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DESIGN CALCULATION

In Accordance with ASME Section VIII Division 1

```
ASME Code Version     : 2017

Analysis Performed by : SPLM Licensed User

Job File              : D:\2-PAYAM\1-PROJECTS\MICROTEC PROJECT\13-MICROT

Date of Analysis      : Feb 20,2026   4:19pm

PV Elite 2019 SP1, March 2019
```

Note:
PV Elite performs all calculations internally in Imperial Units
to remain compliant with the ASME Code and any built in assumptions
in the ASME Code formulas. The finalized results are reflected to show
the user's set of selected units.

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

Class From To: Check of Additional Element Data
==========================================================================
Please insure the C factor entered is in accordance with Figure UG-34.
Please insure the C factor entered is in accordance with Figure UG-34.

There were no geometry errors or warnings.
```

PV Elite Vessel Analysis Program: Input Data

Design Internal Pressure (for Hydrotest)	0.5	bars
Design Internal Temperature	170.0	°C
Type of Hydrotest	not Specified	
Hydrotest Position	Vertical	
Projection of Nozzle from Vessel Top	0	mm.
Projection of Nozzle from Vessel Bottom	0	mm.
Minimum Design Metal Temperature	-28.9	°C
Type of Construction	Welded	
Special Service	None	
Degree of Radiography	RT-1	
Use Higher Longitudinal Stresses (Flag)	Y	
Select t for Internal Pressure (Flag)	N	
Select t for External Pressure (Flag)	N	
Select t for Axial Stress (Flag)	N	
Select Location for Stiff. Rings (Flag)	N	
Consider Vortex Shedding	N	
Perform a Corroded Hydrotest	N	

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

Wind Design Code		ASCE-7 93	
Basic Wind Speed	[V]	112.65	Km/hr
Surface Roughness Category		C: Open Terrain	
Importance Factor		1.0	
Type of Surface		Moderately Smooth	
Base Elevation		0	mm.
Percent Wind for Hydrotest		33.0	
Using User defined Wind Press. Vs Elev.		N	
Damping Factor (Beta) for Wind (Ope)		0.0100	
Damping Factor (Beta) for Wind (Empty)		0.0000	
Damping Factor (Beta) for Wind (Filled)		0.0000	

Seismic Design Code	UBC 94
UBC Seismic Zone (1=1,2=2a,3=2b,4=3,5=4)	0.000
UBC Importance Factor	1.000
UBC Soil Type	S1
UBC Horizontal Force Factor	3.000
UBC Percent Seismic for Hydrotest	0.000

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

Material Database Year Current w/Addenda or Code Year

Configuration Directives:

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

Complete Listing of Vessel Elements and Details:

Element From Node	10	
Element To Node	20	
Element Type	Cylinder	
Description		
Distance "FROM" to "TO"	50	mm.
Inside Diameter	321	mm.
Element Thickness	3	mm.
Internal Corrosion Allowance	0	mm.
Nominal Thickness	3	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	0.5	bars
Design Temperature Internal Pressure	170	°C
Design External Pressure	0.1	bars
Design Temperature External Pressure	50	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-240 316	
Allowable Stress, Ambient	137.9	N./mm²
Allowable Stress, Operating	136.1	N./mm²
Allowable Stress, Hydrotest	179.3	N./mm²
Material Density	0.008027	kg./cm³
P Number Thickness	0	mm.
Yield Stress, Operating	156.1	N./mm²
External Pressure Chart Name	HA-2	
UNS Number	S31600	
Product Form	Plate	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Weld is pre-Heated	No	

Element From Node	10	
Detail Type	Ring	
Detail ID	Ring 1-1	
Dist. from "FROM" Node / Offset dist	0	mm.
Inside Diameter of Ring	327	mm.
Thickness of Ring	12	mm.
Outside Diameter of Ring	405	mm.
Material Name	SA-240 316	
Height of Section Ring	0	mm.
Using Custom Stiffener Section	No	

Element From Node	20
Element To Node	30
Element Type	Conical
Description	

Distance "FROM" to "TO"	1100	mm.
Inside Diameter	321	mm.
Element Thickness	3	mm.
Internal Corrosion Allowance	0	mm.
Nominal Thickness	3	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	0.5	bars
Design Temperature Internal Pressure	170	°C
Design External Pressure	0.1	bars
Design Temperature External Pressure	50	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-240 316	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Cone Diameter at "To" End	1124	mm.
Design Length of Cone	1100	mm.
Half Apex Angle of Cone	20.052082	degrees
Toriconical (Y/N)	N	
Weld is pre-Heated	No	

Element From Node	20	
Detail Type	Ring	
Detail ID	Ring 2-1	
Dist. from "FROM" Node / Offset dist	1095	mm.
Inside Diameter of Ring	1126.3	mm.
Thickness of Ring	10	mm.
Outside Diameter of Ring	1227.3	mm.
Material Name	SA-240 316	
Height of Section Ring	0	mm.
Using Custom Stiffener Section	No	

Element From Node	30	
Element To Node	40	
Element Type	Cylinder	
Description		
Distance "FROM" to "TO"	456	mm.
Inside Diameter	1124	mm.
Element Thickness	3	mm.
Internal Corrosion Allowance	0	mm.
Nominal Thickness	3	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	0.5	bars
Design Temperature Internal Pressure	170	°C
Design External Pressure	0.1	bars
Design Temperature External Pressure	50	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-240 316	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Weld is pre-Heated	No	

Element From Node	40	
Element To Node	50	
Element Type	Flat	
Description		
Distance "FROM" to "TO"	10	mm.
Inside Diameter	1124	mm.
Element Thickness	10	mm.
Internal Corrosion Allowance	0	mm.
Nominal Thickness	10	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	0.5	bars

Design Temperature Internal Pressure	170	°C
Design External Pressure	0.1	bars
Design Temperature External Pressure	50	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-240 316	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Flat Head Attachment Factor	0.2	
Small diameter if Non-Circular	0	mm.
Weld is pre-Heated	No	

Element From Node	50	
Element To Node	60	
Element Type	Cylinder	
Description		
Distance "FROM" to "TO"	115	mm.
Inside Diameter	566	mm.
Element Thickness	3	mm.
Internal Corrosion Allowance	0	mm.
Nominal Thickness	3	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	0.5	bars
Design Temperature Internal Pressure	170	°C
Design External Pressure	0.1	bars
Design Temperature External Pressure	50	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-240 316	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Weld is pre-Heated	No	

Element From Node	50	
Detail Type	Ring	
Detail ID	Ring 5-1	
Dist. from "FROM" Node / Offset dist	108	mm.
Inside Diameter of Ring	572	mm.
Thickness of Ring	10	mm.
Outside Diameter of Ring	670	mm.
Material Name	SA-240 304	
Height of Section Ring	0	mm.
Using Custom Stiffener Section	No	

Element From Node	60	
Element To Node	70	
Element Type	Conical	
Description		
Distance "FROM" to "TO"	3015	mm.
Inside Diameter	566	mm.
Element Thickness	3	mm.
Internal Corrosion Allowance	0	mm.
Nominal Thickness	3	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	0.5	bars
Design Temperature Internal Pressure	170	°C
Design External Pressure	0.1	bars
Design Temperature External Pressure	50	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-240 316	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Cone Diameter at "To" End	1606	mm.
Design Length of Cone	3015	mm.

```
Half Apex Angle of Cone                          9.7855883  degrees
Toriconical (Y/N)                                        N
Weld is pre-Heated                                      No

    Element From Node                                   60
    Detail Type                                       Ring
    Detail ID                                     Ring 6-1
    Dist. from "FROM" Node / Offset dist                 5  mm.
    Inside Diameter of Ring                         571.73  mm.
    Thickness of Ring                                   10  mm.
    Outside Diameter of Ring                        669.73  mm.
    Material Name                               SA-240 316
    Height of Section Ring                               0  mm.
    Using Custom Stiffener Section                      No

    Element From Node                                   60
    Detail Type                                       Ring
    Detail ID                                     Ring 6-2
    Dist. from "FROM" Node / Offset dist              1874  mm.
    Inside Diameter of Ring                         1218.4  mm.
    Thickness of Ring                                   10  mm.
    Outside Diameter of Ring                          1314  mm.
    Material Name                               SA-240 316
    Height of Section Ring                               0  mm.
    Using Custom Stiffener Section                      No

    Element From Node                                   60
    Detail Type                                       Ring
    Detail ID                                     Ring 6-3
    Dist. from "FROM" Node / Offset dist              3010  mm.
    Inside Diameter of Ring                         1610.3  mm.
    Thickness of Ring                                   10  mm.
    Outside Diameter of Ring                        1705.9  mm.
    Material Name                               SA-240 316
    Height of Section Ring                               0  mm.
    Using Custom Stiffener Section                      No

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

Element From Node                                       70
Element To Node                                         80
Element Type                                      Cylinder
Description
Distance "FROM" to "TO"                               2514  mm.
Inside Diameter                                       1606  mm.
Element Thickness                                        3  mm.
Internal Corrosion Allowance                             0  mm.
Nominal Thickness                                        3  mm.
External Corrosion Allowance                             0  mm.
Design Internal Pressure                               0.5  bars
Design Temperature Internal Pressure                   170  °C
Design External Pressure                               0.1  bars
Design Temperature External Pressure                    50  °C
Effective Diameter Multiplier                          1.2
Material Name                                   SA-240 316
Efficiency, Longitudinal Seam                          1.0
Efficiency, Circumferential Seam                       1.0
Weld is pre-Heated                                      No

    Element From Node                                   70
    Detail Type                                       Ring
    Detail ID                                     Ring 7-1
    Dist. from "FROM" Node / Offset dist               100  mm.
    Inside Diameter of Ring                           1612  mm.
    Thickness of Ring                                   10  mm.
    Outside Diameter of Ring                          1706  mm.
```

Material Name	SA-240 316	
Height of Section Ring	0	mm.
Using Custom Stiffener Section	No	

Element From Node	70	
Detail Type	Ring	
Detail ID	Ring 7-2	
Dist. from "FROM" Node / Offset dist	1610	mm.
Inside Diameter of Ring	1612	mm.
Thickness of Ring	10	mm.
Outside Diameter of Ring	1706	mm.
Material Name	SA-240 316	
Height of Section Ring	0	mm.
Using Custom Stiffener Section	No	

Element From Node	80	
Element To Node	90	
Element Type	Flat	
Description		
Distance "FROM" to "TO"	14	mm.
Inside Diameter	1606	mm.
Element Thickness	14	mm.
Internal Corrosion Allowance	0	mm.
Nominal Thickness	14	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	0.5	bars
Design Temperature Internal Pressure	170	°C
Design External Pressure	0.1	bars
Design Temperature External Pressure	50	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-240 316	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Flat Head Attachment Factor	0.2	
Small diameter if Non-Circular	0	mm.
Weld is pre-Heated	No	

Element From Node	90	
Element To Node	100	
Element Type	Cylinder	
Description		
Distance "FROM" to "TO"	200	mm.
Inside Diameter	898	mm.
Element Thickness	3	mm.
Internal Corrosion Allowance	0	mm.
Nominal Thickness	3	mm.
External Corrosion Allowance	0	mm.
Design Internal Pressure	0.5	bars
Design Temperature Internal Pressure	170	°C
Design External Pressure	0.1	bars
Design Temperature External Pressure	50	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-240 316	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	1.0	
Weld is pre-Heated	No	

Element From Node	90	
Detail Type	Ring	
Detail ID	Ring 8.1	
Dist. from "FROM" Node / Offset dist	195	mm.
Inside Diameter of Ring	904	mm.

Thickness of Ring	14	mm.
Outside Diameter of Ring	956	mm.
Material Name	SA-240 316	
Height of Section Ring	0	mm.
Using Custom Stiffener Section	No	

XY Coordinate Calculations:

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
10	20	...	50	...	50
20	30	...	1150	...	1100
30	40	...	1606	...	456
40	50	...	1616	...	10
50	60	...	1731	...	115
60	70	...	4746	...	3015
70	80	...	7260	...	2514
80	90	...	7274	...	14
90	100	...	7474	...	200

Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd bars	Nominal Thickness mm.	Total Corr Allowance mm.	Element Diameter mm.	Allowable Stress(SE) N./mm²
10	20	0.5	3	...	321	136.1
20	30	0.5	3	...	1124	136.1
30	40	0.5	3	...	1124	136.07
40	50	0.5	10	...	1124	136.07
50	60	0.5	3	...	566	136.07
60	70	0.5	3	...	1606	136.07
70	80	0.5	3	...	1606	136.07
80	90	0.5	14	...	1606	136.07
90	100	0.5	3	...	898	136.07

Element Required Thickness and MAWP :

From	To	Design Pressure bars	M.A.W.P. Corroded bars	M.A.P. New & Cold bars	Minimum Thickness mm.	Required Thickness mm.
10	20	0.5	25.1557	25.4884	3	1.5
20	30	0.5	6.80386	6.89384	3	1.5
30	40	0.5	7.23977	7.33728	3	1.5
40	50	0.5	2.12356	2.15217	10	4.85235
50	60	0.5	14.3321	14.5251	3	1.5
60	70	0.5	4.99817	5.06549	3	1.5
70	80	0.5	5.07179	5.14011	3	1.5
80	90	0.5	1.65349	1.67576	14	7.69861
90	100	0.5	9.05452	9.17649	3	1.5
Minimum			1.653	1.676		

MAWP: 1.653 bars, limited by: Flat Head.

Internal Pressure Calculation Results :

ASME Code, Section VIII Division 1, 2017

Cylindrical Shell From 10 To 20 SA-240 316 at 170 °C

Material UNS Number: S31600

Required Thickness due to Internal Pressure [tr]:
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
= (0.5*160.5)/(136.1*1.0-0.6*0.5)
= 0.0590 + 0.0000 = 0.0590 mm.

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 1.5000 mm. 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)
= (136.1*1.0*3.0)/(160.5+0.6*3.0)
= 25.156 bars

Maximum Allowable Pressure, New and Cold [MAPNC]:
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (137.9*1.0*3.0)/(160.5+0.6*3.0)
= 25.488 bars

Actual stress at given pressure and thickness, corroded [Sact]:
```
 = (P*(R+0.6*t))/(E*t)
 = (0.5*(160.5+0.6*3.0))/(1.0*3.0)
 = 2.705 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf)*(1-Rf/Ro) 0.926 %
Note: Please Check Requirements of Table UHA-44 for Elongation limits.

SA-240 316, Min Metal Temp without impact per UHA-51: -196 °C

Conical Section From 20 To 30 SA-240 316 at 170 °C

Material UNS Number: S31600

Required Thickness due to Internal Pressure [tr]:
```
 = (P*D)/(2*cos(a)*(S*E-0.6*P)) per Appendix 1-4 (e)
 = (0.5*1124.0)/(2*0.9394*(136.1*1.0-0.6*0.5))
 = 0.2199 + 0.0000 = 0.2199 mm.
```

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 1.5000 mm. per UG-16 will be used.

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*136.1*1.0*3.0*0.939)/(1124.0+1.2*3.0*0.939)
 = 6.804 bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
 = (2*S*E*t*cos(a))/(D+1.2*t*cos(a)) per App 1-4(e)
 = (2*137.9*1.0*3.0*0.9394)/(1124.0+1.2*3.0*0.9394)
 = 6.894 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
 = (P*(D+1.2*t*cos(a)))/(2*E*t*cos(a))
 = (0.5*(1124.0+1.2*3.0*0.9394))/(2*1.0*3.0*0.9394)
 = 10.002 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf)*(1-Rf/Ro) 0.925 %
Note: Please Check Requirements of Table UHA-44 for Elongation limits.

Note: The Pressure at the Large Diameter is used in the TR calculation.

SA-240 316, Min Metal Temp without impact per UHA-51: -196 °C

Cylindrical Shell From 30 To 40 SA-240 316 at 170 °C

Material UNS Number: S31600

Required Thickness due to Internal Pressure [tr]:
```
 = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
 = (0.5*562.0)/(136.07*1.0-0.6*0.5)
 = 0.2066 + 0.0000 = 0.2066 mm.
```

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 1.5000 mm. 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)
 = (136.07*1.0*3.0)/(562.0+0.6*3.0)
 = 7.240 bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9*1.0*3.0)/(562.0+0.6*3.0)
  = 7.337 bars
```

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

```
  = (P*(R+0.6*t))/(E*t)
  = (0.5*(562.0+0.6*3.0))/(1.0*3.0)
  = 9.397 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf)*(1-Rf/Ro) 0.266 %
Note: Please Check Requirements of Table UHA-44 for Elongation limits.

SA-240 316, Min Metal Temp without impact per UHA-51: -196 °C

Welded Flat Head From 40 To 50 SA-240 316 at 170 °C

Material UNS Number: S31600

Required Thickness due to Internal Pressure [tr]:

```
  = d * sqrt(Z*C*P/(S*E)) per UG-34 (c)(3)
  = 566.0*sqrt(1.0*0.2*0.5/(136.07*1.0))
  = 4.8524 + 0.0000 = 4.8524 mm.
```

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

```
  = (t/d)²*((S*E)/(C*Z)) UG-34 (c)(3)
  = (10.0/566.0))²*((136.07*1.0)/(0.2*1.0))
  = 2.124 bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
  = (t/d)²*((S*E)/(C*Z)) per UG-34 (c) (3)
  = (10.0/566.0)²*((137.9*1.0)/(0.2*1.0))
  = 2.152 bars
```

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

```
  = (Z*C*P)/(((t/d)²)*E)
  = (1.0*0.2*0.5)/(((10.0/566.0)²)*1.0)
  = 32.037 N./mm²
```

SA-240 316, Min Metal Temp without impact per UHA-51: -196 °C

Cylindrical Shell From 50 To 60 SA-240 316 at 170 °C

Material UNS Number: S31600

Required Thickness due to Internal Pressure [tr]:

```
  = (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
  = (0.5*283.0)/(136.07*1.0-0.6*0.5)
  = 0.1040 + 0.0000 = 0.1040 mm.
```

*Note: The thickness required was less than the Code Minimum, therefore
the Code Minimum value of 1.5000 mm. 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)
  = (136.07*1.0*3.0)/(283.0+0.6*3.0)
  = 14.332 bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
  = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
  = (137.9*1.0*3.0)/(283.0+0.6*3.0)
  = 14.525 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
= (P*(R+0.6*t))/(E*t)
= (0.5*(283.0+0.6*3.0))/(1.0*3.0)
= 4.747 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf)*(1-Rf/Ro) 0.527 %
Note: Please Check Requirements of Table UHA-44 for Elongation limits.

SA-240 316, Min Metal Temp without impact per UHA-51: -196 °C

Conical Section From 60 To 70 SA-240 316 at 170 °C

Material UNS Number: S31600

Required Thickness due to Internal Pressure [tr]:
```
= (P*D)/(2*cos(a)*(S*E-0.6*P)) per Appendix 1-4 (e)
= (0.5*1606.0)/(2*0.9855*(136.07*1.0-0.6*0.5))
= 0.2995 + 0.0000 = 0.2995 mm.
```

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 1.5000 mm. per UG-16 will be used.

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*136.07*1.0*3.0*0.985)/(1606.0+1.2*3.0*0.985)
= 4.998 bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
= (2*S*E*t*cos(a))/(D+1.2*t*cos(a)) per App 1-4(e)
= (2*137.9*1.0*3.0*0.9855)/(1606.0+1.2*3.0*0.9855)
= 5.065 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
= (P*(D+1.2*t*cos(a)))/(2*E*t*cos(a))
= (0.5*(1606.0+1.2*3.0*0.9855))/(2*1.0*3.0*0.9855)
= 13.612 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf)*(1-Rf/Ro) 0.527 %
Note: Please Check Requirements of Table UHA-44 for Elongation limits.

Note: The Pressure at the Large Diameter is used in the TR calculation.

SA-240 316, Min Metal Temp without impact per UHA-51: -196 °C

Cylindrical Shell From 70 To 80 SA-240 316 at 170 °C

Material UNS Number: S31600

Required Thickness due to Internal Pressure [tr]:
```
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
= (0.5*803.0)/(136.07*1.0-0.6*0.5)
= 0.2952 + 0.0000 = 0.2952 mm.
```

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 1.5000 mm. 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)
= (136.07*1.0*3.0)/(803.0+0.6*3.0)
= 5.072 bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (137.9*1.0*3.0)/(803.0+0.6*3.0)
= 5.140 bars
```

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

```
= (P*(R+0.6*t))/(E*t)
= (0.5*(803.0+0.6*3.0))/(1.0*3.0)
= 13.414 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf)*(1-Rf/Ro) 0.186 %
Note: Please Check Requirements of Table UHA-44 for Elongation limits.

SA-240 316, Min Metal Temp without impact per UHA-51: -196 °C

Welded Flat Head From 80 To 90 SA-240 316 at 170 °C

Material UNS Number: S31600

Required Thickness due to Internal Pressure [tr]:

```
= d * sqrt(Z*C*P/(S*E)) per UG-34 (c)(3)
= 898.0*sqrt(1.0*0.2*0.5/(136.07*1.0))
= 7.6986 + 0.0000 = 7.6986 mm.
```

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

```
= (t/d)²*((S*E)/(C*Z)) UG-34 (c)(3)
= (14.0/898.0))²*((136.07*1.0)/(0.2*1.0))
= 1.653 bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
= (t/d)²*((S*E)/(C*Z)) per UG-34 (c) (3)
= (14.0/898.0)²*((137.9*1.0)/(0.2*1.0))
= 1.676 bars
```

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

```
= (Z*C*P)/(((t/d)²)*E)
= (1.0*0.2*0.5)/(((14.0/898.0)²)*1.0)
= 41.145 N./mm²
```

SA-240 316, Min Metal Temp without impact per UHA-51: -196 °C

Cylindrical Shell From 90 To 100 SA-240 316 at 170 °C

Material UNS Number: S31600

Required Thickness due to Internal Pressure [tr]:

```
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
= (0.5*449.0)/(136.07*1.0-0.6*0.5)
= 0.1650 + 0.0000 = 0.1650 mm.
```

Note: The thickness required was less than the Code Minimum, therefore the Code Minimum value of 1.5000 mm. 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)
= (136.07*1.0*3.0)/(449.0+0.6*3.0)
= 9.055 bars
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (137.9*1.0*3.0)/(449.0+0.6*3.0)
= 9.176 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(R+0.6*t))/(E*t)
= (0.5*(449.0+0.6*3.0))/(1.0*3.0)
= 7.514 N./mm²

% Elongation per Table UG-79-1 (50*tnom/Rf)*(1-Rf/Ro) 0.333 %
Note: Please Check Requirements of Table UHA-44 for Elongation limits.

SA-240 316, Min Metal Temp without impact per UHA-51: -196 °C

Elements Suitable for Internal Pressure.

External Pressure Calculation Results :

External Pressure Calculations:

From	To	Section Length mm.	Outside Diameter mm.	Corroded Thickness mm.	Factor A	Factor B N./mm²
10	Ring	No Calc	...	3	No Calc	No Calc
Ring	20	50	327	3	0.010394	98.9477
20	Ring	706.449	1126.74	3	0.00026759	25.6883
Ring	30	4.99191	1130.39	3	0.0054666	92.8731
30	40	456	1130	3	0.00047288	45.3961
40	50	No Calc	...	10	No Calc	No Calc
50	Ring	108	572	3	0.0031947	86.5975
Ring	60	7	572	3	0.021854	104.027
60	Ring	4.99249	573.813	3	0.021011	103.811
Ring	Ring	1374.53	1218.51	3	0.00014001	13.4413
Ring	Ring	997.779	1610.36	3	0.00017041	16.3596
Ring	70	4.99741	1612.09	3	0.003216	86.6818
70	Ring	100	1612	3	0.0024223	82.9383
Ring	Ring	1510	1612	3	0.00011383	10.9277
Ring	80	904	1612	3	0.000193	18.528
80	90	No Calc	...	14	No Calc	No Calc
90	Ring	195	904	3	0.001308	73.751
Ring	100	5	904	3	0.0091683	97.8841

External Pressure Calculations:

From	To	External Actual T. mm.	External Required T. mm.	External Design Pressure bars	External M.A.W.P. bars
10	Ring	3	No Calc	0.1	No Calc
Ring	20	3	0.19212	0.1	12.103
20	Ring	3	1.27187	0.1	0.85662
Ring	30	3	0.43542	0.1	3.08702
30	40	3	0.99796	0.1	1.60685
40	50	10	No Calc	0.1	No Calc
50	Ring	3	0.36718	0.1	6.05541
Ring	60	3	0.20698	0.1	7.27422
60	Ring	3	0.2107	0.1	7.13086
Ring	Ring	3	1.66204	0.1	0.43479
Ring	Ring	3	1.72473	0.1	0.40042
Ring	70	3	0.59194	0.1	2.11938
70	Ring	3	0.64382	0.1	2.0579
Ring	Ring	3	2.02088	0.1	0.27114
Ring	80	3	1.63721	0.1	0.45972
80	90	14	No Calc	0.1	No Calc
90	Ring	3	0.61369	0.1	3.26313
Ring	100	3	0.32711	0.1	4.3309
Minimum					0.271

External Pressure Calculations:

From	To	Actual Length Bet. Stiffeners mm.	Allowable Length Bet. Stiffeners mm.	Ring Inertia Required cm**4	Ring Inertia Available cm**4
10	Ring	No Calc	No Calc	No Calc	No Calc
Ring	20	50	4811.25	0.00062658	9.67321
20	Ring	706.449	706.449	No Calc	No Calc

Ring	30	4.99191	4.99191	0.36588	20.652
30	40	456	6566.1	No Calc	No Calc
40	50	No Calc	No Calc	No Calc	No Calc
50	Ring	108	4021.26	No Calc	No Calc
Ring	60	7	487.092	0.0077134	17.0396
60	Ring	4.99249	4.99249	No Calc	No Calc
Ring	Ring	1374.53	1374.53	0.093369	17.0481
Ring	Ring	997.779	997.779	1.53939	18.2173
Ring	70	4.99741	4.99741	1.5006	19.1386
70	Ring	100	2398.86	No Calc	No Calc
Ring	Ring	1510	3984.95	2.40723	18.3065
Ring	80	904	3985.66	3.60856	18.3065
80	90	No Calc	No Calc	No Calc	No Calc
90	Ring	195	5498.92	No Calc	No Calc
Ring	100	5	216.544	0.052954	4.51783

Elements Suitable for External Pressure.

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Cone From 20 to Ring 2-1 Ext. Chart: HA-2 at 50 °C

Elastic Modulus from Chart: HA-2 at 50 °C : 0.192E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

```
     Tca          OD         SLEN        D/t        L/D    Factor A        B
   2.818     1126.74       706.45     399.82     0.6270   0.0002676    25.69
 EMAP = (4*B)/(3*(D/t)) = (4*25.6883)/(3*399.8153) = 0.8566 bars
```

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          OD         SLEN        D/t        L/D    Factor A        B
   1.195     1126.74       706.45     943.05     0.6270   0.0000737     7.07
 EMAP = (4*B)/(3*(D/t)) = (4*7.0738)/(3*943.0535) = 0.1 bars
```

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

Cone From Ring 2-1 to 30 Ext. Chart: HA-2 at 50 °C

Cylindrical Shell From 30 to 40 Ext. Chart: HA-2 at 50 °C

Elastic Modulus from Chart: HA-2 at 50 °C : 0.192E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

```
     Tca          OD         SLEN        D/t        L/D    Factor A        B
   3.000     1130.00       456.00     376.67     0.4035   0.0004729    45.40
 EMAP = (4*B)/(3*(D/t)) = (4*45.3961)/(3*376.6667) = 1.6068 bars
```

Results for Required Thickness (Tca):

```
     Tca          OD         SLEN        D/t        L/D    Factor A        B
   0.998     1130.00       456.00    1132.32     0.4035   0.0000885     8.49
 EMAP = (4*B)/(3*(D/t)) = (4*8.4934)/(3*1132.3154) = 0.1 bars
```

Results for Maximum Stiffened Length (Slen):

```
     Tca          OD         SLEN        D/t        L/D    Factor A        B
   3.000     1130.00      6566.10     376.67     5.8107   0.0000295     2.83
 EMAP = (4*B)/(3*(D/t)) = (4*2.8274)/(3*376.6667) = 0.1001 bars
```

Welded Flat Head

Note: This element's required thickness was computed in the internal Pressure Report using the maximum of the Internal and External pressures.

Cylindrical Shell From 50 to Ring 5-1 Ext. Chart: HA-2 at 50 °C

Elastic Modulus from Chart: HA-2 at 50 °C : 0.192E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	572.00	108.00	190.67	0.1888	0.0031947	86.60

EMAP = (4*B)/(3*(D/t)) = (4*86.5975)/(3*190.6667) = 6.0554 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
0.367	572.00	108.00	1557.80	0.1888	0.0001217	11.68

EMAP = (4*B)/(3*(D/t)) = (4*11.6846)/(3*1557.8004) = 0.1 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	572.00	4021.26	190.67	7.0302	0.0000649	6.23

EMAP = (4*B)/(3*(D/t)) = (4*6.2274)/(3*190.6667) = 0.4355 bars

Cone From 60 to Ring 6-1 Ext. Chart: HA-2 at 50 °C

Cone From Ring 6-1 to Ring 6-2 Ext. Chart: HA-2 at 50 °C

Elastic Modulus from Chart: HA-2 at 50 °C : 0.192E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
2.956	1218.51	1374.53	412.17	1.1280	0.0001400	13.44

EMAP = (4*B)/(3*(D/t)) = (4*13.4413)/(3*412.1667) = 0.4348 bars

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	OD	SLEN	D/t	L/D	Factor A	B
1.638	1218.51	1374.53	743.97	1.1280	0.0000581	5.58

EMAP = (4*B)/(3*(D/t)) = (4*5.5803)/(3*743.9673) = 0.1 bars

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

Cone From Ring 6-2 to Ring 6-3 Ext. Chart: HA-2 at 50 °C

Elastic Modulus from Chart: HA-2 at 50 °C : 0.192E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
2.956	1610.36	997.78	544.71	0.6196	0.0001704	16.36

EMAP = (4*B)/(3*(D/t)) = (4*16.3596)/(3*544.7132) = 0.4004 bars

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	OD	SLEN	D/t	L/D	Factor A	B
1.700	1610.36	997.78	947.48	0.6196	0.0000740	7.11

EMAP = (4*B)/(3*(D/t)) = (4*7.1067)/(3*947.4755) = 0.1 bars

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

Cone From Ring 6-3 to 70 Ext. Chart: HA-2 at 50 °C

Cylindrical Shell From Ring 7-1 to Ring 7-2 Ext. Chart: HA-2 at 50 °C

Elastic Modulus from Chart: HA-2 at 50 °C : 0.192E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	1612.00	1510.00	537.33	0.9367	0.0001138	10.93

EMAP = (4*B)/(3*(D/t)) = (4*10.9277)/(3*537.3333) = 0.2711 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
2.021	1612.00	1510.00	797.67	0.9367	0.0000623	5.98

EMAP = (4*B)/(3*(D/t)) = (4*5.983)/(3*797.673) = 0.1 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	1612.00	3984.95	537.33	2.4721	0.0000420	4.03

EMAP = (4*B)/(3*(D/t)) = (4*4.0331)/(3*537.3333) = 0.1001 bars

Cylindrical Shell From Ring 7-2 to 80 Ext. Chart: HA-2 at 50 °C

Elastic Modulus from Chart: HA-2 at 50 °C : 0.192E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	1612.00	904.00	537.33	0.5608	0.0001930	18.53

EMAP = (4*B)/(3*(D/t)) = (4*18.528)/(3*537.3333) = 0.4597 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
1.637	1612.00	904.00	984.60	0.5608	0.0000769	7.39

EMAP = (4*B)/(3*(D/t)) = (4*7.3851)/(3*984.6019) = 0.1 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	1612.00	3985.66	537.33	2.4725	0.0000420	4.03

EMAP = (4*B)/(3*(D/t)) = (4*4.0324)/(3*537.3333) = 0.1001 bars

Welded Flat Head

Note: This element's required thickness was computed in the internal Pressure Report using the maximum of the Internal and External pressures.

Cylindrical Shell From 90 to Ring 8.1 Ext. Chart: HA-2 at 50 °C

Elastic Modulus from Chart: HA-2 at 50 °C : 0.192E+09 KPa.

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	904.00	195.00	301.33	0.2157	0.0013080	73.75

EMAP = (4*B)/(3*(D/t)) = (4*73.751)/(3*301.3333) = 3.2631 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
0.614	904.00	195.00	1473.05	0.2157	0.0001151	11.05

EMAP = (4*B)/(3*(D/t)) = (4*11.0491)/(3*1473.0518) = 0.1 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	904.00	5498.92	301.33	6.0829	0.0000385	3.70

EMAP = (4*B)/(3*(D/t)) = (4*3.696)/(3*301.3333) = 0.1635 bars

Stiffening Ring Calcs for : Ring 1-1 , SA-240 316 , Bar Ring: 39 x 12 mm.

Effective Length of Shell: 34 mm.

	Area (cm²)	Distance (mm.)	Area*Dist
Shell:	1.034	1.5000	1.550
Ring :	4.680	22.5000	105.300
Total:	5.714		106.850

Centroid of Ring plus Shell: 19 mm.

	Inertia	Distance	A*Dist²
Shell:	0.008	17.2011	305.816
Ring :	5.932	-3.7989	67.540
Total:	5.940		373.357

Available Moment of Inertia, Ring plus Shell: 10 cm**4

Required Stress in Ring plus Shell Breq 0.11 N./mm²
Required Strain in Ring plus Shell Areq 0.0000012

Required Moment of Inertia, Ring plus Shell:
= (OD² * Slen(Tca + Aring/Slen)Areq)/10.9
= (327.0²*25.0(3.0+4.68/25.0)0.000001)/10.9
= 0 cm**4

Results for Stiffening Ring Weld Calculations per UG-30:

Given Stiffening Ring Fillet Weld Size	Wleg	3.000	mm.
Stiffening Ring Attachment Style		CONTINUOUS	
Location of Stiffening Ring		EXTERNAL	
Radial Pressure Load	Pext*Slen	0.03	Kgf/mm.
The Radial Shear Load	V	0.08	Kgf
The First Moment of the Area (Ring + Shell)	Q	1777.89	mm.³
Weld Shear Flow due to Rad. Shear Load	VQ/I	0.00	Kgf/mm.
The Weld Allowable Stress	0.55*S	75.85	N./mm²
Minimum Weld Leg Size Min(6mm, t, tw)	Wldmin	3.00	mm.
The Weld Allowable Load 2*	WLeg*0.55*S	46.40	Kgf/mm.
The Combined Weld Load SRSS of VQ/I and Pext*Slen		0.03	Kgf/mm.

Stiffening Ring Calcs for : Ring 2-1 , SA-240 316 , Bar Ring: 50 x 10 mm.

Effective Length of Shell: 64 mm.

	Area (cm²)	Distance (mm.)	Area*Dist
Shell:	1.918	1.5000	2.877
Ring :	5.046	28.2300	142.449
Total:	6.964		145.326

Centroid of Ring plus Shell: 21 mm.

	Inertia	Distance	A*Dist²
Shell:	0.014	19.3674	719.536
Ring :	10.707	-7.3627	273.537
Total:	10.721		993.073

Available Moment of Inertia, Ring plus Shell: 21 cm**4

Required Stress in Ring plus Shell Breq 1.91 N./mm²
Required Strain in Ring plus Shell Areq 0.0000200

Required Moment of Inertia, Ring plus Shell:
= (OD² * Slen(Tca + Aring/Slen)Areq)/10.9
= (1126.35²*355.7206(3.0+5.046/355.7206)0.00002)/10.9
= 0 cm**4

<u>Stiffening Ring Calcs for : Ring 5-1 , SA-240 304 , Bar Ring: 49 x 10 mm.</u>

Effective Length of Shell: 46 mm.

	Area (cm²)	Distance (mm.)	Area*Dist
Shell:	1.367	1.5000	2.051
Ring :	4.900	27.5000	134.750
Total:	6.267		136.801

Centroid of Ring plus Shell: 22 mm.

	Inertia	Distance	A*Dist²
Shell:	0.010	20.3287	564.925
Ring :	9.804	-5.6713	157.604
Total:	9.814		722.529

Available Moment of Inertia, Ring plus Shell: 17 cm**4

Required Stress in Ring plus Shell Breq 0.37 N./mm²
Required Strain in Ring plus Shell Areq 0.0000039

Required Moment of Inertia, Ring plus Shell:
= (OD² * Slen(Tca + Aring/Slen)Areq)/10.9
= (572.0²*57.5(3.0+4.9/57.5)0.000004)/10.9
= 0 cm**4

<u>Stiffening Ring Calcs for : Ring 6-1 , SA-240 316 , Bar Ring: 49 x 10 mm.</u>

Effective Length of Shell: 46 mm.

	Area (cm²)	Distance (mm.)	Area*Dist
Shell:	1.369	1.5000	2.054
Ring :	4.900	27.5000	134.750
Total:	6.269		136.804

Centroid of Ring plus Shell: 22 mm.

	Inertia	Distance	A*Dist²
Shell:	0.010	20.3220	565.404
Ring :	9.804	-5.6780	157.975
Total:	9.814		723.379

Available Moment of Inertia, Ring plus Shell: 17 cm**4

Required Stress in Ring plus Shell Breq 1.16 N./mm²
Required Strain in Ring plus Shell Areq 0.0000121

Required Moment of Inertia, Ring plus Shell:
= (OD² * Slen(Tca + Aring/Slen)Areq)/10.9
= (573.7247²*689.7628(3.0+4.9/689.7628)0.000012)/10.9
= 0 cm**4

Results for Stiffening Ring Weld Calculations per UG-30:
Given Stiffening Ring Fillet Weld Size Wleg 3.000 mm.
Stiffening Ring Attachment Style INTERMITTENT

```
 Location of Stiffening Ring                           EXTERNAL
 Radial Pressure Load                      Pext*Slen      0.70  Kgf/mm.
 The Radial Shear Load                             V      4.04  Kgf
 The First Moment of the Area ( Ring + Shell )     Q   2782.23  mm.³
 Weld Shear Flow due to Rad. Shear Load         VQ/I      0.07  Kgf/mm.
 The Weld Allowable Stress                    0.55*S     75.85  N./mm²
 Minimum Weld Leg Size Min( 6mm, t, tw )      Wldmin      3.00  mm.
 Maximum Space between Welds  8*TCA                      50.80  mm.
 The Weld Allowable Load                 WLeg*0.55*S     23.20  Kgf/mm.
 The Combined Weld Load   SRSS of VQ/I and Pext*Slen      0.71  Kgf/mm.
```

<u>Stiffening Ring Calcs for : Ring 6-2 , SA-240 316 , Bar Ring: 48 x 10 mm.</u>

```
 Effective Length of Shell:                               67 mm.

                Area (cm²)   Distance (mm.)    Area*Dist
 -------------------------------------------------------
 Shell:            1.995         1.5000          2.993
 Ring :            4.782        26.9100        128.684
 Total:            6.777                       131.676
 -------------------------------------------------------
 Centroid of Ring plus Shell:                             19 mm.

                 Inertia        Distance         A*Dist²
 -------------------------------------------------------
 Shell:            0.015        17.9295        641.370
 Ring :            9.113        -7.4805        267.592
 Total:            9.128                       908.962
 -------------------------------------------------------
 Available Moment of Inertia, Ring plus Shell:         18 cm**4

 Required Stress in Ring plus Shell      Breq       2.69 N./mm²
 Required Strain in Ring plus Shell      Areq  0.0000280
```

Required Moment of Inertia, Ring plus Shell:

```
  = ( OD² * Slen(Tca + Aring/Slen)Areq )/10.9
  = (1218.4214²*1186.1562(3.0+4.782/1186.1562)0.000028)/10.9
  = 2 cm**4
```

Results for Stiffening Ring Weld Calculations per UG-30:

```
 Given Stiffening Ring Fillet Weld Size         Wleg     3.000  mm.
 Stiffening Ring Attachment Style             INTERMITTENT
 Location of Stiffening Ring                           EXTERNAL
 Radial Pressure Load                      Pext*Slen      1.21  Kgf/mm.
 The Radial Shear Load                             V     14.74  Kgf
 The First Moment of the Area ( Ring + Shell )     Q   3577.18  mm.³
 Weld Shear Flow due to Rad. Shear Load         VQ/I      0.29  Kgf/mm.
 The Weld Allowable Stress                    0.55*S     75.85  N./mm²
 Minimum Weld Leg Size Min( 6mm, t, tw )      Wldmin      3.00  mm.
 Maximum Space between Welds  8*TCA                      50.80  mm.
 The Weld Allowable Load                 WLeg*0.55*S     23.20  Kgf/mm.
 The Combined Weld Load   SRSS of VQ/I and Pext*Slen      1.24  Kgf/mm.
```

<u>Stiffening Ring Calcs for : Ring 6-3 , SA-240 316 , Bar Ring: 48 x 10 mm.</u>

```
 Effective Length of Shell:                               76 mm.

                Area (cm²)   Distance (mm.)    Area*Dist
 -------------------------------------------------------
 Shell:            2.294         1.5000          3.440
 Ring :            4.782        26.9100        128.684
 Total:            7.076                       132.124
 -------------------------------------------------------
 Centroid of Ring plus Shell:                             19 mm.
```

	Inertia	Distance	A*Dist²
Shell:	0.017	17.1731	676.429
Ring :	9.113	-8.2369	324.442
Total:	9.130		1000.870

```
Available Moment of Inertia, Ring plus Shell:         19 cm**4

Required Stress in Ring plus Shell      Breq        3.05 N./mm²
Required Strain in Ring plus Shell      Areq   0.0000318
```

Required Moment of Inertia, Ring plus Shell:

```
  = ( OD² * Slen(Tca + Aring/Slen)Areq )/10.9
  = (1610.2754²*501.3885(3.0+4.782/501.3885)0.000032)/10.9
  = 2 cm**4
```

Results for Stiffening Ring Weld Calculations per UG-30:

```
Given Stiffening Ring Fillet Weld Size         Wleg     3.000  mm.
Stiffening Ring Attachment Style              INTERMITTENT
Location of Stiffening Ring                        EXTERNAL
Radial Pressure Load                      Pext*Slen      0.51  Kgf/mm.
The Radial Shear Load                             V      8.23  Kgf
The First Moment of the Area ( Ring + Shell )     Q   3938.88  mm.³
Weld Shear Flow due to Rad. Shear Load         VQ/I      0.17  Kgf/mm.
The Weld Allowable Stress                    0.55*S     75.85  N./mm²
Minimum Weld Leg Size Min( 6mm, t, tw )      Wldmin      3.00  mm.
Maximum Space between Welds  8*TCA                      50.80  mm.
The Weld Allowable Load                 WLeg*0.55*S     23.20  Kgf/mm.
The Combined Weld Load   SRSS of VQ/I and Pext*Slen      0.54  Kgf/mm.
```

<u>Stiffening Ring Calcs for : Ring 7-1 , SA-240 316 , Bar Ring: 47 x 10 mm.</u>

```
Effective Length of Shell:                            76 mm.
```

	Area (cm²)	Distance (mm.)	Area*Dist
Shell:	2.295	1.5000	3.442
Ring :	4.700	26.5000	124.550
Total:	6.995		127.993

```
Centroid of Ring plus Shell:                          18 mm.
```

	Inertia	Distance	A*Dist²
Shell:	0.017	16.7981	647.554
Ring :	8.652	-8.2020	316.180
Total:	8.669		963.734

```
Available Moment of Inertia, Ring plus Shell:         18 cm**4

Required Stress in Ring plus Shell      Breq        3.37 N./mm²
Required Strain in Ring plus Shell      Areq   0.0000350
```

Required Moment of Inertia, Ring plus Shell:

```
  = ( OD² * Slen(Tca + Aring/Slen)Areq )/10.9
  = (1612.0²*805.0(3.0+4.7/805.0)0.000035)/10.9
  = 2 cm**4
```

Results for Stiffening Ring Weld Calculations per UG-30:

```
Given Stiffening Ring Fillet Weld Size         Wleg     3.000  mm.
Stiffening Ring Attachment Style                 CONTINUOUS
Location of Stiffening Ring                        EXTERNAL
Radial Pressure Load                      Pext*Slen      0.82  Kgf/mm.
The Radial Shear Load                             V     13.23  Kgf
The First Moment of the Area ( Ring + Shell )     Q   3854.93  mm.³
```

Weld Shear Flow due to Rad. Shear Load	VQ/I	0.28	Kgf/mm.
The Weld Allowable Stress	0.55*S	75.85	N./mm²
Minimum Weld Leg Size Min(6mm, t, tw)	Wldmin	3.00	mm.
The Weld Allowable Load	2* WLeg*0.55*S	46.40	Kgf/mm.
The Combined Weld Load	SRSS of VQ/I and Pext*Slen	0.87	Kgf/mm.

Stiffening Ring Calcs for : Ring 7-2 , SA-240 316 , Bar Ring: 47 x 10 mm.

Effective Length of Shell: 76 mm.

	Area (cm²)	Distance (mm.)	Area*Dist
Shell:	2.295	1.5000	3.442
Ring :	4.700	26.5000	124.550
Total:	6.995		127.993

Centroid of Ring plus Shell: 18 mm.

	Inertia	Distance	A*Dist²
Shell:	0.017	16.7981	647.554
Ring :	8.652	-8.2020	316.180
Total:	8.669		963.734

Available Moment of Inertia, Ring plus Shell: 18 cm**4

Required Stress in Ring plus Shell	Breq	3.57 N./mm²
Required Strain in Ring plus Shell	Areq	0.0000370

Required Moment of Inertia, Ring plus Shell:

= (OD² * Slen(Tca + Aring/Slen)Areq)/10.9
= (1612.0²*1207.0(3.0+4.7/1207.0)0.000037)/10.9
= 4 cm**4

Results for Stiffening Ring Weld Calculations per UG-30:

Given Stiffening Ring Fillet Weld Size	Wleg	3.000	mm.
Stiffening Ring Attachment Style		CONTINUOUS	
Location of Stiffening Ring		EXTERNAL	
Radial Pressure Load	Pext*Slen	1.23	Kgf/mm.
The Radial Shear Load	V	19.84	Kgf
The First Moment of the Area (Ring + Shell)	Q	3854.93	mm.³
Weld Shear Flow due to Rad. Shear Load	VQ/I	0.42	Kgf/mm.
The Weld Allowable Stress	0.55*S	75.85	N./mm²
Minimum Weld Leg Size Min(6mm, t, tw)	Wldmin	3.00	mm.
The Weld Allowable Load	2* WLeg*0.55*S	46.40	Kgf/mm.
The Combined Weld Load	SRSS of VQ/I and Pext*Slen	1.30	Kgf/mm.

Stiffening Ring Calcs for : Ring 8.1 , SA-240 316 , Bar Ring: 26 x 14 mm.

Effective Length of Shell: 57 mm.

	Area (cm²)	Distance (mm.)	Area*Dist
Shell:	1.719	1.5000	2.578
Ring :	3.640	16.0000	58.240
Total:	5.359		60.818

Centroid of Ring plus Shell: 11 mm.

	Inertia	Distance	A*Dist²
Shell:	0.013	9.8497	166.726
Ring :	2.051	-4.6503	78.716
Total:	2.063		245.442

Available Moment of Inertia, Ring plus Shell: 5 cm**4

Required Stress in Ring plus Shell Breq 1.02 N./mm²
Required Strain in Ring plus Shell Areq 0.0000106

Required Moment of Inertia, Ring plus Shell:

= (OD² * Slen(Tca + Aring/Slen)Areq)/10.9
= (904.0²*100.0(3.0+3.64/100.0)0.000011)/10.9
= 0 cm**4

Element and Detail Weights:

From	To	Element Metal Wgt. kg.	Element ID Volume Cm.	Corroded Metal Wgt. kg.	Corroded ID Volume Cm.	Extra due Misc % kg.
10	20	1.22562	4047.14	1.22562	4047.14	...
20	30	64.2908	497493	64.2908	497493	...
30	40	38.8802	452548	38.8802	452548	...
40	50	79.6512	...	79.6512	...	...
50	60	4.95053	28940	4.95053	28940	...
60	70	252.081	3006753	252.081	3006753	...
70	80	306.025	5093591	306.025	5093591	...
80	90	227.656	...	227.656	...	...
90	100	13.6332	126692	13.6332	126692	...
Total		988	9210065.00	988	9210065.00	0

Weight of Details:

From	Type	Weight of Detail kg.	X Offset, Dtl. Cent. mm.	Y Offset, Dtl. Cent. mm.	Description
10	Ring	4.31963	...	...	Ring 1-1
20	Ring	14.9752	...	1095	Ring 2-1
50	Ring	7.67375	...	108	Ring 5-1
60	Ring	7.67041	...	5	Ring 6-1
60	Ring	15.2695	...	1874	Ring 6-2
60	Ring	19.9959	...	3010	Ring 6-3
70	Ring	19.6637	...	100	Ring 7-1
70	Ring	19.6637	...	1610	Ring 7-2
90	Ring	8.53696	...	195	Ring 8.1

Total Weight of Each Detail Type:

Stiffeners	117.8
Sum of the Detail Weights	117.8 kg.

Weight Summation Results: (kg.)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	988.4	988.4	988.4	988.4	988.4	988.4
Stif. Rings	117.8	117.8	117.8	117.8	117.8	117.8
Test Liquid	...	9204.4	...	...	...	...
Totals	1106.2	10310.6	1106.2	1106.2	1106.2	1106.2

Weight Summary:

Fabricated Wt.	- Bare Weight without Removable Internals	1106.2 kg.
Shop Test Wt.	- Fabricated Weight + Water (Full)	10310.6 kg.
Shipping Wt.	- Fab. Weight + removable Intls.+ Shipping App.	1106.2 kg.
Erected Wt.	- Fab. Wt + or - loose items (trays,platforms etc.)	1106.2 kg.
Ope. Wt. no Liq	- Fab. Weight + Internals. + Details + Weights	1106.2 kg.
Operating Wt.	- Empty Weight + Operating Liq. Uncorroded	1106.2 kg.
Field Test Wt.	- Empty Weight + Water (Full)	10310.6 kg.
Mass of the Upper 1/3 of the Vertical Vessel		546.7 kg.

Outside Surface Areas of Elements:

From	To	Surface Area cm²
10	20	513.65
20	30	26814
30	40	16188
40	50	...
50	60	2066.54
60	70	104969
70	80	127315
80	90	...
90	100	5680

Total 283546.125 cm²

Element and Detail Weights:

From	To	Total Ele. Empty Wgt. kg.	Total. Ele. Oper. Wgt. kg.	Total. Ele. Hydro. Wgt. kg.	Total Dtl. Offset Mom. Kg-m.	Oper. Wgt. No Liquid kg.
10	20	5.54525	5.54525	5.54525	...	5.54525
20	30	79.2661	79.2661	79.2661	...	79.2661
30	40	38.8802	38.8802	38.8802	...	38.8802
40	50	79.6512	79.6512	79.6512	...	79.6512
50	60	12.6243	12.6243	12.6243	...	12.6243
60	70	295.017	295.017	295.017	...	295.017
70	80	345.352	345.352	345.352	...	345.352
80	90	227.656	227.656	227.656	...	227.656
90	100	22.1701	22.1701	22.1701	...	22.1701

Cumulative Vessel Weight

From	To	Cumulative Ope Wgt. No Liquid kg.	Cumulative Oper. Wgt. kg.	Cumulative Hydro. Wgt. kg.
10	20	1106.16	1106.16	1106.16
20	30	1100.62	1100.62	1100.62
30	40	1021.35	1021.35	1021.35
40	50	982.471	982.471	982.471
50	60	902.82	902.82	902.82
60	70	890.195	890.195	890.195
70	80	595.178	595.178	595.178
80	90	249.826	249.826	249.826
90	100	22.1701	22.1701	22.1701

Note: 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. Kg-m.	Cumulative Oper. Mom. Kg-m.	Cumulative Hydro. Mom. Kg-m.
10	20	...	...	...
20	30	...	...	...
30	40	...	...	...
40	50	...	...	...
50	60	...	...	...
60	70	...	...	...

```
    70|  80|        ... |        ... |       ... |
    80|  90|        ... |        ... |       ... |
    90| 100|        ... |        ... |       ... |
 ------------------------------------------------
```

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

<u>Conical Section From 20 To 30 SA-240 316</u>

```
Elastic Modulus Data from ASME Section II Part D at 50 °C

Elastic Modulus of Cone Material                0.193E+09 KPa. at 50 °C
Elastic Modulus of Small Cylinder Material      0.193E+09 KPa. at 50 °C
Elastic Modulus of Large Cylinder Material      0.193E+09 KPa. at 50 °C
Elastic Modulus of Large End Reinforcement      0.193E+09 KPa. at 50 °C
Elastic Modulus of Small End Reinforcement      0.193E+09 KPa. at 50 °C

Elastic Modulus Data from ASME Section II Part D at 170 °C

Elastic Modulus of Cone Material                0.185E+09 KPa. at 170 °C
Elastic Modulus of Small Cylinder Material      0.185E+09 KPa. at 170 °C
Elastic Modulus of Large Cylinder Material      0.185E+09 KPa. at 170 °C
Elastic Modulus of Large End Reinforcement      0.185E+09 KPa. at 170 °C
Elastic Modulus of Small End Reinforcement      0.185E+09 KPa. at 170 °C

Axial Force on Small End of Cone                       0.00  Kgf
Axial Force on Large End of Cone                       0.00  Kgf
Moment on Small End of Cone                            0.00  Kg-m.
Moment on Large End of Cone                            0.00  Kg-m.
```

Note: Since there are no supports, the forces and moments could
not be resolved to the large and small ends of the cone.

Note: Both ends of the Cone are Lines of Support

```
Maximum Centroid Reinforcement Distance Large End    10.2926  mm.
Maximum Centroid Reinforcement Distance Small End     5.5368  mm.
```

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      0.00037
Large end max. half apex angle w/o reinforcement      11.000  degrees
Large end actual half apex angle                      20.052  degrees
```

Intermediate Value [k]:

```
= max( Y / ( Sr * Erl ), 1 )
= max( 0.25122E+11/( 136.1 * 0.18458E+09 ), 1 )
= 1.0002
```

where [Y] is:

```
= Cone Allowable Stress * Cone Elastic Modulus (Int. temp.)
= 136.1 * 0.18458E+09
= 25121794048.0 N./mm²^2
```

Decay Length, Cone Large End:

```
= 2 * sqrt( RL( ts - ca ) )
= 2 * sqrt( 562.0( 3.0 - 0.0 ) )
= 82.122 mm.
```

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

```
= k*QL*Rl/(Ss*E1))*(1-delta/alpha)*tan(alpha)
= 1.0 * 1.4328 * 562.0/( 136 * 1.0 ) *
  ( 1 - 11.0/20.05 ) * 0.365
= 0.0956 cm²
```

Force per Length, Cone Large End [QL]:

```
= P( Rl/2 ) - Faxial/(pi(Dl + Tl)) + Moment/(pi(Rl + Tl/2)(Rl + Tl/2))
= 0.5( 562.0/2 ) - 0.0/(pi(1124.0 + 3.0)) +
  0.0/(pi(562.0 + 3.0/2)(562.0 + 3.0/2))
= 1.433 Kgf/mm.
```

Area of Reinforcement Available in Large end Shell [Ael]:

```
= (Ts-t)*sqrt(Rl*Ts)+(Tc-Tr)*sqrt(Rl*Tc/cos(alpha))
= ( 3.0 - 0.2066 ) * SQRT( 562.0 * 3.0 ) +
  ( 3.0 - 0.2199 ) * SQRT( 562.0 * 3.0/0.9394 )
= 2.3248 cm²
```

Summary of Reinforcement area, Large end, Internal Pressure:

Area of reinforcement required per App. 1-5(1)	0.0956	cm²
Area of reinforcement in shell per App. 1-5(2)	2.3248	cm²
Area of reinforcement in stiffening ring	5.0460	cm²

Required Area of Reinforcement for Large End Under External Pressure

Large end ratio of pressure to allowable stress	0.00007	
Large end max. half apex angle w/o reinforcement	0.181	degrees
Large end actual half apex angle	20.052	degrees

Intermediate Value [k]:

```
= max( Y / ( Srl * Erl ), 1 )
= max( 0.26602E+11/( 137.9 * 0.19291E+09 ), 1 )
= 1.0000
```

where [Y] is:

```
= Cone Allowable Stress * Cone Elastic Modulus (Ext. temp.)
= 137.9 * 0.19291E+09
= 26602469376.0 N./mm²^2
```

Allowable Stress of Large End Material (Ext. Temp)	137.9	N./mm²
Allowable Stress of Cone Material (Ext. Temp)	137.9	N./mm²

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

```
= (k*QL*Rl*tan(angle)/(Ss*E1))*(1-1/4((P*Rl-QL)/QL)*(delta/alpha)
= (1.0*0.2881*565.0*0.365/(138*1.0))*
  (1-1/4((0.1*565.0-0.288)/0.288)*(0.181/20.052)
= 0.0422 cm²
```

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

```
= Pext( Rl/2 ) + Faxial/(pi(Dl - Tl)) + Moment/(pi(Rl - Tl/2)(Rl - Tl/2))
= 0.1( 565.0/2 ) + 0.0/(pi(1130.0 - 3.0)) +
  0.0/(pi(565.0 - 3.0/2)(565.0 - 3.0/2))
= 0.288 Kgf/mm.
```

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

```
= 0.55*( Dl*ts )½ * ( ts + tc/cos(alpha) )
= 0.55 * ( 1130.0 * 3.0 )½ * ( 3.0 + 3.0/0.939 )
= 1.9834 cm²
```

Summary of Reinforcement Area, Large End, External Pressure:

Area of reinforcement required per App. 1-8(1)	0.0422	cm²
Area of reinforcement in shell per App. 1-8(2)	1.9834	cm²
Area of reinforcement in stiffening ring	5.0460	cm²

Intermediate Results, Large End, External Pressure:

Area Available in Cone, Shell, and Reinforcement	29.45	cm²
Force per Unit Length on Shell / Cone Junction	0.61	Kgf/mm.
Actual Buckling Stress associated with this Force	1.72	N./mm²
Material Strain associated with this stress	0.000018	

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

```
= A * Dl² * Atl / 10.9
```

= 0.178E-04 * 1130.0 * 1130.0 * 29.45/10.9
= 6151.72 mm.^{4}

Available Moment of Inertia, Large End, External Pressure:

	Area	Centroid	Ar*Ce	Dist	I	Ar*Di^2
Shl	0.961	0.0000	0.000	18.3378	0.007	323.055
Con	1.023	-5.8442	-5.977	24.1820	0.125	598.033
Sec	5.046	26.7300	134.880	-8.3923	10.707	355.391
TOT	7.029		128.903		10.839	1276.479
Centroid of Section			18.3378	Moment of Inertia		23.60

Summary of Large End Inertia Calculations

Available Moment of Inertia (Large End)	23.604	cm**4
Required Moment of Inertia (Large End)	0.615	cm**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	0.00037	
Small end max. half apex angle w/o reinforcement	4.000	degrees
Small end actual half apex angle	20.052	degrees

Intermediate Value [k]:
= max(Y / (Sr * Ers), 1)
= max(0.25122E+11/(136.1 * 0.18458E+09), 1)
= 1.0002

where [Y] is:
= Cone Allowable Stress * Cone Elastic Modulus (Int. temp.)
= 136.1 * 0.18458E+09
= 25121794048.0 N./mm^2^2

Decay Length, Cone Small End:
= 1.4 * sqrt(Rs(ts - ca))
= 1.4 * sqrt(160.5(3.0 - 0.0))
= 30.720 mm.

Required Area of Reinforcement, Small End, Internal [Ars]:
= k*QS*Rs/(Ss*E1)*(1-delta/alpha)*tan(alpha)
= 1.0 * 0.4092 * 160.5/(136 * 1.0) *
(1 - 4.0/20.05) 0.365
= 0.0138 cm^2

Force per Length, Cone Small End [QS]:
= P(Rs/2) - Faxial/(pi(Ds + Ts)) + Moment/(pi(Rs + Ts/2)(Rs + Ts/2))
= 0.5(160.5/2) - 0.0/(pi(321.0 + 3.0)) +
0.0/(pi(160.5 + 3.0/2)(160.5 + 3.0/2))
= 0.409 Kgf/mm.

Area of Reinforcement Available in Small End Shell [Aes]:
= 0.78(Rs*Ts)½*((Ts-t)+(Tc-Tr)/cos(alpha)))
= 0.78(160.5*3.0)½*((3.0- 0.059)+(3.0- 0.063)/0.94)
= 1.0385 cm^2

Summary of Reinforcement Area, Small End, Internal Pressure:

Area of reinforcement required per App. 1-5(3)	0.0138	cm^2
Area of reinforcement in shell per App. 1-5(4)	1.0385	cm^2
Area of reinforcement in stiffening ring	0.0000	cm^2

Required Area of Reinforcement for Small End Under External Pressure

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

Intermediate Value [k]:

```
= max( Y / ( Srs * Ers ), 1 )
= max( 0.26602E+11/( 137.9 * 0.19291E+09 ), 1 )
= 1.0000
```

where [Y] is:

```
= Cone Allowable Stress * Cone Elastic Modulus (Ext. temp.)
= 137.9 * 0.19291E+09
= 26602469376.0 N./mm²^2
```

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

```
= k * QS * Rs * tan(alpha) / ( Ss * E1 )
= (1.0*0.0834*163.5*0.365/(138*1.0))
= 0.00354 cm²
```

Force per Length, Cone Small End [QS]:

```
= Pext( Rs/2 ) + Faxial/(pi(Ds - Ts)) + Moment/(pi(Rs - Ts/2)(Rs - Ts/2))
= 0.1( 163.5/2 ) + 0.0/(pi(327.0 - 3.0)) +
  0.0/(pi(163.5 - 3.0/2)(163.5 - 3.0/2))
= 0.083 Kgf/mm.
```

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

```
= 0.55*(Ds*ts)½*[(ts-t)+(tc-tr)/cos(alpha))]
= 0.55*(327.0*3.0)½*[(3.0-1.272)+(3.0-0.205)/0.939]
= 0.8103 cm²
```

Summary of Reinforcement Area, Small End, External Pressure:

Area of reinforcement required per App. 1-8(3)	0.0035	cm²
Area of reinforcement in shell per App. 1-8(4)	0.8103	cm²
Area of reinforcement in stiffening ring	0.0000	cm²

Intermediate Results, Small End, External Pressure:

Area Available in Cone, Shell, and Reinforcement	18.31	cm²
Force per Unit Length on Shell / Cone Junction	0.89	Kgf/mm.
Actual Buckling Stress associated with this Force	1.17	N./mm²
Material Strain associated with this stress	0.000012	

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

```
= A * Ds² * Ats / 10.9
= 0.121E-04 * 327.0 * 327.0 * 18.31/10.9
= 217.43 mm.⁴
```

Available Moment of Inertia, Small End, External Pressure:

	Area	Centroid	Ar*Ce	Dist	I	Ar*Di²
Shl	0.517	0.0000	0.000	1.6211	0.004	1.358
Con	0.550	3.1438	1.730	-1.5228	0.023	1.276
Sec	0.000	1.5000	0.000	0.1211	0.000	0.000
TOT	1.067		1.730		0.027	2.634
Centroid of Section			1.6211	Moment of Inertia		0.05

Summary of Small End Inertia Calculations

Available Moment of Inertia (Small End)	0.5301E-01	cm**4
Required Moment of Inertia (Small End)	0.2174E-01	cm**4

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

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

Stress Type	Stress	Allowable	Location
Tensile Stress	5.51	408.30	Small Cyl. Long.
Compres. Stress	-2.81	-408.30	Small Cyl. Long.
Membrane Stress	4.99	-204.15	Small End Tang.
Tensile Stress	5.60	408.30	Cone Longitudinal

```
 Compres. Stress           -2.72         -408.30 Cone Longitudinal
 Compres  Stress            5.16         -204.15   Cone Tangential

 Tensile  Stress           31.69          408.30  Large Cyl. Long.
 Compres. Stress          -22.30         -408.30  Large Cyl. Long.
 Membrane Stress           -5.47         -204.15   Large End Tang.
 Tensile  Stress           31.99          408.30 Cone Longitudinal
 Compres. Stress          -21.99         -408.30 Cone Longitudinal
 Compres  Stress           -4.86         -204.15   Cone Tangential
```

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

Maximum Allowable Pressure Calculations for Cone to Shell Junction:

Pressure Case	Pressure bars	Reason for Failure at this Pressure
MAWP	6.804	Thickness due to internal pressure, Cone Large End
MAPnc	6.893	Thickness due to internal pressure, Cone Large End

These pressures were determined by iteration.

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

Conical Section From 60 To 70 SA-240 316

Elastic Modulus Data from ASME Section II Part D at 50 °C

Elastic Modulus of Cone Material	0.193E+09 KPa. at 50 °C
Elastic Modulus of Small Cylinder Material	0.193E+09 KPa. at 50 °C
Elastic Modulus of Large Cylinder Material	0.193E+09 KPa. at 50 °C
Elastic Modulus of Large End Reinforcement	0.193E+09 KPa. at 50 °C
Elastic Modulus of Small End Reinforcement	0.193E+09 KPa. at 50 °C

Elastic Modulus Data from ASME Section II Part D at 170 °C

Elastic Modulus of Cone Material	0.185E+09 KPa. at 170 °C
Elastic Modulus of Small Cylinder Material	0.185E+09 KPa. at 170 °C
Elastic Modulus of Large Cylinder Material	0.185E+09 KPa. at 170 °C
Elastic Modulus of Large End Reinforcement	0.185E+09 KPa. at 170 °C
Elastic Modulus of Small End Reinforcement	0.185E+09 KPa. at 170 °C

Axial Force on Small End of Cone	0.00	Kgf
Axial Force on Large End of Cone	0.00	Kgf
Moment on Small End of Cone	0.00	Kg-m.
Moment on Large End of Cone	0.00	Kg-m.

Note: Since there are no supports, the forces and moments could
not be resolved to the large and small ends of the cone.

Note: Both ends of the Cone are Lines of Support

Maximum Centroid Reinforcement Distance Large End	12.2933	mm.
Maximum Centroid Reinforcement Distance Small End	7.3229	mm.

Reinforcement Calculations for Cone / Large Cylinder:

Required Area of Reinforcement for Large End Under Internal Pressure

Large end ratio of pressure to allowable stress	0.00037	
Large end max. half apex angle w/o reinforcement	11.000	degrees
Large end actual half apex angle	9.786	degrees

Required Area of Reinforcement for Large End Under External Pressure

Large end ratio of pressure to allowable stress	0.00007	
Large end max. half apex angle w/o reinforcement	0.181	degrees
Large end actual half apex angle	9.786	degrees

Intermediate Value [k]:
= max(Y / (Srl * Erl), 1)
= max(0.26602E+11/(137.9 * 0.19291E+09), 1)
= 1.0000

where [Y] is:
= Cone Allowable Stress * Cone Elastic Modulus (Ext. temp.)
= 137.9 * 0.19291E+09
= 26602469376.0 N./mm²^2

Allowable Stress of Large End Material (Ext. Temp)	137.9	N./mm²
Allowable Stress of Cone Material (Ext. Temp)	137.9	N./mm²

Required Area of Reinforcement, Large End, External [Arl]:
= (k*QL*Rl*tan(angle)/(Ss*E1))*(1-1/4((P*Rl-QL)/QL)*(delta/alpha)
= (1.0*0.411*806.0*0.172/(138*1.0))*
(1-1/4((0.1*806.0-0.411)/0.411)*(0.181/9.786)
= 0.0404 cm²

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

```
  = Pext( Rl/2 ) + Faxial/(pi(Dl - Tl)) + Moment/(pi(Rl - Tl/2)(Rl - Tl/2))
  = 0.1( 806.0/2 ) + 0.0/(pi(1612.0 - 3.0)) +
    0.0/(pi(806.0 - 3.0/2)(806.0 - 3.0/2))
  = 0.411 Kgf/mm.
```

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

```
  = 0.55*( Dl*ts )½ * ( ts + tc/cos(alpha) )
  = 0.55 * ( 1612.0 * 3.0 )½ * ( 3.0 + 3.0/0.985 )
  = 2.3118 cm²
```

Summary of Reinforcement Area, Large End, External Pressure:

Area of reinforcement required per App. 1-8(1)	0.0404	cm²
Area of reinforcement in shell per App. 1-8(2)	2.3118	cm²
Area of reinforcement in stiffening ring	4.7820	cm²

Intermediate Results, Large End, External Pressure:

Area Available in Cone, Shell, and Reinforcement	52.17	cm²
Force per Unit Length on Shell / Cone Junction	1.37	Kgf/mm.
Actual Buckling Stress associated with this Force	3.11	N./mm²
Material Strain associated with this stress	0.000032	

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

```
  = A * Dl² * Atl / 10.9
  = 0.322E-04 * 1612.0 * 1612.0 * 52.17/10.9
  = 40104.17 mm.⁴
```

Available Moment of Inertia, Large End, External Pressure:

	Area	Centroid	Ar*Ce	Dist	I	Ar*Di²
Shl	1.147	0.0000	0.000	16.5877	0.009	315.719
Con	1.164	-3.2983	-3.840	19.8860	0.051	460.457
Sec	4.782	25.4100	121.511	-8.8223	9.113	372.194
TOT	7.094		117.670		9.173	1148.371
Centroid of Section			16.5877	Moment of Inertia		20.66

Summary of Large End Inertia Calculations

Available Moment of Inertia (Large End)	20.656	cm**4
Required Moment of Inertia (Large End)	4.010	cm**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	0.00037	
Small end max. half apex angle w/o reinforcement	4.000	degrees
Small end actual half apex angle	9.786	degrees

Intermediate Value [k]:

```
  = max( Y / ( Sr * Ers ), 1 )
  = max( 0.25116E+11/( 136.1 * 0.18458E+09 ), 1 )
  = 1.0000
```

where [Y] is:

```
  = Cone Allowable Stress * Cone Elastic Modulus (Int. temp.)
  = 136.1 * 0.18458E+09
  = 25115742208.0 N./mm²^2
```

Decay Length, Cone Small End:

```
  = 1.4 * sqrt( Rs( ts - ca ) )
  = 1.4 * sqrt( 283.0( 3.0 - 0.0 ) )
  = 40.793 mm.
```

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

```
  = k*QS*Rs/(Ss*E1)*(1-delta/alpha)*tan(alpha)
  = 1.0 * 0.7215 * 283.0/( 136 * 1.0 ) *
```

```
   ( 1 - 4.0/9.79 ) 0.1725
 = 0.015 cm²
```

Force per Length, Cone Small End [QS]:

```
 = P( Rs/2 ) - Faxial/(pi(Ds + Ts)) + Moment/(pi(Rs + Ts/2)(Rs + Ts/2))
 = 0.5( 283.0/2 ) - 0.0/(pi(566.0 + 3.0)) +
   0.0/(pi(283.0 + 3.0/2)(283.0 + 3.0/2))
 = 0.721 Kgf/mm.
```

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

```
 = 0.78(Rs*Ts)½*((Ts-t)+(Tc-Tr)/cos(alpha) ))
 = 0.78(283.0*3.0)½*(( 3.0- 0.104 )+( 3.0- 0.106 )/0.99)
 = 1.3257 cm²
```

Summary of Reinforcement Area, Small End, Internal Pressure:

Area of reinforcement required per App. 1-5(3)	0.0150	cm²
Area of reinforcement in shell per App. 1-5(4)	1.3257	cm²
Area of reinforcement in stiffening ring	4.9000	cm²

Required Area of Reinforcement for Small End Under External Pressure

Allowable Stress of Small End Material (Ext. Temp)	137.9	N./mm²
Allowable Stress of Cone Material (Ext. Temp)	137.9	N./mm²

Intermediate Value [k]:

```
 = max( Y / ( Srs * Ers ), 1 )
 = max( 0.26602E+11/( 137.9 * 0.19291E+09 ), 1 )
 = 1.0000
```

where [Y] is:

```
  = Cone Allowable Stress * Cone Elastic Modulus (Ext. temp.)
  = 137.9 * 0.19291E+09
  = 26602469376.0 N./mm²^2
```

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

```
 = k * QS * Rs * tan(alpha) / ( Ss * E1 )
 = (1.0*0.1458*286.0*0.1725/(138*1.0))
 = 0.00512 cm²
```

Force per Length, Cone Small End [QS]:

```
 = Pext( Rs/2 ) + Faxial/(pi(Ds - Ts)) + Moment/(pi(Rs - Ts/2)(Rs - Ts/2))
 = 0.1( 286.0/2 ) + 0.0/(pi(572.0 - 3.0)) +
   0.0/(pi(286.0 - 3.0/2)(286.0 - 3.0/2))
 = 0.146 Kgf/mm.
```

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

```
 = 0.55*(Ds*ts)½*[(ts-t)+(tc-tr)/cos(alpha))]
 = 0.55*(572.0*3.0)½*[(3.0-0.211)+(3.0-0.21)/0.985]
 = 1.2805 cm²
```

Summary of Reinforcement Area, Small End, External Pressure:

Area of reinforcement required per App. 1-8(3)	0.0051	cm²
Area of reinforcement in shell per App. 1-8(4)	1.2805	cm²
Area of reinforcement in stiffening ring	4.9000	cm²

Intermediate Results, Small End, External Pressure:

Area Available in Cone, Shell, and Reinforcement	52.41	cm²
Force per Unit Length on Shell / Cone Junction	2.04	Kgf/mm.
Actual Buckling Stress associated with this Force	1.63	N./mm²
Material Strain associated with this stress	0.000017	

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

```
 = A * Ds² * Ats / 10.9
 = 0.169E-04 * 572.0 * 572.0 * 52.41/10.9
 = 2666.48 mm.⁴
```


Available Moment of Inertia, Small End, External Pressure:

	Area	Centroid	Ar*Ce	Dist	I	Ar*Di²
Shl	0.684	0.0000	0.000	20.5131	0.005	287.610
Con	0.694	1.9648	1.363	18.5483	0.014	238.626
Sec	4.900	26.0000	127.400	-5.4869	9.804	147.521
TOT	6.277		128.763		9.823	673.757
Centroid of Section			20.5131	Moment of Inertia		16.56

Summary of Small End Inertia Calculations

Available Moment of Inertia (Small End)	0.1656E+02	cm**4
Required Moment of Inertia (Small End)	0.2666E+00	cm**4

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

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

Stress Type	Stress	Allowable	Location
Tensile Stress	7.00	408.20	Small Cyl. Long.
Compres. Stress	-2.26	-408.20	Small Cyl. Long.
Membrane Stress	7.29	-204.10	Small End Tang.
Tensile Stress	7.04	408.20	Cone Longitudinal
Compres. Stress	-2.23	-408.20	Cone Longitudinal
Compres Stress	7.36	-204.10	Cone Tangential
Tensile Stress	28.73	408.20	Large Cyl. Long.
Compres. Stress	-15.32	-408.20	Large Cyl. Long.
Membrane Stress	1.29	-204.10	Large End Tang.
Tensile Stress	28.83	408.20	Cone Longitudinal
Compres. Stress	-15.22	-408.20	Cone Longitudinal
Compres Stress	1.49	-204.10	Cone Tangential

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

Maximum Allowable Pressure Calculations for Cone to Shell Junction:

Pressure Case	Pressure bars	Reason for Failure at this Pressure
MAWP	4.998	Thickness due to internal pressure, Cone Large End
MAPnc	5.065	Thickness due to internal pressure, Cone Large End

These pressures were determined by iteration.

Shop/Field Installation Options :

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

Center of Gravity of Stiffening Rings	4055.186 mm.
Center of Gravity of Bare Shell New and Cold	4759.567 mm.
Center of Gravity of Bare Shell Corroded	4759.567 mm.
Vessel CG in the Operating Condition	4684.575 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition	4684.575 mm.

Minimum Design Metal Temperature Results Summary :

Description	Notes	Curve	Basic MDMT °C	Reduced MDMT °C	UG-20(f) MDMT °C	Thickness ratio	Gov Thk mm.	E*	PWHT reqd
	[16]		-196						
	[16]		-196						
	[16]		-196						
	[16]		-196						
	[16]		-196						
	[16]		-196						
	[16]		-196						
	[16]		-196						
	[16]		-196						
Warmest MDMT:			-196						

Required Minimum Design Metal Temperature -28.9 °C
Warmest Computed Minimum Design Metal Temperature -196.0 °C

Notes:
[!] - This was an impact tested material.
[1] - Governing Nozzle Weld.
[4] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-c).
[5] - ANSI Flange MDMT Calcs; Thickness ratio per UCS-66(b)(1)(-b).
[6] - MDMT Calculations at the Shell/Head Joint.
[7] - MDMT Calculations for the Straight Flange.
[8] - Cylinder/Cone/Flange Junction MDMT.
[9] - Calculations in the Spherical Portion of the Head.
[10] - Calculations in the Knuckle Portion of the Head.
[11] - Calculated (Body Flange) Flange MDMT.
[12] - Calculated Flat Head MDMT per UCS-66.3
[13] - Tubesheet MDMT, shell side, if applicable
[14] - Tubesheet MDMT, tube side, if applicable
[15] - Nozzle Material
[16] - Shell or Head Material
[17] - Impact Testing required
[18] - Impact Testing not required, see UCS-66(b)(3)
[19] - Select a valid hydrotest type to get the UG-20(f) exemption
[20] - Cylinder/Cone Junction MDMT based on Longitudinal Stress considerations
[21] - Bolting Material

UG-84(b)(2) was not considered.
UCS-66(g) was not considered.
UCS-66(i) was not considered.

Notes:
Impact test temps were not entered in and not considered in the analysis.
UCS-66(i) applies to impact tested materials not by specification and
UCS-66(g) applies to materials impact tested per UG-84.1 General Note (c).
The Basic MDMT includes the (30F) PWHT credit if applicable.

ASME Code, Section VIII Division 1, 2017

Diameter Spec : 321.000 x 1124.000 x 566.000 x 1606.000 x 898.000 mm. ID		
Vessel Design Length, Tangent to Tangent	7474.00	mm.
Distance of Bottom Tangent above Grade	50.00	mm.
Distance of Base above Grade	0.00	mm.
Specified Datum Line Distance	0.00	mm.
Internal Design Temperature	170	°C
Internal Design Pressure	0.500	bars
External Design Temperature	50	°C
External Design Pressure	0.100	bars
Maximum Allowable Working Pressure	1.653	bars
External Max. Allowable Working Pressure	0.271	bars
Hydrostatic Test Pressure	0.000	bars
Required Minimum Design Metal Temperature	-28.9	°C
Warmest Computed Minimum Design Metal Temperature	-196.0	°C
Wind Design Code	ASCE-93	
Earthquake Design Code	UBC-94	

Materials of Construction:

Component Type	Material	Class	Thickness	UNS #	Normalized	Impact Tested
Shell	SA-240 316	...	...	S31600	No	No
Cone	SA-240 316	...	...	S31600	No	No
Cover	SA-240 316	...	...	S31600	No	No
Rings	SA-240 316	...	...	S31600	No	No
Rings	SA-240 304	...	...	S30400	No	No

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

Element Pressures and MAWP (bars & mm.):

Element Description or Type	Design Pressure + Stat. head	Ext. Press.	Element M.A.W.P	Corrosion Allowance	Str. Flg. Gov.	In Creep Range
Cylinder	0.500	0.10	25.156	0.0000	N/A	No
Conical	0.500	0.10	6.804	0.0000	N/A	No
Cylinder	0.500	0.10	7.240	0.0000	N/A	No
Wld Flat	0.500	0.10	2.124	0.0000	N/A	No
Cylinder	0.500	0.10	14.332	0.0000	N/A	No
Conical	0.500	0.10	4.998	0.0000	N/A	No
Cylinder	0.500	0.10	5.072	0.0000	N/A	No
Wld Flat	0.500	0.10	1.653	0.0000	N/A	No
Cylinder	0.500	0.10	9.055	0.0000	N/A	No

Stiffener Ring Specifications:

Elevation mm.	Selected Type	User Description
0.00	Bar 39.0 x 12.	Ring 1-1
1145.00	Bar 50.5 x 10.	Ring 2-1
1724.00	Bar 49.0 x 10.	Ring 5-1
1736.00	Bar 49.0 x 10.	Ring 6-1
3605.00	Bar 47.8 x 10.	Ring 6-2
4741.00	Bar 47.8 x 10.	Ring 6-3
4846.00	Bar 47.0 x 10.	Ring 7-1

6356.00	Bar 47.0 x 10.		Ring 7-2
7469.00	Bar 26.0 x 14.		Ring 8.1

Element Types and Properties:

Element Type	"To" Elev mm.	Element Length mm.	Nominal Thickness mm.	Finished Thickness mm.	Reqd Thk Internal mm.	Reqd Thk External mm.	Long Eff	Circ Eff
Cylinder	50.0	50.0	3.0	3.0	1.5	...	1.00	1.00
Conical	1150.0	1100.0	3.0	3.0	1.5	...	1.00	1.00
Cylinder	1606.0	456.0	3.0	3.0	1.5	...	1.00	1.00
Wld Flat	1616.0	10.0	10.0	10.0	4.9	...	1.00	1.00
Cylinder	1731.0	115.0	3.0	3.0	1.5	...	1.00	1.00
Conical	4746.0	3015.0	3.0	3.0	1.5	...	1.00	1.00
Cylinder	7260.0	2514.0	3.0	3.0	1.5	...	1.00	1.00
Wld Flat	7274.0	14.0	14.0	14.0	7.7	...	1.00	1.00
Cylinder	7474.0	200.0	3.0	3.0	1.5	...	1.00	1.00

External Pressure Calculations:

From	To	External Actual T. mm.	External Required T. mm.	External Design Pressure bars	External M.A.W.P. bars
10	Ring	3	No Calc	0.1	No Calc
Ring	20	3	0.19212	0.1	12.103
20	Ring	3	1.27187	0.1	0.85662
Ring	30	3	0.43542	0.1	3.08702
30	40	3	0.99796	0.1	1.60685
40	50	10	No Calc	0.1	No Calc
50	Ring	3	0.36718	0.1	6.05541
Ring	60	3	0.20698	0.1	7.27422
60	Ring	3	0.2107	0.1	7.13086
Ring	Ring	3	1.66204	0.1	0.43479
Ring	Ring	3	1.72473	0.1	0.40042
Ring	70	3	0.59194	0.1	2.11938
70	Ring	3	0.64382	0.1	2.0579
Ring	Ring	3	2.02088	0.1	0.27114
Ring	80	3	1.63721	0.1	0.45972
80	90	14	No Calc	0.1	No Calc
90	Ring	3	0.61369	0.1	3.26313
Ring	100	3	0.32711	0.1	4.3309

External Pressure Calculations:

From	To	Actual Length Bet. Stiffeners mm.	Allowable Length Bet. Stiffeners mm.	Ring Inertia Required cm**4	Ring Inertia Available cm**4
10	Ring	No Calc	No Calc	No Calc	No Calc
Ring	20	50	4811.25	0.00062658	9.67321
20	Ring	706.449	706.449	No Calc	No Calc
Ring	30	4.99191	4.99191	0.36588	20.652
30	40	456	6566.1	No Calc	No Calc
40	50	No Calc	No Calc	No Calc	No Calc
50	Ring	108	4021.26	No Calc	No Calc
Ring	60	7	487.092	0.0077134	17.0396
60	Ring	4.99249	4.99249	No Calc	No Calc
Ring	Ring	1374.53	1374.53	0.093369	17.0481
Ring	Ring	997.779	997.779	1.53939	18.2173
Ring	70	4.99741	4.99741	1.5006	19.1386
70	Ring	100	2398.86	No Calc	No Calc
Ring	Ring	1510	3984.95	2.40723	18.3065
Ring	80	904	3985.66	3.60856	18.3065

80	90	No Calc	No Calc	No Calc	No Calc
90	Ring	195	5498.92	No Calc	No Calc
Ring	100	5	216.544	0.052954	4.51783

Factored Loads:

Un-Factored Loads:

Weights:

Fabricated	- Bare W/O Removable Internals	1106.2	kg.
Shop Test	- Fabricated + Water (Full)	10310.6	kg.
Shipping	- Fab. + Rem. Intls.+ Shipping App.	1106.2	kg.
Erected	- Fab. + Rem. Intls.+ Insul. (etc)	1106.2	kg.
Empty	- Fab. + Intls. + Details + Wghts.	1106.2	kg.
Operating	- Empty + Operating Liquid (No CA)	1106.2	kg.
Field Test	- Empty Weight + Water (Full)	10310.6	kg.