.3 in3	Weight of Contents	0.0 lb.
Empty Weight	2300.5 lb.	Operating Weight	2300.5 lb.
		Comp. All. Ope. Stress	20892.0 psi

Radiography Information:

User Defined Circ. Joint Efficiency	70 %	User Defined Long. Joint Efficiency E	85 %

Required Thickness due to Internal Pressure [tr]:
```
 = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
 = (100*14.12)/(20000*0.85-0.6*100)
 = 0.0834 + 0.1250 = 0.2084 in.
```

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 0.0938 in. per UG-16 will be used.

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
```
 = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
 = (20000*0.85*0.625)/(14.12+0.6*0.625)
 = 732.8 psig
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
 = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
 = (20000*0.85*0.75)/(14+0.6*0.75)
 = 882.4 psig
```

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

```
 = (P*(R+0.6*t))/(E*t)
 = (100*(14.12+0.6*0.625))/(0.85*0.625)
 = 2729.412 psi
```

% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro)) 2.609 %

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 0.75, tr = 0.0938, c = 0.125 in., E∗ = 0.85
Thickness Ratio = tr * E∗/(tg - c) = 0.128, Temp. Reduction = 140 F

```
Min Metal Temp. w/o impact per UCS-66, Curve B          16 F
Min Metal Temp. at Required thickness (UCS 66.1)      -155 F
Min Metal Temp. w/o impact per UG-20(f)                -20 F
```

MDMT Design Information:

MDMT Curve	B	Press. at MDMT	100.000 psig
UCS-66(b) red.	Yes	Min. Des. Mtl. Temp.	-20 F
Governing Thk.	0.750 in.	Basic MDMT	16 F
Stress/Thk. Ratio	0.128	Temperature Difference	171 F
UCS-66(c) red.	No	Computed Min. Temp.	-155 F
		MDMT per UG-20(f)	-20 F
		Joint Efficiency E*	85 %

EXTERNAL PRESSURE RESULTS for: Shell 3

<u>Cylindrical Shell From 60 to 70 Ext. Chart: CS-2 at 200 F</u>

Elastic Modulus from Chart: CS-2 at 200 F: 29000000 psi

Results for Maximum Allowable Ext. Pressure — MAEP

Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
0.625	29.50	124.33	47.20	4.2147	0.0009662	12216.93

MAEP = (4*B)/(3*(Do/t)) = (4*12217)/(3*47.2) = 345.1 psig

Results for Required Thickness — Tca

Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
0.169	29.50	124.33	174.25	4.2147	0.0001352	1960.33

MAEP = (4*B)/(3*(Do/t)) = (4*1960)/(3*174.2) = 15 psig

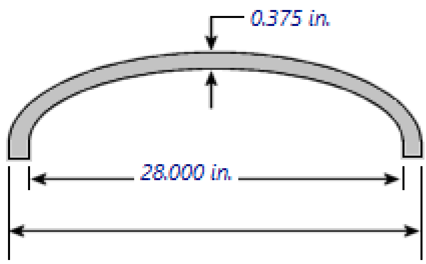
Results for Maximum Stiffened Length — Slen

Tca	Outer Dia	Slen	Do/t	L/D	Factor A	Factor B
0.625	29.50	8040.88	47.20	50.0000	0.0004938	7159.40

MAEP = (4*B)/(3*(Do/t)) = (4*7159)/(3*47.2) = 202.2 psig

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

ASME Code, Section VIII Division 1, 2023



Internal Pressure Results for: Top Head

Elliptical Head Design Information:					
Design Pressure	P	100.000 psig	Int. Design Temperature		200 F
Material		SA-516 70	Ext. Design Temperature		200 F
Length		0.167 ft.	External Pressure Chart		CS-2
			UNS Number		K02700
Int. Corr. All.	c	0.1250 in.	Allowable Stress (ope)	S	20000.0 psi
Ext. Corr. All.	ce	0.0000 in.	Allowable Stress (amb)	Sa	20000.0 psi
Inside Diameter	Di	28.000 in.	Actual Stress		6658.8 psi
Spec. Min. Thk t,e, or sa		0.3750 in.	Spec. Nominal Thk.		... in.
Surface Area		1076.6 sq.in.	SG of Contents		0.000
Element Volume		4105.0 in3	Weight of Contents		0.0 lb.
Empty Weight		121.2 lb.	Operating Weight		121.2 lb.
			Comp. All. Ope. Stress		18377.1 psi
			Aspect Ratio		2.00

Radiography Information:					
User Defined Circ. Joint Efficiency		70 %	User Defined Long. Joint Efficiency	E	85 %

Tolerance for Formed Heads per UG-81(a):

Head inner surface maximum deviation outside the specified shape, 1.25% of D: 0.350 in.
Head inner surface maximum deviation inside the specified shape, 0.625% of D: 0.175 in.

Required Thickness due to Internal Pressure [tr]:

```
= (P*D*K)/(2*S*E-0.2*P) Appendix 1-4(c)
= (100*28.25*1)/(2*20000*0.85-0.2*100)
= 0.0831 + 0.1250 = 0.2081 in.
```

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 0.0938 in. per UG-16 will be used.

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

```
= (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
= (2*20000*0.85*0.25)/(1*28.25+0.2*0.25)
= 300.4 psig
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
  = (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
  = (2*20000*0.85*0.375)/(1*28+0.2*0.375)
  = 454.1 psig
```

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

```
  = (P*(K*D+0.2*t))/(2*E*t)
  = (100*(1*28.25+0.2*0.25))/(2*0.85*0.25)
  = 6658.823 psi
```

Straight Flange Required Thickness:

```
  = (P*R)/(S*E-0.6*P) + c    per UG-27 (c)(1)
  = (100*14.12)/(20000*0.85-0.6*100)+0.125
  = 0.208 in.
```

Straight Flange Maximum Allowable Working Pressure:

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (20000 * 0.85 * 0.25 )/(14.12 + 0.6 * 0.25 )
  = 297.7 psig
```

Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro) 5.685 %
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 0.375, tr = 0.0938, c = 0.125 in., E∗ = 0.85
Thickness Ratio = tr * E∗/(tg - c) = 0.319, Temp. Reduction = 140 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve B            -20 F
 Min Metal Temp. at Required thickness (UCS 66.1)         -155 F
```

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 0.375, tr = 0.0938, c = 0.125 in., E∗ = 0.85
Thickness Ratio = tr * E∗/(tg - c) = 0.319, Temp. Reduction = 140 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve B            -20 F
 Min Metal Temp. at Required thickness (UCS 66.1)         -155 F
```

MDMT Design Information:			
MDMT Curve	B	Press. at MDMT	100.000 psig
UCS-66(b) red.	Yes	Min. Des. Mtl. Temp.	-20 F
Governing Thk.	0.375 in.	Basic MDMT	-20 F
Stress/Thk. Ratio	0.319	Temperature Difference	135 F
UCS-66(c) red.	No	Computed Min. Temp.	-155 F
		MDMT per UG-20(f)	-20 F
		Joint Efficiency E*	85 %

Note: Temperature values displayed above are for the location with the highest basic MDMT

Tolerance for Formed Heads per UG-81(a):

```
 Head inner surface maximum deviation outside the specified shape,  1.25% of D: 0.350 in.
 Head inner surface maximum deviation inside the specified shape,  0.625% of D: 0.175 in.
```

EXTERNAL PRESSURE RESULTS for: Top Head

Elliptical Head From 70 to 80 Ext. Chart: CS-2 at 200 F

Elastic Modulus from Chart: CS-2 at 200 F: 29000000 psi

Results for Maximum Allowable Ext. Pressure				MAEP
Tca	Outer Dia	Do/t	Factor A	Factor B
0.250	28.75	115.00	0.0012077	13182.19

MAEP = B/(K0*Do/t) = 13182/(0.9 *115) = 127.4 psig

Results for Required Thickness				Tca
Tca	Outer Dia	Do/t	Factor A	Factor B
0.074	28.75	386.22	0.0003596	5214.36

MAEP = B/(K0*Do/t) = 5214/(0.9 *386.2) = 15 psig

Hydrostatic Test Pressure Results:

UG99(b)	= 1.30 * M.A.W.P. * Sa/S	136.757 psig
UG99b(b)(35)	= 1.30 * Design Pres * Sa/S	130.000 psig
UG99(c)	= 1.30 * M.A.P. - Head(Hyd)	274.459 psig
UG100	= 1.10 * M.A.W.P. * Sa/S	115.718 psig
PED	= max(1.43*DP, 1.25*DP*ratio)	143.000 psig
PED&UG99(b)(35)	= max(1.43*DP, 1.3*DP*ratio)	143.000 psig
App 27-4	= M.A.W.P.	105.198 psig

UG-99(b) Note 35, Test Pressure Calculation:
= Test Factor * Design Pressure * Stress Ratio
= 1.3 * 100 * 1
= 130.000 psig

Horizontal Test performed per: UG-99b (Note 35)

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
Btm Head	12386.7	26000.0	0.476	131.44
Shell 1	4216.5	26000.0	0.162	131.44
shell 2	4216.5	26000.0	0.162	131.44
Cone	4343.4	26000.0	0.167	131.44
Shell 3	2969.6	26000.0	0.114	131.01
Top Head	5769.6	26000.0	0.222	131.01

Stress ratios for Nozzle and Pad Materials (psi):

Description	Pad/Nozzle	Ambient	Operating	Ratio
Drain	Nozzle	17100.00	17100.00	1.000
Manway	Nozzle	17100.00	17100.00	1.000
Inlet	Nozzle	17100.00	17100.00	1.000
Outlet	Nozzle	17100.00	17100.00	1.000
Vent	Nozzle	17100.00	17100.00	1.000
Minimum				1.000

Stress ratios for Stiffening Ring Materials (psi):

Description	Ambient	Operating	Ratio
Ring:[1 of 1]	20000.00	20000.00	1.000
Minimum			1.000

Stress ratios for Pressurized Vessel Elements (psi):

Description	Ambient	Operating	Ratio
Btm Head	20000.00	20000.00	1.000
Shell 1	20000.00	20000.00	1.000
shell 2	20000.00	20000.00	1.000
Cone	20000.00	20000.00	1.000

Shell 3	20000.00	20000.00	1.000
Top Head	20000.00	20000.00	1.000
Minimum			1.000

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

Description	Ambient	Operating	Ratio
Drain	714.18	22230.00	0.032
Manway	2050.53	22230.00	0.092
Inlet	1502.46	22230.00	0.068
Outlet	1497.50	22230.00	0.067
Vent	629.95	22230.00	0.028

Elements Suitable for Test Pressure.

External Pressure Calculation Results Summary:

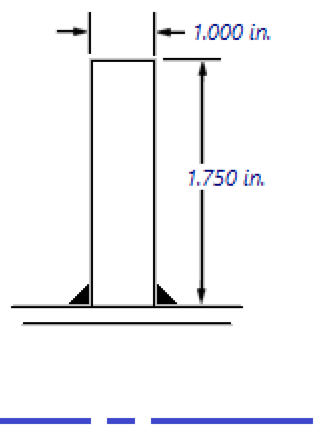
ASME Code, Section VIII Division 1, 2023

MDMT Calculations for: Ring:[1 of 1], Shell to Ring Junction, Curve: B

Govrn. thk, tg = 0.75, tr = 0.119, c = 0.125 in., E✱ = 0.85
Thickness Ratio = tr * E✱/(tg - c) = 0.162, Temp. Reduction = 140 F

Min Metal Temp. w/o impact per UCS-66, Curve B	16 F
Min Metal Temp. at Required thickness (UCS 66.1)	-155 F
Min Metal Temp. w/o impact per UG-20(f)	-20 F

Stiffening Ring Calculations for: Ring:[1 of 1], SA-516 70 , Bar Ring: 1.7500 x 1.0000 in.



Effective Length of Shell: 5.60 in.

	Area (sq.in.)	Distance (in.)	Area*Dist
Shell:	3.501	0.3125	1.094
Ring :	1.750	1.5000	2.625
Total:	5.251		3.719

Centroid of Ring plus Shell: 0.708 in.

	Inertia	Distance	A*Dist²
Shell:	0.114	0.3957	0.548
Ring :	0.447	-0.7918	1.097
Total:	0.561		1.645

Available Moment of Inertia, Ring plus Shell: 2.206 in**4

Required Stress in Ring plus Shell	Breq	735.35 psi
Required Strain in Ring plus Shell	Areq	0.0000507

Required Moment of Inertia, Ring plus Shell:

= (Do² * Ls(t + As/Ls)A)/10.9
= (41.5²*176.7(0.625+1.75/176.7)0.50713E-04)/10.9
= 0.8988 in**4

Results for Stiffening Ring Weld Calculations per UG-30:

Given Stiffening Ring Fillet Weld Size	Wleg	0.500	in.
Stiffening Ring Attachment Style		BOTH	
Location of Stiffening Ring		EXTERNAL	
Radial Pressure Load	Pext*Slen	2650.00	lb./in.
The Radial Shear Load	V	1099.75	lb.
The First Moment of the Area (Ring + Shell)	Q	1.39	in.³
Weld Shear Flow due to Rad. Shear Load	VQ/I	690.76	lb./in.
The Weld Allowable Stress	0.55*S	11000.00	psi
Minimum Weld Leg Size Min(0.25", t, tw)	Wldmin	0.25	in.
Max Clear Spacing bet Toes of Adj Weld Segments, 24t		15.00	in.
The Weld Allowable Load	WLeg*0.55*S	5500.00	lb./in.
The Combined Weld Load	SRSS of VQ/I and Pext*Slen	2738.55	lb./in.
MAEP of Stiffening Ring Weld	Weld MAEP	30.13	psi

External Pressure Calculations:

From	To	Section Length ft.	Outside Diameter in.	Corroded Thickness in.	Factor A	Factor B psi
10	20	No Calc	...	...	No Calc	No Calc
20	30	No Calc	40.5	0.125	0.00042867	6215.71
30	40	29.2444	41.5	0.625	0.000286	4146.94
40	Ring	29.2444	41.5	0.625	0.000286	4146.94
Ring	50	0.2	41.5	0.625	0.1	17800
50	60	1.71084	41.5462	0.625	0.0052117	17384.2
60	70	10.3611	29.5	0.625	0.0009662	12216.9
70	80	No Calc	28.75	0.25	0.0012077	13182.2

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	...	No Calc	...	No Calc
20	30	0.25	0.22986	15	21.32
30	40	0.75	0.4401	15	83.27
40	Ring	0.75	0.4401	15	83.27
Ring	50	0.75	0.16469	15	357.4
50	60	0.75	0.22772	15	338.3
60	70	0.75	0.2943	15	345.1
70	80	0.375	0.19944	15	127.4
Ring:[1 of 1]					30.13
Minimum					21.32

External Pressure Calculations:

From	To	Actual Length Bet. Stiffeners ft.	Allowable Length Bet. Stiffeners ft.	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	29.2444	734.35	No Calc	No Calc
40	Ring	29.2444	734.35	No Calc	No Calc
Ring	50	0.2	4.76572	0.89879	2.20599
50	60	1.71084	1.71084	No Calc	No Calc

```
   60|    70|        10.3611 |          670.073 |      No Calc |      No Calc |
   70|    80|        No Calc |          No Calc |      No Calc |      No Calc |
 -----------------------------------------------------------------------------
```

Elements Suitable for External Pressure.

Element and Detail Weights:

From	To	Element Metal Wgt. lb.	Element ID Volume in3	Corroded Metal Wgt. lb.	Corroded ID Volume in3	Extra due Misc % lb.
10	20	1244.54	...	1244.54	...	248.908
20	30	155.075	10890.9	77.5376	11080.4	31.015
30	40	4727.96	218655	3952.06	221397	945.592
40	50	4727.96	218655	3952.06	221397	945.592
50	60	573.61	22016.3	479.78	22347.8	114.722
60	70	2300.47	73890.3	1925.39	75215.6	460.094
70	80	121.186	4105.01	80.7908	4204.76	24.2373
Total		13850	548212	11712	555641	2770

Weight of Details:

From	Type	Weight of Detail lb.	X Offset, Dtl. Cent. ft.	Y Offset, Dtl. Cent. ft.	Z Offset Dtl. Cent. ft.	Description
20	Nozl	22.1567	...	-1.23958	...	Drain
30	Nozl	234.259	1.91667	3	...	Manway
40	Ring	80.7499	...	14.3	...	Ring:[1 of 1]
40	Nozl	46.0679	1.91667	2.33333	...	Inlet
60	Nozl	46.0679	1.41667	8	...	Outlet
70	Nozl	18.2316	...	0.98438	...	Vent

Total Weight of Each Detail Type:

Stiffeners	80.7
Nozzles	366.8
Sum of the Detail Weights	447.5 lb.

Weight Summation Results: (lb.)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	16621.0	16621.0	16621.0	16621.0	16621.0	16621.0
Stif. Rings	80.7	80.7	80.7	80.7	80.7	80.7
Nozzles	366.8	366.8	366.8	366.8	366.8	366.8
Test Liquid	...	19796.5	...	...	...	...
Totals	17068.5	36865.0	17068.5	17068.5	17068.5	17068.5

Miscellaneous Weight Percent: 20.0 %

Note that the above value for the miscellaneous weight percent has been applied to the shells/heads/flange/tubesheets/tubes etc. in the weight calculations for metallic components.

Weight Summary:

Fabricated Wt.	- Bare weight without removable internals	17068.5 lb.
Shop Test Wt.	- Fabricated weight + water (full)	36865.0 lb.
Shipping Wt.	- Fab. weight + removable intls.+ shipping app.	17068.5 lb.
Erected Wt.	- Fab. wt + or - loose items (trays,platforms etc.)	17068.5 lb.
Ope. Wt. no Liq	- Fab. weight + internals. + details + weights	17068.5 lb.

Operating Wt. - Empty weight + operating liq. uncorroded 17068.5 lb.

Weights used in Vortex Shedding Calculations:

Mass of the Upper 1/3 of the Vertical Vessel (operating) 3982.2 lb.
Mass of the Upper 1/3 of the Vertical Vessel (filled w/water) 8790.4 lb.
Mass of the Upper 1/3 of the Vertical Vessel (empty) 4761.0 lb.

Surface Areas of Elements:

From	To	Outside Surface Area sq.in.	Inside Surface Area sq.in.
10	20	4806.64	4693.54
20	30	2032.48	1985.7
30	40	22685.4	21865.5
40	50	22685.4	21865.5
50	60	2762.6	2642.44
60	70	11121.2	10555.8
70	80	1076.62	1025.77
Total		67170.5	64634.2 sq.in.
Total		466.5	448.8 ft^2

Element and Detail Weights:

From	To	Total Ele. Empty Wgt. lbm	Total. Ele. Oper. Wgt. lbm	Total. Ele. Hydro. Wgt. lbm	Total Dtl. Offset Mom. ft.lb.	Oper. Wgt. No Liquid lbm
10	20	1493.45	1493.45	1493.45	...	1493.45
20	30	208.247	208.247	601.528	...	208.247
30	40	5907.81	5907.81	13803.7	448.997	5907.81
40	50	5800.37	5800.37	13696.2	88.2969	5800.37
50	60	688.332	688.332	1483.36	...	688.332
60	70	2806.63	2806.63	5474.89	65.2629	2806.63
70	80	163.655	163.655	311.892	...	163.655

Cumulative Vessel Weight

From	To	Cumulative Ope Wgt. No Liquid lbm	Cumulative Oper. Wgt. lbm	Cumulative Hydro. Wgt. lbm
10	20	17068.5	17068.5	36865
20	30	15575	15575	35371.6
30	40	15366.8	15366.8	34770.1
40	50	9458.99	9458.99	20966.4
50	60	3658.62	3658.62	7270.15
60	70	2970.29	2970.29	5786.78
70	80	163.655	163.655	311.892

The cumulative operating weights no liquid in the column above are the cumulative operating weights minus the operating liquid weight minus any weights absent in the empty condition.

Cumulative Vessel Moment

From	To	Cumulative Empty Mom.	Cumulative Oper. Mom.	Cumulative Hydro. Mom.

		ft.lb.	ft.lb.	ft.lb.
10	20	602.557	602.557	602.557
20	30	602.557	602.557	602.557
30	40	602.557	602.557	602.557
40	50	153.56	153.56	153.56
50	60	65.2629	65.2629	65.2629
60	70	65.2629	65.2629	65.2629
70	80	...	...	...

Nozzle Flange MAWP Results: (psig & F)

Nozzle Description	Flange Rating Ope.	Flange Rating Ambient	Des. Temp	Class	Grade/Group	Equiv. Press	Max Pressure UG-44	Max Pressure 50%	Max Pressure DNV
Drain	260.0	285.0	200	150	GR 1.1	...	...	...	...
Manway	260.0	285.0	200	150	GR 1.1	...	...	...	...
Inlet	260.0	285.0	200	150	GR 1.1	...	...	...	...
Outlet	260.0	285.0	200	150	GR 1.1	...	...	...	...
Vent	260.0	285.0	200	150	GR 1.1	...	...	...	...
Min Rating	260.0	285.0, [for Core Elements]					...	...	...

Flange Pressure Ratings are per ASME B16.5 2020 Edition

The Natural Frequencies for the vessel have been computed iteratively by solving a system of matrices. These matrices describe the mass and the stiffness of the vessel. This is the generalized eigenvalue/ eigenvector problem and is referenced in some mathematical texts.

The Natural Frequency for the Vessel (Empty.) is 4.69928 Hz.

The Natural Frequency for the Vessel (Ope...) is 4.69928 Hz.

Wind Load Calculation Results:

Input Values:

Wind Design Code	NBC-2005	
Design Wind Speed	70	mile/hr
Exposure Category	B, Rough Terrain	
Importance Factor	1.0	
Roughness Classification	Moderately smooth	
Base Elevation	0	ft.
Percent Wind for Hydrotest	33.0	
Using User defined Wind Press. Vs Elev.	N	
Damping Factor (Beta) for Wind (Ope)	0.0080	
Damping Factor (Beta) for Wind (Empty)	0.0000	
Damping Factor (Beta) for Wind (Filled)	0.0000	
Height of Hill or Escarpment H or Hh	0	ft.
Distance Upwind of Crest Lh	0	ft.
Distance from Crest to the Vessel x	0	ft.
Type of Terrain (Hill, Escarpment)	Flat	

Calculated Values:

Gust Effect Factor	[Cg]	2.00	
Force Coefficient	[Cf]	0.665	
External Pressure Coefficient	[Cp]	1.000	
Vessel Height to Diameter ratio		18.76	
Natural Frequency of Vessel (Operating)		4.699	Hz
Natural Frequency of Vessel (Empty)		4.699	Hz
Natural Frequency of Vessel (Test)		3.506	Hz

Equation to determine the Wind Pressure at level h [p(h)]:
= Iw * q * Ce(height,Exp) * Cg * Cp [4.1.7.1](2005/2010)

Intermediate values for each element are shown below, Static Analysis:

Element	Ce	Cg	Iw	q
Skirt	0.700	2.000	1.000	13.230
Btm Head	0.700	2.000	1.000	13.230
Shell 1	0.700	2.000	1.000	13.230
shell 2	0.700	2.000	1.000	13.230
Cone	0.700	2.000	1.000	13.230
Shell 3	0.700	2.000	1.000	13.230
Top Head	0.726	2.000	1.000	13.230

Height to diameter ratio was greater than 4 and Fn > 1, therefore Cg = 2.

Wind Pressure on the first element [p]:
= Iw * q * Ce * Cg
= 1 * 13.23 * 0.7 * 2
= 18.522 psf

Force on the first element [F]:
= p * Wind Area * Cf
= 18.52 * 12.75 * 0.665
= 157.123 lb.

Wind Vibration Calculations

This evaluation is based on work by Kanti Mahajan and Ed Zorilla

Nomenclature

```
 Cf  - Correction factor for natural frequency
  D  - Average outer insulated diameter of vessel, ft.
 Df  - Damping Factor < 0.75 Unstable,  > 0.95 Stable
 Dr  - Average outer insulated of top half of vessel, ft.
  f  - Natural frequency of vibration (Hertz)
 f1  - Natural frequency of bare vessel based on a unit value of (D/L²)(10⁴)
  L  - Total height of structure ft.
 Lc  - Total length of conical section(s) of vessel, ft.
 tb  - Uncorroded plate thickness at bottom of vessel, in.
 V30 - Design Wind Speed provided by user, mile/hr
 Vc  - Critical wind velocity, mile/hr
 Vw  - Maximum wind speed at top of structure, mile/hr
 W   - Total corroded weight of structure, lb.
 Ws  - Cor. vessel weight excl. weight of parts which do not effect stiff. lb.
  Z  - Maximum amplitude of vibration at top of vessel, in.
 Dl  - Logarithmic decrement ( taken as 0.03 for Welded Structures )
 Vp  - Vib. Chance, <= 20.00 (High); 20.00 < 25.00 (Probable)
 P30 - wind pressure 30 feet above the base
```

Check other Conditions and Basic Assumptions:

```
 :: Total Cone Length / Total Length < 0.5
 :: 2/44.33 = 0.0451

 :: [ D / L² ] * 10⁴ < 8 (English Units, ft.)
 :: [ 3.212/44.33² ] * 10⁴ = 16.34 [Geometry Violation]
```

Compute the vibration possibility. If Vp > 25.00 no chance. [Vp]:

```
  = W / ( L * Dr²)
  = 14502/( 44.33 * 2.954² )
  = 0.37484E+02
```

Since Vp is > 25.00 no further vibration analysis is required !

The Natural Frequency for the Vessel (Ope...) is 4.69928 Hz.

Wind Load Calculation:

From	To	Wind Height ft.	Wind Diameter ft.	Wind Area sq.in.	Wind Pressure psf	Element Wind Load lb.
10	20	1.5	4.25	1836	18.522	157.123
20	30	3.08333	4.05	97.2	18.522	8.31829
30	40	10.4167	4.15	8665.2	18.522	741.56
40	50	24.9167	4.15	8665.2	18.522	741.56
50	60	33.1078	3.55	1022.4	18.522	87.4961
60	70	39.1667	2.95	4248	18.522	363.54
70	80	44.5058	2.875	268.835	19.2157	23.8683

Earthquake Load Calculation Results:

Input Values:

Seismic Design Code	NBC-2005
Importance Factor	1.000
Overstrength Factor	1.0000
Ductility Factor	3.0000
Height Ratio (hx/hn)	0.0000
Component Amplification factor [Rp]	2.5000
Element or Component factor [Cp]	1.0000
Component Force factor [Ar]	2.5000
Site Class	C
Acceleration Sa(0.2)	0.1500
Acceleration Sa(0.5)	0.0840
Acceleration Sa(1.0)	0.0410
Acceleration Sa(2.0)	0.0230

To determine values of Sa(T), copy and paste the following link into your browser:
https://www.earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/nbc2020-cnb2020-en.php

Computed Results:

Fundamental Period of Vibration [T]:
```
  = 1/Fn
  = 1/4.699
  = 0.213 Seconds
```

Design Spectral Acceleration Candidates per 4.1.8.4:

Case #	Fa:Fv	Sa()	Value	Applicable Time Period
1	0.150	Sa(0.2)	0.150	T <= 0.2s
2	0.147	Sa(0.5)	0.084	T = 0.5s
3	0.041	Sa(1.0)	0.041	T = 1.0s
4	0.023	Sa(2.0)	0.023	T = 2.0s
5	0.012	Sa(2.0)/2	0.023	T >= 4.0s

Final Selected value of S(Ta) based on the calculated period [S(Ta)]:
```
  = 0.147 g's
```

Base Shear per 4.1.8.11 [V]:
```
  = S(Ta) * Ie * W / ( Ro * Rd )
  = 0.147 * 1 * 17068/( 1 * 3 )
  = 837.4 lb.
```

Minimum Base Shear per 4.1.8.11 [Vmin]:
```
  = S(2.0) * Ie * W / ( Ro * Rd )
  = 0.023 * 1 * 17068/( 1 * 3 )
  = 130.9 lb.
```

For Rd >= 1.5, V need not be greater than [Vmax]:
```
  = 2/3 * S(0.2) * Ie * W / ( Ro * Rd )
  = 2/3 * 0.15 * 1 * 17068/( 1 * 3 )
  = 569 lb.
```

Sample Force Calculation for the first Element [F]:
```
  = ( (V-Ft) * Wx * Hx / (Sum of Wi * hi )) * Scalar
  = ( (569 ) * 1493 * 1.5/(348946 )) * 1
  = 3.7 lb.
```

The Natural Frequency for the Vessel (Ope...) is 4.69928 Hz.

Earthquake Load Calculation:

From	To	Earthquake Height ft.	Earthquake Weight lb.	Element Ope Load lb.	Element Emp Load lb.	Element Vertical Load lb.
10	20	1.5	1493.45	3.65257	3.65257	...
20	30	3.08333	208.247	1.04692	1.04692	...
30	40	10.4167	5907.81	100.339	100.339	...
40	50	24.9167	5800.37	235.647	235.647	...
50	60	33.1667	688.332	37.2234	37.2234	...
60	70	39.1667	2806.63	179.233	179.233	...
70	80	44.25	163.655	11.8075	11.8075	...

The Earthquake Weight does not include the weight of the saddles.

The following table is for the Operating Case.

Wind/Earthquake Shear, Bending:

From	To	Distance to Support ft.	Cumulative Wind Shear lb.	Earthquake Shear lb.	Wind Bending ft.lb.	Earthquake Bending ft.lb.
10	20	1.5	2123.47	568.95	44666	15705.5
20	30	3.08333	1966.34	565.297	38531.3	14004.1
30	40	10.4167	1958.03	564.251	38204.3	13910
40	50	24.9167	1216.46	463.911	15189.2	6455.82
50	60	33.1667	474.905	228.264	2926.79	1437.55
60	70	39.1667	387.408	191.041	2064.48	1018.25
70	80	44.25	23.8683	11.8075	8.09539	4.00475

Note:
The Wind Shears/Moments and the Earthquake Shears/Moments calculated and printed in the Wind/Earthquake Shear and Bending report have been factored by the input Scalar/Load reductions factors of;
Wind: 1.000; Earthquake: 1.000.

Wind Deflection Calculations:

The following table is for Wind Deflection; Operating Case.

Wind Load Deflection:

From	To	Cumulative Shear lb.	Centroid Deflection in.	Elem. End Deflection in.	Elem. Ang. Rotation
10	20	2123.47	0.00020234	0.00079022	0.42847E-04
20	30	1966.34	0.00083555	0.00088583	0.52743E-04
30	40	1958.03	0.0086438	0.021214	0.00016432
40	50	1216.46	0.036682	0.053645	0.00019961
50	60	474.905	0.056048	0.058465	0.00020199
60	70	387.408	0.070775	0.083251	0.0002082
70	80	23.8683	0.083459	0.083667	0.0002082

Critical Wind Velocity for Tower Vibration:

From	To	1st Crit. Wind Speed mile/hr	2nd Crit. Wind Speed mile/hr
10	20	67.9046	424.404
20	30	64.7091	404.432
30	40	66.3068	414.418
40	50	66.3068	414.418
50	60	56.7203	354.502
60	70	47.1338	294.586
70	80	45.9354	287.096

Allowable deflection at the Tower Top (Ope)(6.000"/100ft. Criteria)
Allowable deflection : 2.660 Actual deflection : 0.084 in.

Longitudinal Stress Constants:

From	To	Metal Area New sq.in.	Metal Area Corroded sq.in.	Section Modulus New in.^3	Section Modulus Corroded in.^3
10	20	65.9734	65.9734	684.669	684.669
20	30	31.6123	15.8552	316.147	159.546
30	40	96.0149	80.2579	960.8	807.973
40	50	96.0149	80.2579	960.8	807.973
50	60	99.026	82.7824	990.973	833.571
60	70	67.7406	56.6959	474.83	400.79
70	80	33.4285	22.3838	234.081	158.11

Longitudinal Allowable Stresses:

From	To	Tensile psi	Hydrotest Tensile psi	Compressive psi	Hydrotest Compressive psi
10	20	16800	21840	-19414.6	-19414.6
20	30	16800	21840	-13388.6	-16972.4
30	40	16800	21840	-20122	-20563.3
40	50	16800	21840	-20122	-20563.3
50	60	16800	21840	-20197.3	-20627.6
60	70	16800	21840	-20892	-21204.7
70	80	16800	21840	-18377.1	-19725.5

Longitudinal Stress Report

Longitudinal Operating and Empty Stresses are computed in the corroded condition. Stresses due to loads in the hydrostatic test cases have been computed in the new and cold condition.

Longitudinal Pressure Stresses due to:

From	To	Longitudinal Stress Internal Pressure psi	Longitudinal Stress External Pressure psi	Longitudinal Stress Hydrotest Pressure psi
10	20	...	...	...
20	30	8030	-1218.76	5174
30	40	1590	-252.807	1707.33
40	50	1590	-252.807	1707.33
50	60	1589.69	-253.203	1706.53
60	70	1110	-180.831	1187.33
70	80	2805	-435.033	2400.67

Longitudinal Stresses due to Weight Loads for these Conditions:

From	To	Wght. Str. Empty psi	Wght. Str. Operating psi	Wght. Str. Hydrotest psi	Wght. Str. Emp. Mom. psi	Wght. Str. Opr. Mom. psi
10	20	-258.718	-258.718	...	10.5608	10.5608
20	30	-982.329	-982.329	...	45.3203	45.3203
30	40	-191.468	-191.468	...	8.94917	8.94917
40	50	-117.857	-117.857	...	2.28067	2.28067
50	60	-44.1956	-44.1956	...	0.93952	0.93952
60	70	-52.3898	-52.3898	...	1.95403	1.95403
70	80	-7.31131	-7.31131	...	...	...

Longitudinal Stresses due to Weight Loads and Bending for these Conditions:

From	To	Wght. Str. Hyd. Mom. psi	Bend. Str. Oper. Wind psi	Bend. Str. Oper. Equ. psi	Bend. Str. Hyd. Wind psi	Bend. Str. Hyd. Equ. psi
10	20	...	782.849	275.266	...	...
20	30	...	2898.07	1053.3	...	...
30	40	...	567.409	206.591	...	...
40	50	...	225.59	95.8818	...	...
50	60	...	42.1338	20.6948	...	...
60	70	...	61.8122	30.4871	...	...
70	80	...	0.61441	0.30395	...	...

Longitudinal Stresses due to these Conditions:

From	To	Vortex Shedding Operating Case psi	Vortex Shedding Empty Case psi	Vortex Shedding Test Case psi	Earthquake Empty Case psi
10	20	...	...	...	275.266
20	30	...	...	...	1053.3

30	40	...	...	...	206.591
40	50	...	...	...	95.8818
50	60	...	...	...	20.6948
60	70	...	...	...	30.4871
70	80	...	...	...	0.30395

Longitudinal Stresses due to Applied Axial Forces:

From	To	Longitudinal Stress Y Forces Wind psi	Longitudinal Stress Y Forces Seismic psi
10	20	...	...
20	30	...	...
30	40	...	...
40	50	...	...
50	60	...	...
60	70	...	...
70	80	...	...

Longitudinal Stresses due to User Forces and Moments:

From	To	Wind For/Mom Corroded psi	Earthquake For/Mom Corroded psi	Wind For/Mom No Corrosion psi	Earthquake For/Mom No Corrosion psi
10	20	...	...	...	...
20	30	...	...	...	...
30	40	...	...	...	...
40	50	...	...	...	...
50	60	...	...	...	...
60	70	...	...	...	...
70	80	...	...	...	...

Bending Stresses due to Blast Load:

From	To	Bending Stress psi
10	20	...
20	30	...
30	40	...
40	50	...
50	60	...
60	70	...
70	80	...

Stress Combination Load Cases for Vertical Vessels:

Load Case Definition Key

IP = Longitudinal Stress due to Internal Pressure
EP = Longitudinal Stress due to External Pressure
HP = Longitudinal Stress due to Hydrotest Pressure
NP = No Pressure
EW = Longitudinal Stress due to Weight (No Liquid)
OW = Longitudinal Stress due to Weight (Operating)
HW = Longitudinal Stress due to Weight (Hydrotest)
WI = Bending Stress due to Wind Moment (Operating)
EQ = Bending Stress due to Earthquake Moment (Operating)
EE = Bending Stress due to Earthquake Moment (Empty)
HI = Bending Stress due to Wind Moment (Hydrotest)
HE = Bending Stress due to Earthquake Moment (Hydrotest)
WE = Bending Stress due to Wind Moment (Empty) (no CA)
WF = Bending Stress due to Wind Moment (Filled) (no CA)
CW = Longitudinal Stress due to Weight (Empty) (no CA)
VO = Bending Stress due to Vortex Shedding Loads (Ope)
VE = Bending Stress due to Vortex Shedding Loads (Emp)
VF = Bending Stress due to Vortex Shedding Loads (Test No CA.)
FW = Axial Stress due to Vertical Forces for the Wind Case
FS = Axial Stress due to Vertical Forces for the Seismic Case
BW = Bending Stress due to Lat. Forces for the Wind Case, Corroded
BS = Bending Stress due to Lat. Forces for the Seismic Case, Corroded
BN = Bending Stress due to Lat. Forces for the Wind Case, UnCorroded
BU = Bending Stress due to Lat. Forces for the Seismic Case, UnCorroded
BL = Bending Stress due to Blast Loads, Corroded

General Notes:

Case types HI and HE are in the Un-Corroded condition.

Case types WE, WF, and CW are in the Un-Corroded condition.

A blank stress and stress ratio indicates that the corresponding stress comprising those components that did not contribute to that type of stress.

An asterisk (*) in the final column denotes overstress.

Analysis of Load Case 1 : NP+EW+WI+FW+BW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	534.69	16800.00	-1052.13	19414.63	0.0318	0.0542
20	1961.06	16800.00	-3925.72	13388.63	0.1167	0.2932
30	384.89	16800.00	-767.83	20122.00	0.0229	0.0382
40	110.01	16800.00	-345.73	20122.00	0.0065	0.0172
50		16800.00	-87.27	20197.31		0.0043
60	11.38	16800.00	-116.16	20892.02	0.0007	0.0056
70		16800.00	-7.93	18377.09		0.0004

Analysis of Load Case 2 : NP+EW+EE+FS+BS

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	27.11	16800.00	-544.54	19414.63	0.0016	0.0280
20	116.29	16800.00	-2080.95	13388.63	0.0069	0.1554
30	24.07	16800.00	-407.01	20122.00	0.0014	0.0202
40		16800.00	-216.02	20122.00		0.0107

50		16800.00	-65.83	20197.31		0.0033
60		16800.00	-84.83	20892.02		0.0041
70		16800.00	-7.62	18377.09		0.0004

Analysis of Load Case 3 : NP+OW+WI+FW+BW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	534.69	16800.00	-1052.13	19414.63	0.0318	0.0542
20	1961.06	16800.00	-3925.72	13388.63	0.1167	0.2932
30	384.89	16800.00	-767.83	20122.00	0.0229	0.0382
40	110.01	16800.00	-345.73	20122.00	0.0065	0.0172
50		16800.00	-87.27	20197.31		0.0043
60	11.38	16800.00	-116.16	20892.02	0.0007	0.0056
70		16800.00	-7.93	18377.09		0.0004

Analysis of Load Case 4 : NP+OW+EQ+FS+BS

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	27.11	16800.00	-544.54	19414.63	0.0016	0.0280
20	116.29	16800.00	-2080.95	13388.63	0.0069	0.1554
30	24.07	16800.00	-407.01	20122.00	0.0014	0.0202
40		16800.00	-216.02	20122.00		0.0107
50		16800.00	-65.83	20197.31		0.0033
60		16800.00	-84.83	20892.02		0.0041
70		16800.00	-7.62	18377.09		0.0004

Analysis of Load Case 5 : NP+HW+HI

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	21840.00	0.00	19414.63	0.0000	0.0000
20	0.00	21840.00	0.00	16972.43	0.0000	0.0000
30	0.00	21840.00	0.00	20563.32	0.0000	0.0000
40	0.00	21840.00	0.00	20563.32	0.0000	0.0000
50	0.00	21840.00	0.00	20627.61	0.0000	0.0000
60	0.00	21840.00	0.00	21204.65	0.0000	0.0000
70	0.00	21840.00	0.00	19725.53	0.0000	0.0000

Analysis of Load Case 6 : NP+HW+HE

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	21840.00	0.00	19414.63	0.0000	0.0000
20	0.00	21840.00	0.00	16972.43	0.0000	0.0000
30	0.00	21840.00	0.00	20563.32	0.0000	0.0000
40	0.00	21840.00	0.00	20563.32	0.0000	0.0000
50	0.00	21840.00	0.00	20627.61	0.0000	0.0000
60	0.00	21840.00	0.00	21204.65	0.0000	0.0000
70	0.00	21840.00	0.00	19725.53	0.0000	0.0000

Analysis of Load Case 7 : IP+OW+WI+FW+BW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	534.69	16800.00	-1052.13	19414.63	0.0318	0.0542
20	9991.06	16800.00		13388.63	0.5947	
30	1974.89	16800.00		20122.00	0.1176	
40	1700.01	16800.00		20122.00	0.1012	
50	1588.57	16800.00		20197.31	0.0946	
60	1121.38	16800.00		20892.02	0.0667	

70	2798.30	16800.00		18377.09	0.1666	

Analysis of Load Case 8 : IP+OW+EQ+FS+BS

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	27.11	16800.00	-544.54	19414.63	0.0016	0.0280
20	8146.29	16800.00		13388.63	0.4849	
30	1614.07	16800.00		20122.00	0.0961	
40	1570.30	16800.00		20122.00	0.0935	
50	1567.13	16800.00		20197.31	0.0933	
60	1090.05	16800.00		20892.02	0.0649	
70	2797.99	16800.00		18377.09	0.1665	

Analysis of Load Case 9 : EP+OW+WI+FW+BW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	534.69	16800.00	-1052.13	19414.63	0.0318	0.0542
20	742.30	16800.00	-5144.48	13388.63	0.0442	0.3842
30	132.08	16800.00	-1020.63	20122.00	0.0079	0.0507
40		16800.00	-598.54	20122.00		0.0297
50		16800.00	-340.47	20197.31		0.0169
60		16800.00	-296.99	20892.02		0.0142
70		16800.00	-442.96	18377.09		0.0241

Analysis of Load Case 10 : EP+OW+EQ+FS+BS

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	27.11	16800.00	-544.54	19414.63	0.0016	0.0280
20		16800.00	-3299.71	13388.63		0.2465
30		16800.00	-659.82	20122.00		0.0328
40		16800.00	-468.83	20122.00		0.0233
50		16800.00	-319.03	20197.31		0.0158
60		16800.00	-265.66	20892.02		0.0127
70		16800.00	-442.65	18377.09		0.0241

Analysis of Load Case 11 : HP+HW+HI

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	21840.00	0.00	19414.63	0.0000	0.0000
20	5174.00	21840.00		16972.43	0.2369	
30	1707.33	21840.00		20563.32	0.0782	
40	1707.33	21840.00		20563.32	0.0782	
50	1706.53	21840.00		20627.61	0.0781	
60	1187.33	21840.00		21204.65	0.0544	
70	2400.67	21840.00		19725.53	0.1099	

Analysis of Load Case 12 : HP+HW+HE

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	21840.00	0.00	19414.63	0.0000	0.0000
20	5174.00	21840.00		16972.43	0.2369	
30	1707.33	21840.00		20563.32	0.0782	
40	1707.33	21840.00		20563.32	0.0782	
50	1706.53	21840.00		20627.61	0.0781	
60	1187.33	21840.00		21204.65	0.0544	
70	2400.67	21840.00		19725.53	0.1099	

Analysis of Load Case 13 : IP+WE+EW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		16800.00	-269.28	19414.63		0.0139
20	7092.99	16800.00		13388.63	0.4222	
30	1407.48	16800.00		20122.00	0.0838	
40	1474.42	16800.00		20122.00	0.0878	
50	1546.44	16800.00		20197.31	0.0920	
60	1059.56	16800.00		20892.02	0.0631	
70	2797.69	16800.00		18377.09	0.1665	

Analysis of Load Case 14 : IP+WF+CW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		16800.00	-258.72	19414.63		0.0133
20	7537.31	16800.00		13388.63	0.4486	
30	1429.95	16800.00		20122.00	0.0851	
40	1491.48	16800.00		20122.00	0.0888	
50	1552.75	16800.00		20197.31	0.0924	
60	1066.15	16800.00		20892.02	0.0635	
70	2800.10	16800.00		18377.09	0.1667	

Analysis of Load Case 15 : IP+VO+OW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		16800.00	-269.28	19414.63		0.0139
20	7092.99	16800.00		13388.63	0.4222	
30	1407.48	16800.00		20122.00	0.0838	
40	1474.42	16800.00		20122.00	0.0878	
50	1546.44	16800.00		20197.31	0.0920	
60	1059.56	16800.00		20892.02	0.0631	
70	2797.69	16800.00		18377.09	0.1665	

Analysis of Load Case 16 : IP+VE+EW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		16800.00	-269.28	19414.63		0.0139
20	7092.99	16800.00		13388.63	0.4222	
30	1407.48	16800.00		20122.00	0.0838	
40	1474.42	16800.00		20122.00	0.0878	
50	1546.44	16800.00		20197.31	0.0920	
60	1059.56	16800.00		20892.02	0.0631	
70	2797.69	16800.00		18377.09	0.1665	

Analysis of Load Case 17 : NP+VO+OW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		16800.00	-269.28	19414.63		0.0139
20		16800.00	-1027.65	13388.63		0.0768
30		16800.00	-200.42	20122.00		0.0100
40		16800.00	-120.14	20122.00		0.0060
50		16800.00	-45.14	20197.31		0.0022
60		16800.00	-54.34	20892.02		0.0026
70		16800.00	-7.31	18377.09		0.0004

Analysis of Load Case 18 : FS+BS+IP+OW

From Tensile All. Tens. Comp. All. Comp. Tens. Comp.

PV Elite 27 Licensee: Kedkep Consulting Inc
FileName : Tower Analysis ----------------------------------
Stress due to Combined Loads: Step: 22 9:37pm Jun 10,2025

Node	Stress	Stress	Stress	Stress	Ratio	Ratio
10		14000.00	-269.28	16178.86		0.0166
20	7092.99	14000.00		11157.20	0.5066	
30	1407.48	14000.00		16768.34	0.1005	
40	1474.42	14000.00		16768.34	0.1053	
50	1546.44	14000.00		16831.09	0.1105	
60	1059.56	14000.00		17410.02	0.0757	
70	2797.69	14000.00		15314.24	0.1998	

Analysis of Load Case 19 : FS+BS+EP+OW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		14000.00	-269.28	16178.86		0.0166
20		14000.00	-2246.41	11157.20		0.2013
30		14000.00	-453.22	16768.34		0.0270
40		14000.00	-372.95	16768.34		0.0222
50		14000.00	-298.34	16831.09		0.0177
60		14000.00	-235.17	17410.02		0.0135
70		14000.00	-442.34	15314.24		0.0289

Absolute Maximum of the all of the Stress Ratio's 0.5947

Governing Element: Btm Head
Governing Load Case 7 : IP+OW+WI+FW+BW

Element Description	Long Pressure Stress	Weight + Axial Load Stress	Eccentric Moment Stress	Wind or Earthquake Stress	Combined Stress	Which Side
Skirt	...	-258.7	10.6	782.8	534.7	+ Tens
Skirt	...	-258.7	-10.6	-782.8	-1052.1	- Comp
Btm Head	8030.0	-982.3	45.3	2898.1	9991.1	+ Tens
Btm Head	8030.0	-982.3	-45.3	-2898.1	...	- Comp
Shell 1	1590.0	-191.5	8.9	567.4	1974.9	+ Tens
Shell 1	1590.0	-191.5	-8.9	-567.4	...	- Comp
shell 2	1590.0	-117.9	2.3	225.6	1700.0	+ Tens
shell 2	1590.0	-117.9	-2.3	-225.6	...	- Comp
Cone	1589.7	-44.2	0.9	42.1	1588.6	+ Tens
Cone	1589.7	-44.2	-0.9	-42.1	...	- Comp
Shell 3	1110.0	-52.4	2.0	61.8	1121.4	+ Tens
Shell 3	1110.0	-52.4	-2.0	-61.8	...	- Comp
Top Head	2805.0	-7.3	...	0.6	2798.3	+ Tens
Top Head	2805.0	-7.3	...	-0.6	...	- Comp

Skirt Support Analysis Per EN 13445-3 Section 16.12:

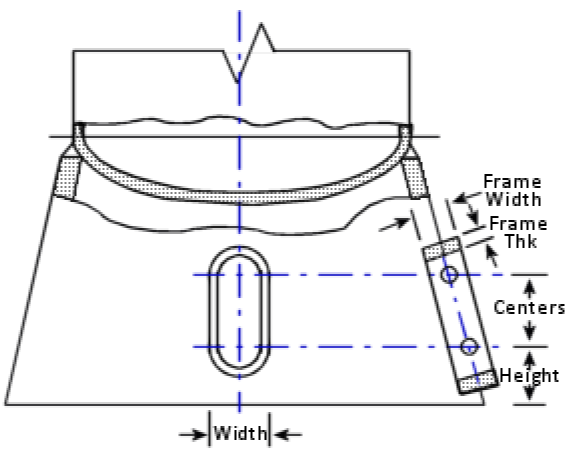
The analysis of this skirt has been conducted referencing the EN 13445-3 design code. It is important to note that the selected design code does not explicitly cover the analysis of this component. Therefore, the results provided herein should be regarded as informational only.

Item: Skirt

```
Total vessel (empty) weight            Fg        15823.959 lb.
Head Weight below section 2-2      DeltaFg         208.247 lb.
Weight of vessel contents (liquid)      Ff           0.000 lb.
Vessel Gross Weight                Fg + Ff       15823.959 lb.

Skirt Mean Diameter                     Dz          42.000 in.
Skirt Analysis Thickness (Corroded)     ez           0.500 in.
Skirt Height                             H          36.000 in.

Additional Axial Force at section 1-1   F1           0.000 lb.
Moment at section 1-1                   M1       38531.301 ft.lb.
Applied Moment - Bottom of Skirt        Mb       44666.016 ft.lb.
Weight at Bottom of Skirt                W       17068.498 lb.
```

Structural Type C Skirt per EN 13445 Figure 16.12-3:

```
Cylinder Mean Diameter at Skirt Top        Db           40.750 in.
Cylinder Corroded Thickness                eb            0.750 in.
```



There are no Access Openings in the Skirt - Plain Skirt Considered

```
Moment of Inertia        Ixx =        14547.146 in**4
Moment of Inertia        Iyy =        14547.146 in**4
Section Modulus            W =          692.721 in.³
Section Metal Area         A =           65.973 sq.in.
```

<u>Analysis of the Section at weakest section Modulus [Z min]:</u>

Radius of Gyration of Skirt at 4-4 [rg]:

```
= sqrt( min( Ixx, Iyy ) / Area )
= sqrt( min( 14547, 14547 )/65.97 ) )
= 14.85 in.
```

Skirt Slenderness Ratio [rg/L]:

```
= rg / L
= 14.85/36
```

```
  = 0.412
```

Correct the Moment [M4]:

```
  top of skirt is the critical end
  Controlling Moment [M4] = 38531 ft.lb.
```

Axial Stress at Residual (Weakest) Surface Area [Sigma]:
Downwind Side:

```
  = -M / Z - W / A
  = -38531/2771 - 17068/65.97
  = -425.6 psi
```

Upwind Side:

```
  = +( M ) / Z - W / A
  = +38531/2771 - 17068/65.97
  = -91.85 psi
```

16.12.3.4 Checking at connection areas:

Force at the joint, 16.12-1 [Fzp]:

```
  = F1 - Fg - Ff + 4 * M1 / Dz
  = 0  - 15824 - 0 + 4 * 38531/42
  = 28212 lb.
```

Force at the joint, 16.12-2 [Fzq]:

```
  = F1 - Fg - Ff - 4 * M1 / Dz
  = 0  - 15824 - 0 - 4 * 38531/42
  = -59860 lb.
```

16.12.3.4.1 Membrane stresses:

Membrane stress at 1-1, 16.12-3 & 4:

Stress [sigma_(1p)^m]:

```
  = ( Fzp + DeltaF_(g) ) + Ff )/( pi * Db * eb ) + P * Db /( 4 * eb )
  = ( 28212 + 208.2 + 0 )/( pi * 40.75 * 0.75 ) + 100 * 40.75/( 4 * 0.75 )
  = 1654.33 psi
```

Stress [sigma_(1q)^m]:

```
  = ( Fzq + DeltaF_(g) + Ff )/( pi * Db * eb ) + P * Db / ( 4 * eb )
  = ( -59860 + 208.2 + 0 )/( pi * 40.75 * 0.75 ) + 100 * 40.75/( 4 * 0.75 )
  = 737.06 psi
```

Membrane stress at 2-2, 16.12-9:

Stress [sigma_(2p)^m & sigma_(2q)^m]:

```
  = ( Ff + DeltaF_(g) )/( pi * Db * eb ) + P * Db / ( 4 * eb )
  = ( 0 + 208.2 )/( pi * 40.75 * 0.75 ) + 100 * 40.75/( 4 * 0.75 )
  = 1360.50 psi
```

Membrane stress at 3-3, 16.12 12 & 13:

Stress [sigma_(3p)^m]:

```
  = Fzp / ( pi * Dz * ez )
  = 28212/( pi * 42 * 0.5 )
  = 427.62 psi
```

Stress [sigma_(3q)^m]:

```
  = Fzq / ( pi * Dz * ez )
  = -59860/( pi * 42 * 0.5 )
  = -907.33 psi
```

16.12.3.4.2 Bending stresses:

Moment due to eccentricity between shell and skirt, 16.12-37 [Mp]:
```
  = 0.5( Dz - Db ) * fZn
  = 0.5( 42 - 40.75 ) * 28212
  = 1469.365 ft.lb.
```

Moment due to eccentricity between shell and skirt, 16.12-38 [Mq]:
```
  = 0.5( Dz - Db ) * FZq
  = 0.5( 42 - 40.75 ) * -59860
  = -3117.695 ft.lb.
```

Stress at section 1-1 and 2-2 [sigma_(1p)^b & sigma_(2p)^b]:
```
  = 3 * Mp /( pi * Db * eb^2 )
  = 3 * 1469/( pi * 40.75 * 0.75^2 )
  = 734.57 psi
```

Stress at section 1-1 and 2-2 [sigma_(1q)^b & sigma_(2q)^b]:
```
  = 3 * Mq /( pi * Db * eb^2 )
  = 3 * -3118/( pi * 40.75 * 0.75^2 )
  = -1558.61 psi
```

Stress at section 3-3 [sigma_(3p)^b]:
```
  = 6 * Mp /( pi * Dz * ez^2 )
  = 6 * 1469/( pi * 42 * 0.5^2 )
  = 3207.18 psi
```

Stress at section 3-3 [sigma_(3q)^b]:
```
  = 6 * Mq /( pi * Dz * ez^2 )
  = 6 * -3118/( pi * 42 * 0.5^2 )
  = -6804.98 psi
```

16.12.3.4.3 Total stresses and strength conditions:

Structural shape B and C:

Stress [sigma_(1pi)^{tot}]:
```
  = sigma_(1p)^m - sigma_(1p)^b(o) + sigma_(1)^b(p)
  = 1654 - 734.6 + 0
  = 919.76 psi
```

Stress [sigma_(1po)^{tot}]:
```
  = sigma_(1p)^m + sigma_(1p)^b(o) - sigma_(1)^b(p)
  = 1654 - 734.6 + 0
  = 2388.90 psi
```

Stress [sigma_(1qi)^{tot}]:
```
  = sigma_(1q)^m - sigma_(1q)^b(o) + sigma_(1)^b(p)
  = 737.1 - -1559 + 0
  = 2295.67 psi
```

Stress [sigma_(1qo)^{tot}]:
```
  = sigma_(1q)^m + sigma_(1q)^b(o) - sigma_(1)^b(p)
  = 737.1 - -1559 + 0
  = -821.54 psi
```

Stress [sigma_(2pi)^{tot}]:
```
  = sigma_(2p)^m + sigma_(2p)^b(o) + sigma_(2)^b(p)
  = 1361 - 734.6 + 0
  = 2095.07 psi
```

Stress [sigma_(2po)^{tot}]:
```
  = sigma_(2p)^m - sigma_(2p)^b(o) - sigma_(2)^b(p)
  = 1361 - 734.6 + 0
```

```
  = 625.93 psi
```

Stress [sigma_(2qi)^{tot}]:

```
  = sigma_(2q)^m + sigma_(2q)^b(o) + sigma_(2)^b(p)
  = 1361 - -1559 + 0
  = -198.10 psi
```

Stress [sigma_(2qo)^{tot}]:

```
  = sigma_(2p)^m - sigma_(2p)^b(o) - sigma_(2)^b(p)
  = 1361 - -1559 + 0
  = 2919.11 psi
```

Stress [sigma_(3pi)^{tot}]:

```
  = sigma_(3p)^m - sigma_(3p)^b
  = 427.6 - 3207
  = -2779.55 psi
```

Stress [sigma_(3po)^{tot}]:

```
  = sigma_(3p)^m + sigma_(3p)^b
  = 427.6 + 3207
  = 3634.80 psi
```

Stress [sigma_(3qi)^{tot}]:

```
  = sigma_(3q)^m - sigma_(3q)^b
  = -907.3 - -6805
  = 5897.65 psi
```

Stress [sigma_(3qo)^{tot}]:

```
  = sigma_(3q)^m + sigma_(3q)^b
  = -907.3 + -6805
  = -7712.31 psi
```

Allowable stresses:

For sigma_(1pi)^{tot} and sigma_(1po)^{tot}, the stress must not exceed:

```
  = fs( 3 - ( 1 / 1.5 ) * ( sigma_(1p)^m / f )² )
  = 20000 ( 3 - ( 1/1.5 ) * ( 1654/20000 )² )
  = 59908.77 psi
```

For sigma_(1qi)^{tot} and sigma_(1qo)^{tot}, the stress must not exceed:

```
  = fs( 3 - ( 1 / 1.5 ) * ( sigma_(1q)^m / f )² )
  = 20000 ( 3 - ( 1/1.5 ) * ( 737.1/20000 )² )
  = 59981.89 psi
```

For sigma_(2pi)^{tot} and sigma_(2po)^{tot}, the stress must not exceed:

```
  = fs( 3 - (1 / 1.5) * ( sigma_(2p)^m / f )² )'
  = 20000 ( 3 - (1/1.5) * ( 1361/20000 )² )
  = 59938.30 psi
```

For sigma_(2qi)^{tot} and sigma_(2qo)^{tot}, the stress must not exceed:

```
  = fs( 3 - (1 / 1.5) * ( sigma_(2q)^m / f )² )
  = 20000 ( 3 - (1/1.5) * ( 1361/20000 )² )
  = 59938.30 psi
```

For sigma_(3pi)^{tot} & sigma_(3po)^{tot}, the stress must not exceed:

```
  = fs( 3 - (1 / 1.5) * ( sigma_(3p)^m / f )² )
  = 20000 ( 3 - (1/1.5) * ( 427.6/20000 )² )
  = 59993.91 psi
```

For sigma_(3qi)^{tot} & sigma_(3qo)^{tot}, the stress must not exceed:

```
  = fs( 3 - (1 / 1.5) * ( sigma_(3q)^m / f )² )
  = 20000 ( 3 - (1/1.5) * ( -907.3/20000 )² )
  = 59972.56 psi
```

Note: Moments are displayed as in-lbf units.

Please note: None of the following stresses in the table below are in the region where there is an access opening.

Summary of Stresses: (psi)

Stress	Actual	Allowed	Result	Equation
Stot1pi	919.76	59908.77	Pass	46
Stot1po	2388.90	59908.77	Pass	47
Stot1qi	2295.67	59981.89	Pass	48
Stot1qo	-821.54	59981.89	Pass	49
Stot2pi	2095.07	59938.30	Pass	50
Stot2po	625.93	59938.30	Pass	51
Stot2qi	-198.10	59938.30	Pass	52
Stot2qo	2919.11	59938.30	Pass	53
Stot3pi	-2779.55	59993.91	Pass	54
Stot3po	3634.80	59993.91	Pass	55
Stot3qi	5897.65	59972.56	Pass	56
Stot3qo	-7712.31	59972.56	Pass	57

The stresses are satisfactory in the region without openings.

Shop/Field Installation Options :

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

Center of Gravity of the Stiffening Rings	31.967 ft.
Center of Gravity of the Nozzles	14.097 ft.
Center of Gravity of Bare Shell New and Cold	20.491 ft.
Center of Gravity of Bare Shell Corroded	20.202 ft.
Vessel CG in the Operating Condition	20.113 ft.
Vessel CG in the Fabricated (Shop/Empty) Condition	20.408 ft.
Vessel CG in the Test Condition	20.773 ft.

Skirt Data :

```
 Skirt Outside Diameter at Base      SOD, D6          42.5000  in.
 Skirt Thickness                        STHK           0.5000  in.
 Skirt Internal Corrosion Allowance      SCA           0.0000  in.
 Skirt External Corrosion Allowance                    0.0000  in.
 Skirt Material                                     SA-516 70
```

Basering Input: Type of Geometry: Basering W/Gussets & Chair Cap

```
 Thickness of Basering             TBA,  ea4           1.5000  in.
 Design Temperature of the Basering                    100.00  F
 Basering Material                                  SA-516 70
 Basering Ope. All. Stress        BASOPE, f4         20000.00  psi
 Basering Yield Stress                               38000.00  psi
 Inside Diameter of Basering          DI, D4          41.5000  in.
 Outside Diameter of Basering        DOU, D5          51.5000  in.

 Nominal Diameter of Bolts        BND, d(b0)           2.0000  in.
 Bolt Corrosion Allowance                BCA           0.0000  in.
 Bolt Material                                      SA-193 B7
 Bolt Material Class/Thickness Range                 <= 2 1/2
 Bolt Operating Allowable Stress      SA, fB         25000.00  psi
 Number of Bolts                      RN, nb                8
 Diameter of Bolt Circle             DC, DBC          47.5000  in.

 Thickness of Gusset Plates          TGA, e7           0.7500  in.
 Width of Gussets at Top Plate          TWDT           4.5000  in.
 Width of Gussets at Base Plate         BWDT           4.5000  in.
 Gusset Plate Elastic Modulus              E       28884600.0  psi
 Gusset Plate Yield Stress                SY          38000.0  psi
 Height of Gussets                    HG, h1           9.0000  in.
 Distance between Gussets             RG, b6           3.5000  in.
 Dist. from Bolt Center to Gusset (Rg/2)  CG           1.7500  in.
 Number of Gussets per bolt               NG                2

 Thickness of Top Plate or Ring      TTA, e5           1.7500  in.
 Radial Width of the Top Plate    TOPWTH, b5           4.5000  in.
 Circum. Width of the Top Plate    CMWTH, b4           7.0000  in.
 Anchor Bolt Hole Dia. in Top Plate    dia,H           2.1250  in.

 External Corrosion Allowance             CA           0.0000  in.

 Dead Weight of Vessel                    DW          17068.5  lb.
 Operating Weight of Vessel              ROW          17068.5  lb.
 Earthquake Moment on Basering         EQMOM          15705.5  ft.lb.
 Wind Moment on Basering               WIMOM          44666.0  ft.lb.
 Percent Bolt Preload                    ppl            100.0

 Use AISC A5.2 Increase in Fc and Bolt Stress            No
 Use Allowable Weld Stress per AISC J2.5                 No

 Factor for Increase of Allowables     Fact          1.0000
```

Results for Basering Analysis : Analyze Option

Basering Thickness Calculation method used : Simplified (Steel on Steel)

Calculation of Bolt Loads for Multiple Loading Conditions:

Bolt Load, Earthquake Operating Case [F_(B,e)]:

```
  = (( 4 * M/DC ) - W )/nb     per Jawad & Farr, Eq. 12.3
  = (( 4 * 188466/47.5 ) - 17068 )/8
  = -149.7 lb.
```

Bolt Load, Windload Empty Case [F_(B,w)]:

```
  = (( 4 * M/DC ) - W )/nb     per Jawad & Farr, Eq. 12.3
  = (( 4 * 535992/47.5 ) - 17068 )/8
  = 3508.5 lb.
```

Bolt Load, Windload Vortex Shedding Case [F_(B,v)]:

```
  = (( 4 * M/DC ) - W )/nb     per Jawad & Farr, Eq. 12.3
  = (( 4 * 0/47.5 ) - 17068 )/8
  = -2133.6 lb.
```

Calculation of Maximum Load per Bolt [W/Bolt], Wind + Dead Weight Condition:
where: W = ROW   M = WIMOM

```
  = (( 4 * M/DC ) - W )/nb     per Jawad & Farr, Eq. 12.3
  = (( 4 * 535992/47.5 ) - 17068 )/8
  = 3508.5 lb.

 Required Area for Each Bolt, Based on Max Load        0.1403  sq.in.
 Area Available in a Single Bolt (Corr)                2.3000  sq.in.
 Area Available in all the Bolts (Corr)               18.4000  sq.in.
 Bolt Stress Based on Simplified Analysis              1525.4  psi
 Allowable Bolt Stress    25000.0  [Fact]            25000.00  psi

 Concrete Contact Area of Base Ring            CCA     730.42  sq.in.
 Concrete Contact Section Modulus of Base Ring        7755.40  in.³
```

Concrete Load (Simplified method), Wind in Operating Condition [Sc]:

```
  = ((ppl/100*(Abt*Sa)+W)/Cca) + M/CZ per Jawad & Farr Eq. 12.1
  = (1 (18.4 *25000 +17068 )/730.4 ) + 535992/7755
  = 722.25 psi

 Concrete Allowable Stress                            1200.00  psi
```

Determine Maximum Bending Width of Basering Section [Rw1]:

```
  = ( Dou - SkirtOD )/2
  = ( 51.5 - 42.5 )/2
  = 4.5 in.
```

Determine Maximum Bending Width of Basering Section [Rw2]:

```
  = ( SkirtID - Di + 2*Sca )/2
  = ( 41.5 - 41.5 + 2*0 )/2
  = 0 in.
```

Calculation of required Basering Thickness, (Simplified) [Tb]:
Allowable Bending Stress 1.5 Basope = 30000.000 psi

```
  = max(Rw1,Rw2) * sqrt( 3 * Sc / S ) + CA per Jawad & Farr Eq. 12.12
  = max(4.5,0 ) * sqrt( 3 * 722.3/30000 ) + 0
  = 1.2094 in.
```

Basering Stress at given Thickness [Sb]:

```
  = 3 * Sc( max[Rw1, Rw2]/(Tb - Ca) )²
  = 3 * 722.3 ( max[4.5, 0 ]/(1.5 - 0 ) )²
  = 19501, must be less than 30000 psi
```

Required Thickness of Top Plate in Tension:
(Calculated as a fixed beam per Megyesy)

```
     Ft = (Sa*Abss),        Bolt Allowable Stress * Area
     Rm = (Ft * 2 * Cg)/8,  Bending Moment
```

```
     Sb                     Allowable Bending Stress
     Wt = (Topwth  -  Bnd), Width of Section
```

Required Thickness of Top Plate [T]:

```
  = sqrt( 6 * Rm / ( Sb * Wt )) + CA
  = sqrt( 6 * 25156/( 30000 * 2.5 )) + 0
  = 1.419 in.
```

Top Chair Cap Plate per Moss:

```
   P  = (Sa*Abss)            Bolt Allowable Stress * Area
   e  = (Topwth-Bhole)/2     Distance to Edge of Hole
   Sb                        Allowable Bending Stress
   b  = Cg                   Gusset Plate Dimension
   db = Bhole                Bolt Hole Diameter
```

Top Chair Cap Plate Required Thickness [Tc]:
Allowable Bending Stress 1.5 Basope = 30000.000 psi

```
  = sqrt( P /( Sb * e ) * ( 0.375 * b - 0.22 * db ) ) + CA
  = sqrt( 57500/( 30000 * 0.938 ) * ( 0.375 * 3.5 - 0.22 * 2.125 ) ) + 0
  = 1.3144 in.
```

Stress in the Top Plate at given Thickness [Stpl]:

```
  = P( 0.375 * b - 0.22 * db ) / e / ( Tta - Ca )²
  = 57500 ( 0.375 * 3.5 - 0.22 * 2.125 )/0.938/( 1.75 - 0 )²
  = 16923 psi, must be less than 30000 psi
```

Required Thickness of Gusset in Compression, per AISC E2-1:
1. Allowed Compression at Given Thickness:

```
    Factor Kl/r Per E2-1                              41.5685
    Factor Cc Per E2-1                               122.4916
    Allowable Buckling Str. per E2-1                 20017.37  psi
    Actual Buckling Str. at Given Thickness           8518.52  psi

 Required Gusset/Support Plate thickness, + CA         0.3977  in.
```

2. Allowed Compression at Calculated Thickness:

```
    Factor Kl/r Per E2-1                              78.3862
    Factor Cc Per E2-1                               122.4916
    Allowable Buckling Str. per E2-1                 16126.55  psi
    Act. Buckling Str. at Calculated Thickness       16063.46  psi
```

Summary of Basering Thickness Calculations:

```
 Required Basering Thickness (simplified)              1.2094  in.
 Actual Basering Thickness                             1.5000  in.

 Required Top Ring/Plate Thickness as a Fixed Beam     1.4186  in.
 Required Thickness of Chair Cap per Moss/AISI         1.3144  in.
 Actual Top Plate/Ring Thickness                       1.7500  in.

 Required Gusset/Support Plate thickness, + CA         0.3977  in.
 Actual Gusset/Support Plate Thickness                 0.7500  in.
```

Local Stress at the Top Plate per AISI, including axial Stress [S]:

```
  = Wmax*e/t²[1.32*Z/(1.43*Cmwth*(Hg+Tta)²/(R*Tskirt)
    + (4(Cmwth)(Hg+Tta)²)^.333 + 0.031 /sqrt(R*Tskirt)
  = 3508*2.5/0.5²[1.32*0.161/(1.43*7*(9.75)²/(20.75*0.5)
    + (4*7 (9 +0.75 )²)^.333 + 0.031/sqrt(20.75 *0.5 )
  = 396.9 psi
```

Where [Z]:

```
  = 1/[(0.177*Wgp*Tba/sqrt(R*t))*(Tba/t)² + 1]
  = 1/[(0.177*7*1.5/sqrt(20.75*0.5))*(1.5/0.5)²+1]
  = 0.161
```

Where [e]:

```
  = ( Dc - Ds ) / 2
  = ( 47.5 - 42.5 )/2
  = 2.500 in.
```

```
 Local Stress in the Skirt due to the Gussets            396  psi
 Weight plus Bending Stress in the Skirt (Highest)      1052  psi
 Comb. loc. + bending stress  Worst Load Case           1449  psi
 Allowed membrane+bending stress( 1.5* Skirt All.)     30000  psi
```

Weld Size Calculations per Steel Plate Engineering Data - Vol. 2

Compute the Weld load at the Skirt/Base Junction [W]:

```
  = SkirtStress * ( SkirtThickness - CA )
  = 1052 * ( 0.5 - 0 )
  = 526.1 lb./in.
```

Results for Computed Minimum Basering Weld Size [BWeld]:

```
  = W / [( 0.4 * Yield ) * 2 * 0.707]
  = 526.1/[( 0.4 * 34800 ) * 2 * 0.707]
  = 0.0267 in.
```

Results for Computed Minimum Gusset and Top Plate to Skirt Weld Size

Vertical Plate Load [Wv]:

```
  = Bolt Load / ( Cmwth + 2 * ( Hg + Tta ) )
  = 57500/( 5 + 2 * ( 9 + 1.75 ) )
  = 2170 lb./in.
```

Horizontal Plate Load [Wh]:

```
  = Bolt Load * e / ( Cmwth * (Hg+Tta) + 0.6667 * (Hg+Tta)² )
  = 57500 * 2.5/(5 * (10.75 ) + 0.6667 * (10.75 )² )
  = 1099 lb./in.
```

Resultant Weld Load [Wr]:

```
  = sqrt( Wv² + Wh²)
  = sqrt( 2170² + 1099²)
  = 2432 lb./in.
```

Results for Computed Min Gusset and Top Plate to Skirt Weld Size [GsWeld]:

```
  = Wr / [( 0.4 * Yield ) * 2 * 0.707]
  = 2432/[( 0.4 * 34800 ) * 2 * 0.707]
  = 0.124 in.
```

Results for Computed Minimum Gusset to Top Plate Weld Size

Weld Load [Wv]:

```
  = Bolt Load / ( 2 * TopWth )
  = 57500/( 2 * 4.5 )
  = 6389 lb./in.
```

Weld Load [Wh]:

```
  = Bolt Load * e / ( 2 * Hgt * TopWth )
  = 57500 * 2.5/( 2 * 10.75 * 4.5 )
  = 1486 lb./in.
```

Resultant Weld Load [Wr]:

```
  = sqrt( Wv² + Wh²)
```



```
  = sqrt( 6389² + 1486²)
  = 6559 lb./in.
```

Results for Computed Min Gusset to Top Plate Weld Size [GtpWeld]:

```
  = Wr / [( 0.4 * Yield ) * 2 * 0.707]
  = 6559/[( 0.4 * 34800 ) * 2 * 0.707]
  = 0.333 in.
```

Note: The calculated weld sizes need not exceed the component thickness framing into the weld. At the same time, the weld must meet a minimum size specification which is 3/16 in. (4.76 mm) or 1/4 in. (6.35 mm), depending on the component thickness.

Summary of Required Weld Sizes:

Required Basering to Skirt Double Fillet Weld Size	0.1875	in.
Required Gusset to Skirt Double Fillet Weld Size	0.2500	in.
Required Top Plate to Skirt Weld Size	0.3333	in.
Required Gusset to Top Plate Double Fillet Weld Size	0.3333	in.

Review notes about nozzle loadings and supports in the Warnings report.

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

Input Values:

Cone

Design Internal Pressure, Small End		100.000	psig
Design Internal Pressure, Large End		100.000	psig
Temperature for Internal Pressure		200.0	F
Design External Pressure		15.000	psig
Temperature for External Pressure		200.0	F

CONE Properties:

Cone Material		SA-516 70	
Cone Allowable Stress at Temperature	Ss	20000.00	psi
Cone Allowable Stress At Ambient		20000.00	psi
Longitudinal Joint Efficiency of Cone		0.85	
Circumferential Joint Efficiency of Cone		0.70	
Actual Thickness of Cone	Tc	0.7500	in.
Corrosion Allowance for Cone	Cac	0.1250	in.
Diameter Basis for Cone and Cylinders		ID	
Diameter of Small End of Cone	Ds	28.000	in.
Diameter of Large End of Cone	Dl	40.000	in.
Half Apex Angle for Cone		14.04	degrees
Axial Length of Cone	Lc	24.000	in.

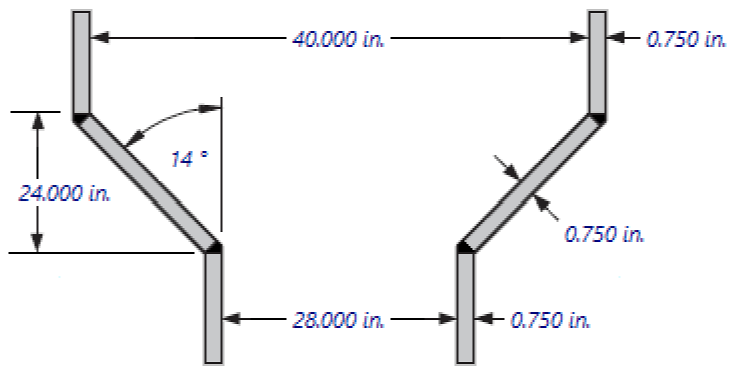
SMALL-END Properties:

Attached Small End Material Specification		SA-516 70	
Operating Allowable Stress	Ss	20000.00	psi
Ambient Allowable Stress		20000.00	psi
Joint Efficiency	Es	0.8500	
Actual Thickness	Ts	0.7500	in.
Corrosion Allowance	Cas	0.1250	in.
Axial Length of Attached Element	Ls	124.333	in.

LARGE-END Properties:

Attached Large End Material Specification		SA-516 70	
Operating Allowable Stress	Sl	20000.00	psi
Ambient Allowable Stress		20000.00	psi
Joint Efficiency	El	0.8500	
Actual Thickness	Tl	0.7500	in.
Corrosion Allowance	Cal	0.1250	in.
Axial Length of Attached Element	Ll	2.400	in.

Type of Reinforcement at Large End of Cone:	None
Type of Reinforcement at Small End of Cone:	None
Force Arl & Ars calculation, cone -> flange	No
Force Arl & Ars calculation, cone -> cylinder	No



Cone Geometry

Calculated Values:

```
Elastic Modulus Data from ASME Section II Part D at 200 F

Elastic Modulus of Cone Material              0.288E+08 psi at 200 F
Elastic Modulus of Small Cylinder Material    0.288E+08 psi at 200 F
Elastic Modulus of Large Cylinder Material    0.288E+08 psi at 200 F
Elastic Modulus of Large End Reinforcement    0.288E+08 psi at 200 F
Elastic Modulus of Small End Reinforcement    0.288E+08 psi at 200 F

Elastic Modulus Data from ASME Section II Part D at 200 F

Elastic Modulus of Cone Material              0.288E+08 psi at 200 F
Elastic Modulus of Small Cylinder Material    0.288E+08 psi at 200 F
Elastic Modulus of Large Cylinder Material    0.288E+08 psi at 200 F
Elastic Modulus of Large End Reinforcement    0.288E+08 psi at 200 F
Elastic Modulus of Small End Reinforcement    0.288E+08 psi at 200 F
```

Forces and Moments on the ends of the Cone:

```
Axial Force on Small End of Cone                   2970.29  lb.
Axial Force on Large End of Cone                   3658.62  lb.
Moment on Small End of Cone                        2129.74  ft.lb.
Moment on Large End of Cone                        2992.06  ft.lb.
```

The moments above are computed from the Wind & Seismic loads as well as any user defined moments and include effects due to eccentric masses. The vertical forces include the weight of the elements and details above and below the cone as well as any user defined vertical forces. Vertical forces also include loads cause from vertical accelerations due to earthquake loading.

Note: Both ends of the Cone are Lines of Support

```
Maximum Centroid Reinforcement Distance Large End     0.9003  in.
Maximum Centroid Reinforcement Distance Small End     0.7591  in.
```

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

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

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

Required Area of Reinforcement for Large End Under Internal Pressure

Large end ratio of pressure to allowable stress [P/Ss E1]: 0.00588

Large End Maximum half apex angle w/o reinforcement [delta]:
```
  = 326.6 * sqrt( P /( Ss * E1 ) )   per 1-5 equation 1
  = 326.6 * sqrt( 100/( 20000 * 0.85 ) )
  = 25.049 degrees
```

Large end actual half apex angle [alpha]: 14.036 degrees

Because delta is greater than alpha, reinforcement calculations are not required for the large end under internal pressure.

Required Area of Reinforcement for Large End Under External Pressure

Large end ratio of pressure to allowable stress [P/Ss E1]: 0.00088

Large End Maximum half apex angle w/o reinforcement [delta]:
```
  = 104 * sqrt( P /( Ss * E1 ) )   per 1-8 equation 1
  = 104 * sqrt( 15/( 20000 * 0.85 ) )
  = 3.089 degrees
```

Large end actual half apex angle [alpha]: 14.036 degrees

Intermediate Value [k]:
```
  = max( Y / ( Srl * Erl ), 1 )
  = max( 576.00E+09/( 20000 * 28800000 ), 1 )
  = 1.0000
```

where [Y] is:
```
   = Large End All. Stress * Large End Elastic Modulus (Ext. temp.)
   = 20000 * 28800000
   = 575999967232.0 (psi)^2

 Allowable Stress of Large End Material (Ext. Temp)   20000.0  psi
 Allowable Stress of Cone Material (Ext. Temp)        20000.0  psi
```

Required Area of Reinforcement, Large End, External [Arl]:
```
  = (k*QL*Rl*tan(angle)/(Ss*E1))*(1-1/4((P*Rl-QL)/QL)*(delta/alpha)
  = (1*211.7*20.75*0.25/(20000*0.85))*
    (1-1/4((15*20.75-211.7)/211.7)*(3.089/14.04)
  = 0.0629 sq.in.
```

Force per Length, Cone Large End External Pressure, compressive side [QL-]:
```
  = Pext( Rl/2 ) + f1
  = 15 ( 20.75/2 ) + 56.11
  = 211.733 lb./in.
```

Axial Load per Unit Circumference excluding Pressure [f1]:
```
  = Faxial/(pi(Dl + Tl)) + Moment/(pi(Rl - Tl/2)^2)
  = +3659/(pi(41.5-0.75))+35905/(pi(20.75-0.75/2)^2)
  = 56.1 lb./in.
```

Force per Length, Cone Large End External Pressure, tensile side [QL+]:
```
  = Pext( Rl/2 ) + f1
  = 15 ( 20.75/2 ) + 1.049
  = 156.674 lb./in.
```

Axial Load per Unit Circumference excluding Pressure [f1]:
```
  = Faxial/(pi(Dl + Tl)) - Moment/(pi(Rl - Tl/2)^2)
  = +3659/(pi(41.5-0.75))-35905/(pi(20.75-0.75/2)^2)
  = 1.0 lb./in.
```

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

```
  = 0.55[ sqrt(Dl * ts)(ts - t) + sqrt(Dl * tc / cos(alpha))(tc - tr)) per 1-8 eqn. 3
  = 0.55[ sqrt( 41.5 * 0.625 )( 0.625 - 0.0397 ) +
    sqrt( 41.5 * 0.625/0.97 )( 0.625 - 0.103 ) ]
  = 3.1248 sq.in.
```

Summary of Reinforcement Area, Large End, External Pressure:

Area of reinforcement required per App. 1-8(1)	0.0629	sq.in.
Area of reinforcement in shell per App. 1-8(2)	3.1248	sq.in.
Area of reinforcement in stiffening ring	0.0000	sq.in.

Intermediate Results, Large End, External Pressure:

Calculate Cylinder Decay Length:

```
  = 2 * sqrt( RL * ts )
  = 2*sqrt(20.75*0.625)
  = 7.2024 in.
```

Note: LL is zero since large cylinder length is less than the decay length

Area Available in Cone, Shell, and Reinforcement [AT]:

```
  = LL * ts/2 + Lc * tc/2 + As
  = 0 * 0.625/2 + 24.74 * 0.625/2 + 0
  = 7.731 sq.in.
```

Determine the Meridian Length [M]:

```
  = -RL*tan(alpha)/2 + LL/2 + (RL²-RS²)/(3*RL*tan(alpha))
  = -20.75 * tan( 14.04 )/2 + 0/2 + ( 20.75² - 14.75² )/(3 * 20.75 * tan( 14.04 ))
  = 11.093 in.
```

Force per Unit Length on the Cone/Shell Junction [FL]:

```
  = P * M + tan(alpha)( Force/( pi * D ) + Moment/( pi * Radius² ))
  = 15 * 11.09 + tan(14.04 )( 3659/( pi * 41.5 ) + 35905/( pi * 20.75² ))
  = 180.046 lb./in.
```

Actual Buckling Stress associated with force FL, [B]:

```
  = 0.75( FL * DL / ATL )
  = 0.75( 180 * 41.5/7.731 )
  = 724.883 psi

 Material Strain associated with this stress [A]:   0.000050
```

Required Moment of Inertia, Large End, External Pressure [I's]:

```
  = A * Dl² * Atl / 10.9
  = 0.50339E-04 * 41.5 * 41.5 * 7.731/10.9
  = 0.06 in.⁴
```

Available Moment of Inertia, Large End, External Pressure:

	Area	Centroid	Ar*Ce	Dist	I	Ar*Di²
Shl	1.500	0.0000	0.000	-0.1912	0.049	0.055
Con	1.805	-0.3501	-0.632	0.1589	0.136	0.046
Sec	0.000	0.3125	0.000	-0.5037	0.000	0.000
TOT	3.305		-0.632		0.185	0.100

```
-------------------------------------------------------------------
 Centroid of Section        -0.1912     Moment of Inertia         0.29
```

Summary of Large End Inertia Calculations

Available Moment of Inertia (Large End)	0.285	in**4
Required Moment of Inertia (Large End)	0.061	in**4

Reinforcement Calculations for Cone / Small Cylinder:

Required Area of Reinforcement for Small End under Internal Pressure

Small end ratio of pressure to allowable stress [P/Ss E1]: 0.00588

Small End Maximum half apex angle w/o reinforcement [delta]:
```
  = 89 * sqrt( P /( Ss * E1 ) )   per 1-5 equation 6
  = 89 * sqrt( 100/( 20000 * 0.85 ) )
  = 6.826 degrees
```

Small end actual half apex angle [alpha]: 14.036 degrees

Intermediate Value [k]:
```
  = max( Y / ( Sr * Ers ), 1 )
  = max( 576.00E+09/( 20000 * 28800000 ), 1 )
  = 1.0000
```

where [Y] is:
```
   = Small End All. Stress * Small End Elastic Modulus (Int. temp.)
   = 20000 * 28800000
   = 575999967232.0 (psi)^2
```

Decay Length, Cone Small End:
```
  = 1.4 * sqrt( Rs( ts - ca ) )
  = 1.4 * sqrt( 14.12 ( 0.75 - 0.125 ) )
  = 4.160 in.
```

Required Area of Reinforcement, Small End, Internal [Ars]:
```
  = k*QS*Rs/(Ss*E1)*(1-delta/alpha)*tan(alpha)  per 1-5 equation 7
  = 1 * 712.1 * 14.12/( 20000 * 0.85 )*( 1 - 6.826/14.04 )0.25
  = 0.076 sq.in.
```

Force per Length, Cone Small End, tensile side [QS+]:
```
  = P( Rs/2 ) + f2
  = 100 ( 14.12/2 ) + 5.806
  = 712.056 lb./in.
```

Axial Load per Unit Circumference excluding Pressure [f2]:
```
  = Faxial/(pi(Ds + Ts)) + Moment/(pi(Rs + Ts/2)^2)
  = -2970/(pi(28.25+0.75))+25557/(pi(14.12+0.75/2)^2)
  = 5.8 lb./in.
```

Force per Length, Cone Small End, compressive side [QS-]:
```
  = P( Rs/2 ) + f2
  = 100 ( 14.12/2 ) + -71.58
  = 634.672 lb./in.
```

Axial Load per Unit Circumference excluding Pressure [f2]:
```
  = Faxial/(pi(Ds + Ts)) - Moment/(pi(Rs + Ts/2)^2)
  = -2970/(pi(28.25+0.75))-25557/(pi(14.12+0.75/2)^2)
  = -71.6 lb./in.
```

Area of Reinforcement Available in Small End Shell [Aes]:
```
  = 0.78[ sqrt(Rs*ts)*(ts-t) + sqrt( Rs * tc/cos(alpha)) * ( tc - tr ) ]  per 1-5 eqn. 8
  = 0.78[ sqrt( 14.12 * 0.625 )*( 0.625 - 0.0834 ) +
    sqrt( 14.12 * 0.625/0.97 ) * ( 0.625 - 0.0859 ) ]
  = 2.5236 sq.in.
```

Summary of Reinforcement Area, Small End, Internal Pressure:

Area of reinforcement required per App. 1-5(7)	0.0760	sq.in.
Area of reinforcement in shell per App. 1-5(8)	2.5236	sq.in.
Area of reinforcement in stiffening ring	0.0000	sq.in.

Required Area of Reinforcement for Small End Under External Pressure

```
 Allowable Stress of Small End Material (Ext. Temp)    20000.0  psi
 Allowable Stress of Cone Material (Ext. Temp)         20000.0  psi
```

Intermediate Value [k]:
```
  = max( Y / ( Srs * Ers ), 1 )
  = max( 576.00E+09/( 20000 * 28800000 ), 1 )
  = 1.0000
```

where [Y] is:
```
   = Small End All. Stress * Small End Elastic Modulus (Ext. temp.)
   = 20000 * 28800000
   = 575999967232.0 (psi)^2
```

Area of Reinforcement Required in Small End Shell [Ars]:
```
  = k * QS * Rs * tan(alpha) / ( Ss * E1 )
  = (1*182.9*14.75*0.25/(20000*0.85))
  = 0.0397 sq.in.
```

Force per Length, Cone Small End External Pressure, compressive side [QS-]:
```
  = Pext( Rs/2 ) + f2
  = 15 ( 14.75/2 ) + 72.25
  = 182.879 lb./in.
```

Axial Load per Unit Circumference excluding Pressure [f2]:
```
  = Faxial/(pi(Ds + Ts)) + Moment/(pi(Rs - Ts/2)^2)
  = +2970/(pi(29.5-0.75))+25557/(pi(14.75-0.75/2)^2)
  = 72.3 lb./in.
```

Force per Length, Cone Small End External Pressure, tensile side [QS+]:
```
  = Pext( Rs/2 ) + f2
  = 15 ( 14.75/2 ) + -6.482
  = 104.143 lb./in.
```

Axial Load per Unit Circumference excluding Pressure [f2]:
```
  = Faxial/(pi(Ds + Ts)) - Moment/(pi(Rs - Ts/2)^2)
  = +2970/(pi(29.5-0.75))-25557/(pi(14.75-0.75/2)^2)
  = -6.5 lb./in.
```

Area of Reinforcement Available in Small End Shell [Aes]:
```
  = 0.55[ sqrt(Ds*ts)(ts-t) + sqrt(Ds*tc/cos(alpha))(tc-tr) ]
  = 0.55[ sqrt( 29.5 * 0.625 )( 0.625 - 0.169 ) +
    sqrt( 29.5 * 0.625/0.97 )( 0.625 - 0.0841 )]
  = 2.3731 sq.in.
```

Summary of Reinforcement Area, Small End, External Pressure:
```
 Area of reinforcement required per App. 1-8(6)       0.0397  sq.in.
 Area of reinforcement in shell per App. 1-8(7)       2.3731  sq.in.
 Area of reinforcement in stiffening ring             0.0000  sq.in.
```

Intermediate Results, Small End, External Pressure:
```
 Area Available in Cone, Shell, and Reinforcement      46.58  sq.in.
 Force per Unit Length on Shell / Cone Junction      1121.92  lb./in.
 Actual Buckling Stress associated with this Force    532.84  psi
 Material Strain associated with this stress        0.000037
```

Required Moment of Inertia, Small End, External Pressure [I's]:
```
  = A * Ds² * Ats / 10.9
  = 0.37003E-04 * 29.5 * 29.5 * 46.58/10.9
  = 0.14 in.⁴
```

Available Moment of Inertia, Small End, External Pressure:

	Area	Centroid	Ar*Ce	Dist	I	Ar*Di²
Shl	1.476	0.0000	0.000	0.1498	0.048	0.033
Con	1.521	0.2952	0.449	-0.1454	0.097	0.032
Sec	0.000	0.3125	0.000	-0.1627	0.000	0.000
TOT	2.997		0.449		0.145	0.065

Centroid of Section 0.1498 Moment of Inertia 0.21

Summary of Small End Inertia Calculations

Available Moment of Inertia (Small End)	0.210	in**4
Required Moment of Inertia (Small End)	0.138	in**4

Because the 1/2 apex angle is less than 30 degrees, the following discontinuity stress evaluation results are for information only.

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

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

Stress Type	Stress	Allowable	Location
Tensile Stress	2786.69	69600.00	Small Cyl. Long.
Compres. Stress	-456.58	-69600.00	Small Cyl. Long.
Membrane Stress	3202.61	30000.00	Small End Tang.
Tensile Stress	2822.54	69600.00	Cone Longitudinal
Compres. Stress	-420.72	-69600.00	Cone Longitudinal
Tensile Stress	3273.70	30000.00	Cone Tangential
Tensile Stress	4337.85	69600.00	Large Cyl. Long.
Compres. Stress	-1071.46	-69600.00	Large Cyl. Long.
Membrane Stress	1861.07	-30000.00	Large End Tang.
Tensile Stress	4388.11	69600.00	Cone Longitudinal
Compres. Stress	-1021.20	-69600.00	Cone Longitudinal
Compres Stress	1961.71	-30000.00	Cone Tangential

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

Maximum Allowable Pressure Calculations for Cone to Shell Junction:

Pressure Case	Pressure psig	Reason for Failure at this Pressure
MAWP	503.090	Thickness due to internal pressure, Cone Large End
MAPnc	605.290	Thickness due to internal pressure, Cone Large End

These pressures were determined by iteration.

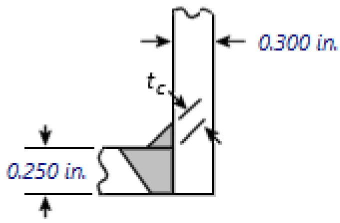
Input, Nozzle Desc: Drain From: 20

Pressure for Reinforcement Calculations	P	100.000	psig
Temperature for Internal Pressure	Temp	200	F
Design External Pressure	Pext	15.00	psig
Temperature for External Pressure	Tempex	200	F
Parent Material		SA-516 70	
Parent Allowable Stress at Temperature	Sv	20000.00	psi
Parent Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Elliptical Head	D	40.0000	in.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	0.2500	in.
Head Internal Corrosion Allowance	c	0.1250	in.
Head External Corrosion Allowance	co	0.0000	in.
Distance from Head Centerline	L1	0.0000	in.
User Entered Minimum Design Metal Temperature		-20.00	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)		Inside	
Layout Angle		0.00	deg
Diameter		3.0000	in.
Size and Thickness Basis		Nominal	
Nominal Thickness		80	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	0.1250	in.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	6.0000	in.
Weld leg size between Nozzle and Pad/Shell	Wo	0.3750	in.
Groove weld depth between Nozzle and Vessel	Wgnv	0.2500	in.
Inside Projection	h	0.0000	in.
Weld leg size, Inside Element to Shell	Wi	0.0000	in.
ASME Code Weld Type		UW-16.1(C)	
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.



UW-16 (c)

Reinforcement CALCULATION, Description: Drain

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

```
Actual Inside Diameter Used in Calculation            2.900  in.
Actual Thickness Used in Calculation                  0.300  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Elliptical Head, tr [Int. Press]

```
 = P*D*K1/(2*Sv*E-0.2*P) per Appendix 1-4(c)
 = 100*40.25*0.9/(2*20000*1-0.2*100)
 = 0.0906 in.
```

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

```
 = P*R/(Sn*E-0.6*P) per UG-27 (c)(1)
 = 100*1.575/(17100*1-0.6*100)
 = 0.0092 in.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0140 in.

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

```
Parallel to Vessel Wall (Diameter Limit)          Dl     6.3000  in.
Parallel to Vessel Wall, opening length            d     3.1500  in.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp   0.3125  in.
```

Taking a UG-36(c)(3)(a) exemption for nozzle: Drain.
This calculation is valid for nozzles that meet all the requirements of paragraph UG-36. Please check the Code carefully, especially for nozzles that are not isolated or do not meet Code spacing requirements. To force the computation of areas for small nozzles go to Tools->Configuration and check the box to force the UG-37 small nozzle area calculation.

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

```
Wall Thickness for Internal/External pressures      ta = 0.1390 in.
Wall Thickness per UG16(b),                      tr16b = 0.2188 in.
Wall Thickness, shell/head, internal pressure     trb1 = 0.2257 in.
Wall Thickness                 tb1 = max(trb1, tr16b) = 0.2257 in.
Wall Thickness, shell/head, external pressure     trb2 = 0.1401 in.
Wall Thickness                 tb2 = max(trb2, tr16b) = 0.2188 in.
Wall Thickness per table UG-45                     tb3 = 0.3140 in.
```

Determine Nozzle Thickness candidate [tb]:

```
 = min[ tb3, max( tb1,tb2) ]
 = min[ 0.314, max( 0.226, 0.219 ) ]
 = 0.2257 in.
```

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

```
  = max( ta, tb )
  = max( 0.139, 0.226 )
  = 0.2257 in.
```

Available Nozzle Neck Thickness = 0.875 * 0.300 = 0.263 in. -> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 0.263, tr = 0.00924, c = 0.125 in., E∗ = 1
Thickness Ratio = tr * E∗/(tg - c) = 0.0672, Temp. Reduction = 140 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve B            -20 F
 Min Metal Temp. at Required thickness (UCS 66.1)         -155 F
```

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

Govrn. thk, tg = 0.25, tr = 0.0906, c = 0.125 in., E∗ = 1
Thickness Ratio = tr * E∗/(tg - c) = 0.725, Temp. Reduction = 28 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve B            -20 F
 Min Metal Temp. at Required thickness (UCS 66.1)          -48 F

 Gov. MDMT of the nozzle to shell joint welded assembly :   -48 F
```

Flange MDMT including Temperature reduction per UCS-66.1:

```
 Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)      0 F
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -55 F
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
 Design Pressure/Ambient Rating = 100.00/285.00 = 0.351

Weld Size Calculations, Description: Drain

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.1250  in.
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
 Nozzle Weld          0.0875 = 0.7 * tmin.  0.2651 = 0.7 * Wo in.
```

The Drop for this Nozzle is : 0.0423 in.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 6.2923 in.

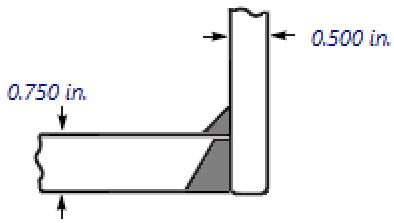
Input, Nozzle Desc: Manway From: 30

Pressure for Reinforcement Calculations	P	100.000	psig
Temperature for Internal Pressure	Temp	200	F
Design External Pressure	Pext	15.00	psig
Temperature for External Pressure	Tempex	200	F
Parent Material		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	40.0000	in.
Design Length of Section	L	350.9333	in.
Shell Finished (Minimum) Thickness	t	0.7500	in.
Shell Internal Corrosion Allowance	c	0.1250	in.
Shell External Corrosion Allowance	co	0.0000	in.
Distance from Bottom/Left Tangent		3.17	ft.
User Entered Minimum Design Metal Temperature		-20.00	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)		Inside	
Layout Angle		0.00	deg
Diameter		16.0000	in.
Size and Thickness Basis		Nominal	
Nominal Thickness		40	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	0.1250	in.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	6.0000	in.
Weld leg size between Nozzle and Pad/Shell	Wo	0.3750	in.
Groove weld depth between Nozzle and Vessel	Wgnv	0.7500	in.
Inside Projection	h	0.0000	in.
Weld leg size, Inside Element to Shell	Wi	0.0000	in.
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.



Reinforcement CALCULATION, Description: Manway

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

```
 Actual Inside Diameter Used in Calculation            15.000  in.
 Actual Thickness Used in Calculation                   0.500  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)
  = 100*20.12/(20000*1-0.6*100)
  = 0.1009 in.
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]
```
  = P*R/(Sn*E-0.6*P) per UG-27 (c)(1)
  = 100*7.625/(17100*1-0.6*100)
  = 0.0447 in.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0342 in.

UG-40, Limits of Reinforcement: [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl    30.5000  in.
 Parallel to Vessel Wall, opening length              d    15.2500  in.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     0.9375  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 [fr3]:
```
  = min( fr2, fr4 )
  = min( 0.855, 1 )
  = 0.855
```

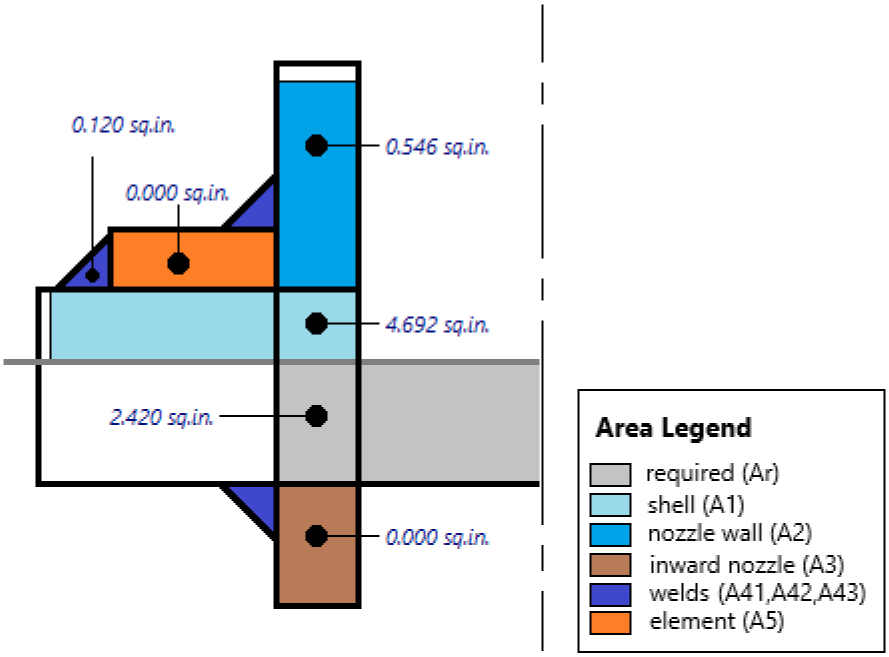


Figure UG 37.1 Nozzle Areas

Results of Nozzle Reinforcement Area Calculations: (sq.in.)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	1.550	2.420	NA
Area in Shell	A1	7.935	4.692	NA
Area in Nozzle Wall	A2	0.529	0.546	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.120	0.120	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	8.585	5.359	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 degs.

The area available without a pad is Sufficient.

Area Required [A]:
```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(15.25*0.315*1+2*0.375*0.315*1(1-0.855))
  = 2.420 sq.in.
```

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 )
  = 15.25 ( 1 * 0.625 - 1 * 0.315 ) - 2 * 0.375
    ( 1 * 0.625 - 1 * 0.315 ) * ( 1 - 0.855 )
  = 4.692 sq.in.
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 0.938 )( 0.375 - 0.0342 )0.855
```

```
  = 0.546 sq.in.
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 0.375² * 0.855 + ( 0 )² * 0.855
  = 0.120 sq.in.
```

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

```
 Wall Thickness for Internal/External pressures      ta = 0.1697 in.
 Wall Thickness per UG16(b),                       tr16b = 0.2188 in.
 Wall Thickness, shell/head, internal pressure     trb1 = 0.2259 in.
 Wall Thickness                 tb1 = max(trb1, tr16b) = 0.2259 in.
 Wall Thickness, shell/head, external pressure     trb2 = 0.1401 in.
 Wall Thickness                 tb2 = max(trb2, tr16b) = 0.2188 in.
 Wall Thickness per table UG-45                     tb3 = 0.4530 in.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.453, max( 0.226, 0.219 ) ]
  = 0.2259 in.
```

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

```
  = max( ta, tb )
  = max( 0.17, 0.226 )
  = 0.2259 in.
```

Available Nozzle Neck Thickness = 0.875 * 0.500 = 0.438 in. -> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 0.438, tr = 0.0447, c = 0.125 in., E∗ = 1
Thickness Ratio = tr * E∗/(tg - c) = 0.143, Temp. Reduction = 140 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve B             -14 F
 Min Metal Temp. at Required thickness (UCS 66.1)          -155 F
 Min Metal Temp. w/o impact per UG-20(f)                    -20 F
```

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

Govrn. thk, tg = 0.438, tr = 0.0447, c = 0.125 in., E∗ = 1
Thickness Ratio = tr * E∗/(tg - c) = 0.143, Temp. Reduction = 140 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve B             -14 F
 Min Metal Temp. at Required thickness (UCS 66.1)          -155 F
 Min Metal Temp. w/o impact per UG-20(f)                    -20 F

 Gov. MDMT of the nozzle to shell joint welded assembly :  -155 F
```

Flange MDMT including Temperature reduction per UCS-66.1:

```
 Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)       0 F
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -55 F
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :

```
 Design Pressure/Ambient Rating = 100.00/285.00 = 0.351
```

Weld Size Calculations, Description: Manway

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.3750  in.
```

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	0.2500 = Min per Code	0.2651 = 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, (2.42 - 4.692 + 2 * 0.375 * 0.855 *
  (1 * 0.625 - 0.315 ) )20000 )
= max( 0, -41474.09) lb.
```

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

Weld Load [W1]:
```
= (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
= ( 0.546 + 0 + 0.12 - 0 * 0.855 ) * 20000
= 13331.24 lb.
```

Weld Load [W2]:
```
= (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
= ( 0.546 + 0 + 0.12 + ( 0.401 ) ) * 20000
= 21346.87 lb.
```

Weld Load [W3]:
```
= (A2+A3+A4+A5+(2*tn*t*fr1))*S
= ( 0.546 + 0 + 0.12 + 0 + ( 0.401 ) ) * 20000
= 21346.87 lb.
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
= (pi/2) * Dlo * Wo * 0.49 * Snw
= ( 3.142/2.0 ) * 16 * 0.375 * 0.49 * 17100
= 78970. lb.
```

Shear, Nozzle Wall [Snw]:
```
= (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
= (3.142 * 7.812 ) * ( 0.5 - 0.125 ) * 0.7 * 17100
= 110170. lb.
```

Tension, Shell Groove Weld [Tngw]:
```
= (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
= ( 3.142/2.0 ) * 16 * ( 0.75 - 0.125 ) * 0.74 * 20000
= 232478. lb.
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:
```
= ( SONW + SNW ) = ( 78970 + 110170 ) = 189141 lb.
```

Failure Path [Path 2-2]:
```
= ( Sonw + Tpgw + Tngw + Sinw )
= ( 78970 + 0 + 232478 + 0 ) = 311448 lb.
```

Failure Path [Path 3-3]:
```
= ( Sonw + Tngw + Sinw )
= ( 78970 + 232478 + 0 ) = 311448 lb.
```

Summary of Failure Path Calculations:
```
Path 1-1 = 189140  lb., must exceed W = 0 lb.       or W1 = 13331 lb.
```

```
Path 2-2 = 311448  lb., must exceed W = 0 lb.        or W2 = 21346 lb.
Path 3-3 = 311448  lb., must exceed W = 0 lb.        or W3 = 21346 lb.
```

Maximum Allowable Pressure for this Nozzle at this Location:

Converged Maximum Allowable Pressure in the Operating case: 308.2 psig

Nozzle is O.K. for the External Pressure: 15 psig

The Drop for this Nozzle is : 1.6697 in.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 8.4197 in.

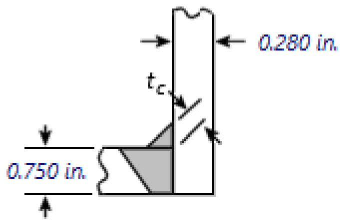
Input, Nozzle Desc: Inlet From: 40

Pressure for Reinforcement Calculations	P	100.000	psig
Temperature for Internal Pressure	Temp	200	F
Design External Pressure	Pext	15.00	psig
Temperature for External Pressure	Tempex	200	F
Parent Material		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	40.0000	in.
Design Length of Section	L	350.9333	in.
Shell Finished (Minimum) Thickness	t	0.7500	in.
Shell Internal Corrosion Allowance	c	0.1250	in.
Shell External Corrosion Allowance	co	0.0000	in.
Distance from Bottom/Left Tangent		17.00	ft.
User Entered Minimum Design Metal Temperature		-20.00	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)		Inside	
Layout Angle		0.00	deg
Diameter		6.0000	in.
Size and Thickness Basis		Nominal	
Nominal Thickness		40	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	0.1250	in.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	6.0000	in.
Weld leg size between Nozzle and Pad/Shell	Wo	0.3750	in.
Groove weld depth between Nozzle and Vessel	Wgnv	0.7500	in.
Inside Projection	h	0.0000	in.
Weld leg size, Inside Element to Shell	Wi	0.0000	in.
ASME Code Weld Type		UW-16.1(C)	
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.



UW-16 (c)

Reinforcement CALCULATION, Description: Inlet

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

```
 Actual Inside Diameter Used in Calculation            6.065  in.
 Actual Thickness Used in Calculation                  0.280  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)
  = 100*20.12/(20000*1-0.6*100)
  = 0.1009 in.
```

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

```
  = P*R/(Sn*E-0.6*P) per UG-27 (c)(1)
  = 100*3.158/(17100*1-0.6*100)
  = 0.0185 in.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0204 in.

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

```
 Parallel to Vessel Wall (Diameter Limit)            Dl    12.6300  in.
 Parallel to Vessel Wall, opening length              d     6.3150  in.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     0.3875  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 [fr3]:

```
  = min( fr2, fr4 )
  = min( 0.855, 1 )
  = 0.855
```

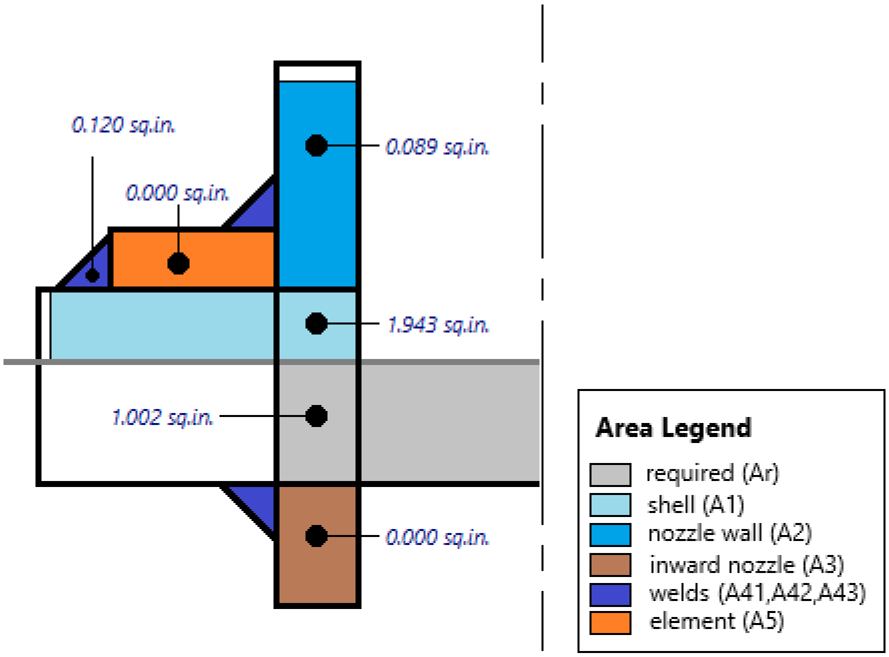


Figure UG 37.1 Nozzle Areas

Results of Nozzle Reinforcement Area Calculations: (sq.in.)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.642	1.002	NA
Area in Shell	A1	3.286	1.943	NA
Area in Nozzle Wall	A2	0.090	0.089	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.120	0.120	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	3.497	2.152	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 degs.

The area available without a pad is Sufficient.

Area Required [A]:
```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(6.315*0.315*1+2*0.155*0.315*1(1-0.855))
  = 1.002 sq.in.
```

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 )
  = 6.315 ( 1 * 0.625 - 1 * 0.315 ) - 2 * 0.155
    ( 1 * 0.625 - 1 * 0.315 ) * ( 1 - 0.855 )
  = 1.943 sq.in.
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 0.387 )( 0.155 - 0.0204 )0.855
```

```
  = 0.089 sq.in.
```

Area Available in Inward Weld + Outward Weld [A41 + A43]:

```
  = Wo² * fr2 + ( Wi-can/0.707 )² * fr2
  = 0.375² * 0.855 + ( 0 )² * 0.855
  = 0.120 sq.in.
```

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

```
 Wall Thickness for Internal/External pressures      ta = 0.1454 in.
 Wall Thickness per UG16(b),                       tr16b = 0.2188 in.
 Wall Thickness, shell/head, internal pressure     trb1 = 0.2259 in.
 Wall Thickness                 tb1 = max(trb1, tr16b) = 0.2259 in.
 Wall Thickness, shell/head, external pressure     trb2 = 0.1401 in.
 Wall Thickness                 tb2 = max(trb2, tr16b) = 0.2188 in.
 Wall Thickness per table UG-45                      tb3 = 0.3699 in.
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.37, max( 0.226, 0.219 ) ]
  = 0.2259 in.
```

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

```
  = max( ta, tb )
  = max( 0.145, 0.226 )
  = 0.2259 in.
```

Available Nozzle Neck Thickness = 0.875 * 0.280 = 0.245 in. -> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 0.245, tr = 0.0185, c = 0.125 in., E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.154, Temp. Reduction = 140 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve B             -20 F
 Min Metal Temp. at Required thickness (UCS 66.1)          -155 F
```

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

Govrn. thk, tg = 0.245, tr = 0.0185, c = 0.125 in., E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.154, Temp. Reduction = 140 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve B             -20 F
 Min Metal Temp. at Required thickness (UCS 66.1)          -155 F

 Gov. MDMT of the nozzle to shell joint welded assembly :  -155 F
```

Flange MDMT including Temperature reduction per UCS-66.1:

```
 Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)       0 F
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -55 F
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :

```
 Design Pressure/Ambient Rating = 100.00/285.00 = 0.351
```

Weld Size Calculations, Description: Inlet

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.1550  in.
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
```

Nozzle Weld 0.1085 = 0.7 * tmin. 0.2651 = 0.7 * Wo in.

Maximum Allowable Pressure for this Nozzle at this Location:

Converged Maximum Allowable Pressure in the Operating case: 118.9 psig

Nozzle is O.K. for the External Pressure: 15 psig

The Drop for this Nozzle is : 0.2762 in.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 7.0262 in.

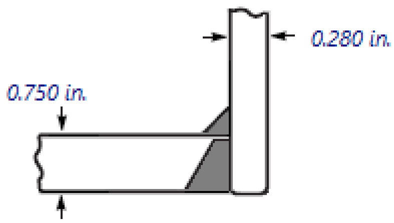
Input, Nozzle Desc: Outlet From: 60

```
Pressure for Reinforcement Calculations        P       100.000  psig
Temperature for Internal Pressure           Temp           200  F
Design External Pressure                    Pext         15.00  psig
Temperature for External Pressure         Tempex           200  F

Parent Material                                     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       28.0000  in.
Design Length of Section                       L      124.3333  in.
Shell Finished (Minimum) Thickness             t        0.7500  in.
Shell Internal Corrosion Allowance             c        0.1250  in.
Shell External Corrosion Allowance            co        0.0000  in.

Distance from Bottom/Left Tangent                        39.17  ft.

User Entered Minimum Design Metal Temperature           -20.00  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)                       Inside
Layout Angle                                              0.00  deg
Diameter                                                6.0000  in.

Size and Thickness Basis                               Nominal
Nominal Thickness                                           40

Flange Material                                         SA-105
Flange Type                                  Weld Neck Flange

Corrosion Allowance                          can        0.1250  in.
Joint Efficiency of Shell Seam at Nozzle      E1          1.00
Joint Efficiency of Nozzle Neck               En          1.00

Outside Projection                            ho        6.0000  in.
Weld leg size between Nozzle and Pad/Shell    Wo        0.3750  in.
Groove weld depth between Nozzle and Vessel Wgnv        0.7500  in.
Inside Projection                              h        0.0000  in.
Weld leg size, Inside Element to Shell        Wi        0.0000  in.

Flange Class                                               150
Flange Grade                                            GR 1.1
```

The Pressure Design option was Design Pressure + static head.



Reinforcement CALCULATION, Description: Outlet

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

```
 Actual Inside Diameter Used in Calculation              6.065  in.
 Actual Thickness Used in Calculation                    0.280  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)
  = 100*14.12/(20000*1-0.6*100)
  = 0.0708 in.
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]
```
  = P*R/(Sn*E-0.6*P) per UG-27 (c)(1)
  = 100*3.158/(17100*1-0.6*100)
  = 0.0185 in.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0204 in.

UG-40, Limits of Reinforcement: [Internal Pressure]
```
 Parallel to Vessel Wall (Diameter Limit)            Dl    12.6300  in.
 Parallel to Vessel Wall, opening length              d     6.3150  in.
 Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     0.3875  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 [fr3]:
```
  = min( fr2, fr4 )
  = min( 0.855, 1 )
  = 0.855
```

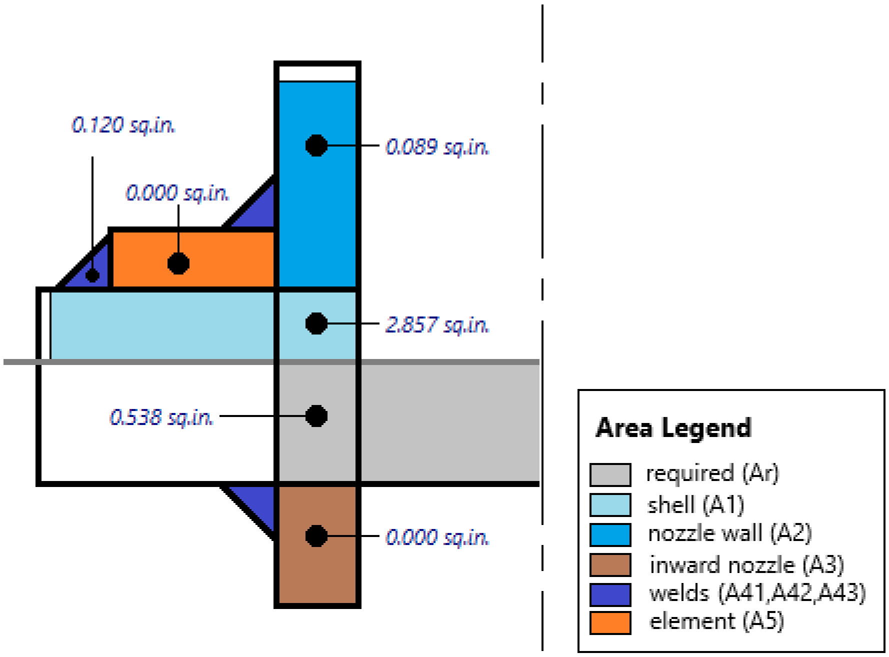


Figure UG 37.1 Nozzle Areas

Results of Nozzle Reinforcement Area Calculations: (sq.in.)

AREA AVAILABLE, A1 to A5		Design	External	Mapnc
Area Required	Ar	0.451	0.538	NA
Area in Shell	A1	3.475	2.857	NA
Area in Nozzle Wall	A2	0.090	0.089	NA
Area in Inward Nozzle	A3	0.000	0.000	NA
Area in Welds	A41+A42+A43	0.120	0.120	NA
Area in Element	A5	0.000	0.000	NA
TOTAL AREA AVAILABLE	Atot	3.685	3.067	NA

The External Pressure Case Governs the Analysis.

Nozzle Angle Used in Area Calculations 90.00 degs.

The area available without a pad is Sufficient.

Area Required [A]:
```
  = 0.5( d * tr*F + 2 * tn * tr*F(1-fr1) ) per UG-37(d)
  = 0.5(6.315*0.169*1+2*0.155*0.169*1(1-0.855))
  = 0.538 sq.in.
```

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 )
  = 6.315 ( 1 * 0.625 - 1 * 0.169 ) - 2 * 0.155
    ( 1 * 0.625 - 1 * 0.169 ) * ( 1 - 0.855 )
  = 2.857 sq.in.
```

Area Available in Nozzle Projecting Outward [A2]:
```
  = ( 2 * tlnp )( tn - trn )fr2
  = ( 2 * 0.387 )( 0.155 - 0.0204 )0.855
```

= 0.089 sq.in.

Area Available in Inward Weld + Outward Weld [A41 + A43]:
= Wo^2 * fr2 + (Wi-can/0.707 $)^2$ * fr2
= 0.375^2 * 0.855 + (0 $)^2$ * 0.855
= 0.120 sq.in.

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

```
Wall Thickness for Internal/External pressures      ta = 0.1454 in.
Wall Thickness per UG16(b),                       tr16b = 0.2188 in.
Wall Thickness, shell/head, internal pressure     trb1 = 0.1958 in.
Wall Thickness                 tb1 = max(trb1, tr16b) = 0.2188 in.
Wall Thickness, shell/head, external pressure     trb2 = 0.1356 in.
Wall Thickness                 tb2 = max(trb2, tr16b) = 0.2188 in.
Wall Thickness per table UG-45                     tb3 = 0.3699 in.
```

Determine Nozzle Thickness candidate [tb]:
= min[tb3, max(tb1,tb2)]
= min[0.37, max(0.219, 0.219)]
= 0.2188 in.

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(0.145, 0.219)
= 0.2188 in.

Available Nozzle Neck Thickness = 0.875 * 0.280 = 0.245 in. -> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 0.245, tr = 0.0185, c = 0.125 in., E∗ = 1
Thickness Ratio = tr * E∗/(tg - c) = 0.154, Temp. Reduction = 140 F

```
Min Metal Temp. w/o impact per UCS-66, Curve B             -20 F
Min Metal Temp. at Required thickness (UCS 66.1)          -155 F
```

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

Govrn. thk, tg = 0.245, tr = 0.0185, c = 0.125 in., E∗ = 1
Thickness Ratio = tr * E∗/(tg - c) = 0.154, Temp. Reduction = 140 F

```
Min Metal Temp. w/o impact per UCS-66, Curve B             -20 F
Min Metal Temp. at Required thickness (UCS 66.1)          -155 F

Gov. MDMT of the nozzle to shell joint welded assembly :  -155 F
```

Flange MDMT including Temperature reduction per UCS-66.1:

```
Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)       0 F
Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)       -55 F
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
Design Pressure/Ambient Rating = 100.00/285.00 = 0.351

<u>Weld Size Calculations, Description: Outlet</u>

```
Intermediate Calc. for nozzle/shell Welds   Tmin      0.1550  in.
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
```

```
 Nozzle Weld          0.1085 = 0.7 * tmin.  0.2651 = 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, (0.538 - 2.857 + 2 * 0.155 * 0.855 *
    (1 * 0.625 - 0.169 ) )20000 )
  = max( 0, -43962.02) lb.
```

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

Weld Load [W1]:
```
  = (A2+A5+A4-(Wi-Can/.707)²*fr2)*Sv
  = ( 0.0892 + 0 + 0.12 - 0 * 0.855 ) * 20000
  = 4188.58 lb.
```

Weld Load [W2]:
```
  = (A2 + A3 + A4 + (2 * tn * t * fr1)) * Sv
  = ( 0.0892 + 0 + 0.12 + ( 0.166 ) ) * 20000
  = 7501.71 lb.
```

Weld Load [W3]:
```
  = (A2+A3+A4+A5+(2*tn*t*fr1))*S
  = ( 0.0892 + 0 + 0.12 + 0 + ( 0.166 ) ) * 20000
  = 7501.71 lb.
```

Strength of Connection Elements for Failure Path Analysis

Shear, Outward Nozzle Weld [Sonw]:
```
  = (pi/2) * Dlo * Wo * 0.49 * Snw
  = ( 3.142/2.0 ) * 6.625 * 0.375 * 0.49 * 17100
  = 32699. lb.
```

Shear, Nozzle Wall [Snw]:
```
  = (pi *( Dlr + Dlo )/4 ) * ( Thk - Can ) * 0.7 * Sn
  = (3.142 * 3.235 ) * ( 0.28 - 0.125 ) * 0.7 * 17100
  = 18856. lb.
```

Tension, Shell Groove Weld [Tngw]:
```
  = (pi/2) * Dlo * ( T - cas ) * 0.74 * Sng
  = ( 3.142/2.0 ) * 6.625 * ( 0.75 - 0.125 ) * 0.74 * 20000
  = 96260. lb.
```

See UG-41 and UW-15 for clarification of allowable stresses.

Strength of Failure Paths:

Failure Path [Path 1-1]:
```
  = ( SONW + SNW ) = ( 32699 + 18856 ) = 51555 lb.
```

Failure Path [Path 2-2]:
```
  = ( Sonw + Tpgw + Tngw + Sinw )
  = ( 32699 + 0 + 96260 + 0 ) = 128959 lb.
```

Failure Path [Path 3-3]:
```
  = ( Sonw + Tngw + Sinw )
  = ( 32699 + 96260 + 0 ) = 128959 lb.
```

Summary of Failure Path Calculations:
```
 Path 1-1 = 51554   lb., must exceed W = 0 lb.        or W1 = 4188 lb.
 Path 2-2 = 128958  lb., must exceed W = 0 lb.        or W2 = 7501 lb.
```

Path 3-3 = 128958 lb., must exceed W = 0 lb.   or W3 = 7501 lb.

Maximum Allowable Pressure for this Nozzle at this Location:

Converged Maximum Allowable Pressure in the Operating case: 169.1 psig

Nozzle is O.K. for the External Pressure: 15 psig

The Drop for this Nozzle is : 0.3975 in.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 7.1475 in.

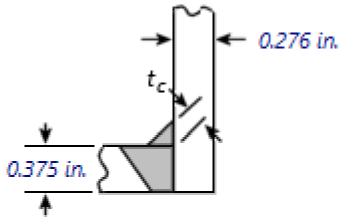
Input, Nozzle Desc: Vent From: 70

Pressure for Reinforcement Calculations	P	100.000	psig
Temperature for Internal Pressure	Temp	200	F
Design External Pressure	Pext	15.00	psig
Temperature for External Pressure	Tempex	200	F
Parent Material		SA-516 70	
Parent Allowable Stress at Temperature	Sv	20000.00	psi
Parent Allowable Stress At Ambient	Sva	20000.00	psi
Inside Diameter of Elliptical Head	D	28.0000	in.
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	0.3750	in.
Head Internal Corrosion Allowance	c	0.1250	in.
Head External Corrosion Allowance	co	0.0000	in.
Distance from Head Centerline	L1	0.0000	in.
User Entered Minimum Design Metal Temperature		-20.00	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)		Inside	
Layout Angle		0.00	deg
Diameter		2.5000	in.
Size and Thickness Basis		Nominal	
Nominal Thickness		80	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	0.1250	in.
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	6.0000	in.
Weld leg size between Nozzle and Pad/Shell	Wo	0.3750	in.
Groove weld depth between Nozzle and Vessel	Wgnv	0.3750	in.
Inside Projection	h	0.0000	in.
Weld leg size, Inside Element to Shell	Wi	0.0000	in.
ASME Code Weld Type		UW-16.1(C)	
Flange Class		150	
Flange Grade		GR 1.1	

The Pressure Design option was Design Pressure + static head.



UW-16 (c)

Reinforcement CALCULATION, Description: Vent

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

```
Actual Inside Diameter Used in Calculation            2.323  in.
Actual Thickness Used in Calculation                  0.276  in.
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a) of Elliptical Head, tr [Int. Press]
```
  = P*D*K1/(2*Sv*E-0.2*P) per Appendix 1-4(c)
  = 100*28.25*0.9/(2*20000*1-0.2*100)
  = 0.0636 in.
```

Reqd thk per UG-37(a) of Nozzle Wall, trn [Int. Press]
```
  = P*R/(Sn*E-0.6*P) per UG-27 (c)(1)
  = 100*1.286/(17100*1-0.6*100)
  = 0.0075 in.
```

Required Nozzle thickness under External Pressure per UG-28 : 0.0124 in.

UG-40, Limits of Reinforcement: [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl     5.1460  in.
Parallel to Vessel Wall, opening length              d     2.5730  in.
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     0.3775  in.
```

*Taking a UG-36(c)(3)(a) exemption for nozzle: Vent.
This calculation is valid for nozzles that meet all the requirements of paragraph UG-36. Please check the Code carefully, especially for nozzles that are not isolated or do not meet Code spacing requirements. To force the computation of areas for small nozzles go to Tools->Configuration and check the box to force the UG-37 small nozzle area calculation.*

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures      ta = 0.1374 in.
Wall Thickness per UG16(b),                       tr16b = 0.2188 in.
Wall Thickness, shell/head, internal pressure     trb1 = 0.1957 in.
Wall Thickness              tb1 = max(trb1, tr16b) = 0.2188 in.
Wall Thickness, shell/head, external pressure     trb2 = 0.1356 in.
Wall Thickness              tb2 = max(trb2, tr16b) = 0.2188 in.
Wall Thickness per table UG-45                     tb3 = 0.3030 in.
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 0.303, max( 0.219, 0.219 ) ]
  = 0.2188 in.
```

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

```
  = max( ta, tb )
  = max( 0.137, 0.219 )
  = 0.2188 in.
```

Available Nozzle Neck Thickness = 0.875 * 0.276 = 0.241 in. -> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 0.241, tr = 0.00755, c = 0.125 in., E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.0648, Temp. Reduction = 140 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve B            -20 F
 Min Metal Temp. at Required thickness (UCS 66.1)         -155 F
```

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

Govrn. thk, tg = 0.241, tr = 0.00755, c = 0.125 in., E✱ = 1
Thickness Ratio = tr * E✱/(tg - c) = 0.0648, Temp. Reduction = 140 F

```
 Min Metal Temp. w/o impact per UCS-66, Curve B            -20 F
 Min Metal Temp. at Required thickness (UCS 66.1)         -155 F

 Gov. MDMT of the nozzle to shell joint welded assembly :  -155 F
```

Flange MDMT including Temperature reduction per UCS-66.1:

```
 Unadjusted MDMT of ASME B16.5/47 flanges per UCS-66(c)      0 F
 Flange MDMT with Temp reduction per UCS-66(b)(1)(-b)      -55 F
```

Where the Stress Reduction Ratio per UCS-66(b)(1)(-b) is :
 Design Pressure/Ambient Rating = 100.00/285.00 = 0.351

<u>Weld Size Calculations, Description: Vent</u>

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      0.1510  in.
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
 Nozzle Weld          0.1057 = 0.7 * tmin.  0.2651 = 0.7 * Wo in.
```

The Drop for this Nozzle is : 0.0406 in.
The Cut Length for this Nozzle is, Drop + Ho + H + T : 6.4156 in.