Project No.	Discipline	Document Type	Plant / Equipment No	Sequence No.	Rev.
MODIFIED STARCH FLASH DRYER PROJECT					
FLASH DRYER THICKNESS CALCULATION					
5204	ME	CL	000	02	00

FLASH DRYER THICKNESS CALCULATION

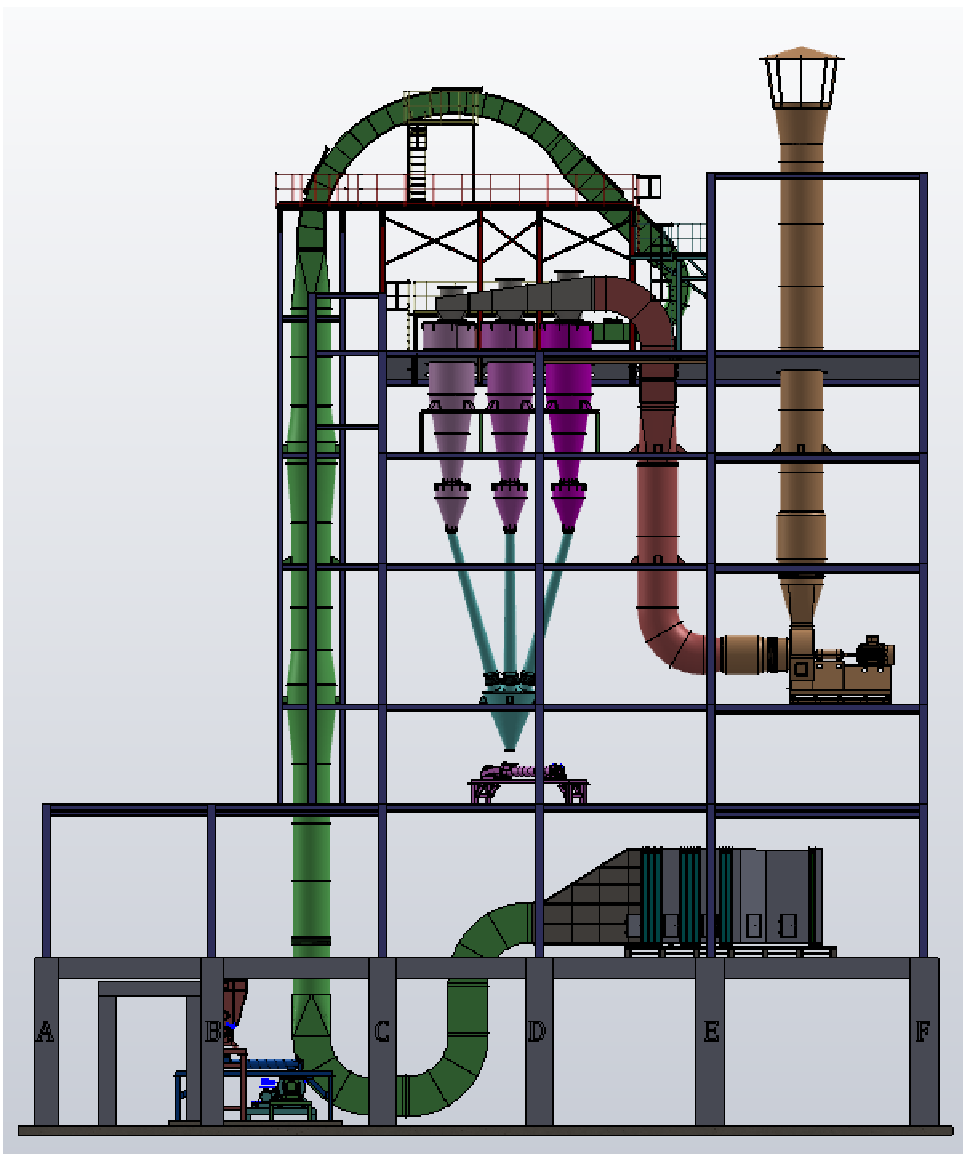


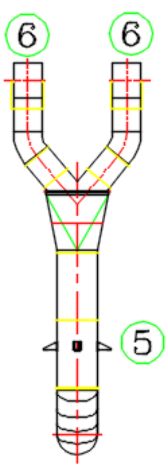
TABLE OF CONTENTS

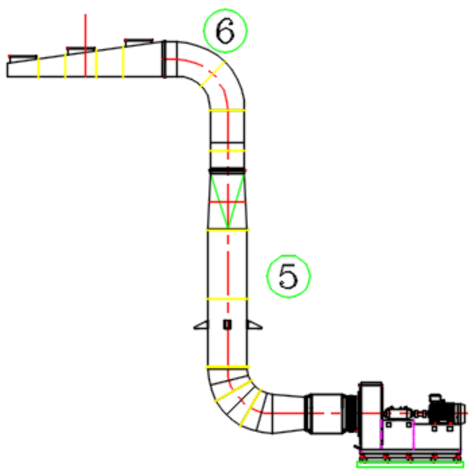
1- INTRODUCTION

Given that the duct of the flash dryer is under the negative pressure induced by the suction fan (0.065 bar), the stress analysis of the duct is performed based on the fan's maximum suction pressure, incorporating an appropriate safety factor. As is known, the maximum inlet air temperature of the fan is approximately 170°C, which decreases along the length of the dryer. To achieve a more accurate analysis and to incorporate a safety margin, the air temperature is assumed to be constant at 170°C throughout the entire length of the dryer. A maximum positive pressure of 0.5 bar (gauge) is considered in accordance with the manufacturer's recomendation.

A critical aspect of the stress analysis and minimum thickness calculation for the dryer is that the calculated minimum required thickness must be compared against the actual thickness specified for each section to ensure it does not exceed the actual value. Furthermore, based on the actual thickness, the maximum allowable working pressure for each section has been calculated. The significance of this maximum allowable working pressure lies in its application for vent sizing calculations; specifically, the Maimum over pressure generated by an explosive atmosphere (Preq.) used in vent sizing must not exceed the maximum allowable pressure of any section, or in other words, the weakest section within each controlled volume.

For the purpose of calculating and analyzing stresses induced by pressure, vacuum, and temperature, the dryer duct has been divided into several sections. This division falls into two main categories: sections with circular cross-sections and sections with rectangular cross-sections. Sections with circular cross-sections have been simulated and analyzed using PV Elite software, while sections with rectangular cross-sections have been analyzed using CodeCalc software. It should be noted that, according to the zoning illustrated in the figure below,





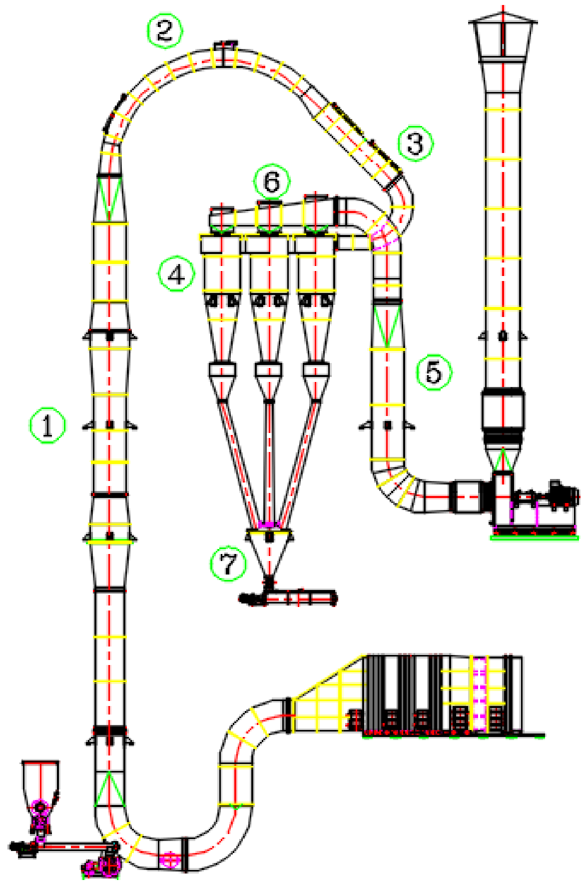


Fig.1 – Flash

Dryer Zones

Zone 1 of the dryer duct, which begins approximately above the material inlet and extends to Zone 2. Furthermore, the cyclones (Zone 4) , Fan inlet duct (Zone5) and hopper (Zone 7) have circular cross-sections and have been analyzed using PV Elite software .

Zone 2 , Zone 3 and Zone 6 have rectangular cross-section and have been analyzed using CodeCalc software .

2- ASSUMPTIONS

The circular section of Zone 5, with a diameter of 1400 mm, is similar to Zone 1; therefore, the analysis results for Zone 1 are also applicable to Zone 5, and a separate analysis is not required.

Zones 2, 3, and the portion of Zone 6 with a rectangular cross-section have been analyzed using CodeCalc software. Zone 3 is the most critical section, as it has both larger dimensions and the highest risk for explosion. Consequently, the analysis results for this section can be generalized to the other rectangular sections, which is a conservative approach that increases the safety factor.

However, stress analysis will be performed for Zones 2, 3, and 6 separatly.

The design assumptions, based on the mechanical specifications of the equipment and the data received from the manufacturer, are as presented in th below

- Operating Internal Temperature = 55° C - 165° C
- Design Internal Temperature = 170° C
- Operating External Temperature = -20° C to 35 ° C
- Design External Temperature = 50° C
- Maximum Operating internal pressure (Openning Pressure of Explosion Vents) = 0.1 bar
- Design Internal Pressure = 0.5 bar
- Maximum External Pressure (Maximum Vacuume Pressure of fan)= 0.065 bar
- Design External Pressure (Design Vacuume Pressure) = 0.1 bar
- Circular Duct Thickness(Zone 1 , 4) = 3 mm
- Rectangular Duct Thickness (Zone 2 , 3, 6) = 3 mm
- Duct Material= AISI SS 316

Finally, following the calculations detailed in Appendices 1 through 6, a summary of the calculations and stress analysis is presented in the table below.As can be observed, the actual thicknesses considered are adequate, and the maximum allowable working pressure for each section has been duly incorporated into the calculations for the required vent size.

3- SUMMARY OF CALCULATIONS

The stresses calculations and analysis summary for the different areas of the dryer duct are as follows :

Table 1- Assumption and Design Data

Zone	Title	Section	Material	Actual Thickness (mm)	Design Internal Pressure (Bar)	Design External Pressure (Bar)	Design Internal Temperature ©	Design External Temperature ©
1	Duct	Circular	AISI 316	3	0.5	0.1	170	50
2	Duct	Rectangular	AISI 316	3	0.5	0.1	170	50
3	Duct	Rectangular	AISI 316	3	0.5	0.1	170	50
4	Cyclone	Circular	AISI 316	3	0.5	0.1	170	50
5	Duct	Circular	AISI 316	3	0.5	0.1	170	50
6	Duct	Rectangular	AISI 316	3	0.5	0.1	170	50
7	Hopper	Circular	AISI 316	3	0.5	0.1	170	50

Table 2- Calculated Data

Zone	Title	Section	Maximum Allowable Internal Working Pressure (Bar)	Maximum Allowable External Working Pressure (Bar)	Minimum Required Thickness (mm)
1	Duct	Circular	3.5	0.137	2.6
2	Duct	Rectangular	0.83	0.1	2.8
3	Duct	Rectangular	0.81	0.1	2.8
4	Cyclone	Circular	1.6	0.27	2
5	Duct	Circular	3.5	0.137	2.6
6	Duct	Rectangular	0.81	0.1	2.8
7	Hopper	Circular	3.9	0.23	2.15

APPENDIX 1
CALCULATION
CIRCULAR SECTION OF DUCT
ZONE 1

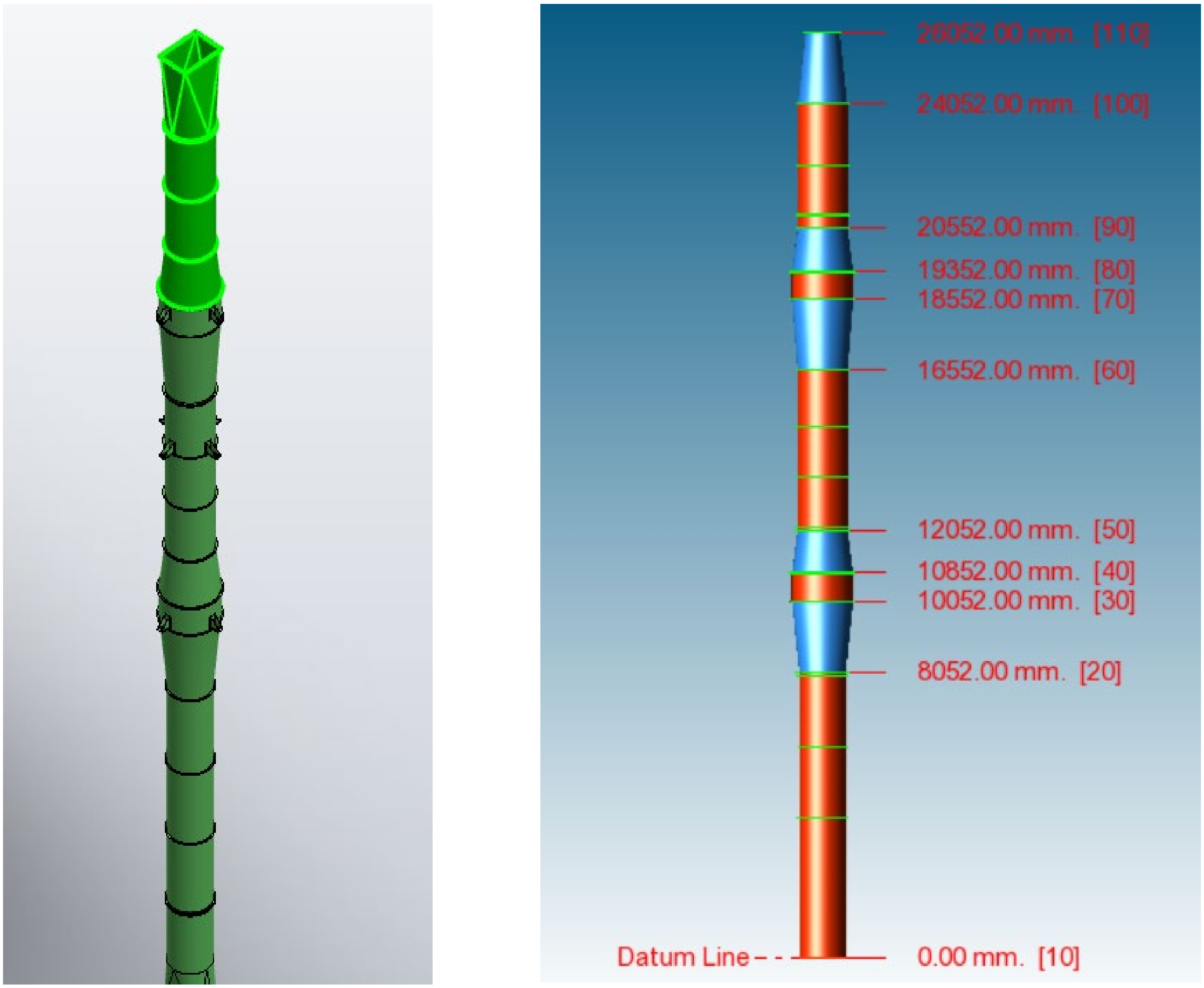


Figure A – Circular Duct - Zone 1

Table of Contents

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   4:14pm

PV Elite 2019 SP1, March 2019
```

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

Class From To : Basic Element Checks.
==

Class From To: Check of Additional Element Data
==

There were no geometry errors or warnings.

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

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	Horizontal	
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"                                  8052  mm.
Inside Diameter                                          1300  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                        104.16  N./mm²
    Allowable Stress, Hydrotest                        179.27  N./mm²
    Material Density                                 0.008027  kg./cm³
    P Number Thickness                                      0  mm.
    Yield Stress, Operating                            156.11  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 of 1]
    Dist. from "FROM" Node / Offset dist                 3958  mm.
    Inside Diameter of Ring                              1306  mm.
    Thickness of Ring                                      10  mm.
    Outside Diameter of Ring                             1400  mm.
    Material Name                                 SA-240 316
    Height of Section Ring                                  0  mm.
    Using Custom Stiffener Section                         No

    Element From Node                                      10
    Detail Type                                          Ring
    Detail ID                                   Ring:[2 of 2]
    Dist. from "FROM" Node / Offset dist                 5946  mm.
    Inside Diameter of Ring                              1306  mm.
    Thickness of Ring                                      10  mm.
```

```
    Outside Diameter of Ring                            1400  mm.
    Material Name                                 SA-240 316
    Height of Section Ring                                 0  mm.
    Using Custom Stiffener Section                        No

    Element From Node                                     10
    Detail Type                                         Ring
    Detail ID                                Ring:[3 of 3]
    Dist. from "FROM" Node / Offset dist                7939  mm.
    Inside Diameter of Ring                             1306  mm.
    Thickness of Ring                                     10  mm.
    Outside Diameter of Ring                            1400  mm.
    Material Name                                 SA-240 316
    Height of Section Ring                                 0  mm.
    Using Custom Stiffener Section                        No

    Element From Node                                     10
    Detail Type                                         Ring
    Detail ID                                Ring:[4 of 4]
    Dist. from "FROM" Node / Offset dist                7952  mm.
    Inside Diameter of Ring                             1306  mm.
    Thickness of Ring                                     10  mm.
    Outside Diameter of Ring                            1400  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"                                 2000  mm.
Inside Diameter                                         1300  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                               1730  mm.
Design Length of Cone                                   2000  mm.
Half Apex Angle of Cone                            6.1357331  degrees
Toriconical (Y/N)                                          N
Weld is pre-Heated                                        No

    Element From Node                                     20
    Detail Type                                         Ring
    Detail ID                                        Ring 16
    Dist. from "FROM" Node / Offset dist                   0  mm.
    Inside Diameter of Ring                             1306  mm.
    Thickness of Ring                                     10  mm.
    Outside Diameter of Ring                            1500  mm.
    Material Name                                 SA-240 304
    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"	800	mm.
Inside Diameter	1730	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	30	
Detail Type	Ring	
Detail ID	Ring5	
Dist. from "FROM" Node / Offset dist	0	mm.
Inside Diameter of Ring	1736	mm.
Thickness of Ring	10	mm.
Outside Diameter of Ring	1830	mm.
Material Name	SA-240 304	
Height of Section Ring	0	mm.
Using Custom Stiffener Section	No	

Element From Node	40	
Element To Node	50	
Element Type	Conical	
Description		
Distance "FROM" to "TO"	1200	mm.
Inside Diameter	1730	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	1400	mm.
Design Length of Cone	1200	mm.
Half Apex Angle of Cone	7.8290772	degrees
Toriconical (Y/N)	N	
Weld is pre-Heated	No	

Element From Node	40	
Detail Type	Ring	
Detail ID	Ring:17	
Dist. from "FROM" Node / Offset dist	1199	mm.
Inside Diameter of Ring	1406.3	mm.
Thickness of Ring	10	mm.
Outside Diameter of Ring	1500	mm.
Material Name	SA-240 304	
Height of Section Ring	0	mm.

```
    Using Custom Stiffener Section                          No

    Element From Node                                       40
    Detail Type                                           Ring
    Detail ID                                          Ring 21
    Dist. from "FROM" Node / Offset dist                     0  mm.
    Inside Diameter of Ring                               1736  mm.
    Thickness of Ring                                       10  mm.
    Outside Diameter of Ring                              1836  mm.
    Material Name                                   SA-240 304
    Height of Section Ring                                   0  mm.
    Using Custom Stiffener Section                          No

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

Element From Node                                           50
Element To Node                                             60
Element Type                                          Cylinder
Description
Distance "FROM" to "TO"                                   4500  mm.
Inside Diameter                                           1400  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 6
    Dist. from "FROM" Node / Offset dist                    90  mm.
    Inside Diameter of Ring                               1406  mm.
    Thickness of Ring                                       10  mm.
    Outside Diameter of Ring                              1500  mm.
    Material Name                                   SA-240 304
    Height of Section Ring                                   0  mm.
    Using Custom Stiffener Section                          No

    Element From Node                                       50
    Detail Type                                           Ring
    Detail ID                                           Ring 7
    Dist. from "FROM" Node / Offset dist                   103  mm.
    Inside Diameter of Ring                               1406  mm.
    Thickness of Ring                                       10  mm.
    Outside Diameter of Ring                              1500  mm.
    Material Name                                   SA-240 304
    Height of Section Ring                                   0  mm.
    Using Custom Stiffener Section                          No

    Element From Node                                       50
    Detail Type                                           Ring
    Detail ID                                           Ring 8
    Dist. from "FROM" Node / Offset dist                  1513  mm.
    Inside Diameter of Ring                               1406  mm.
    Thickness of Ring                                       10  mm.
    Outside Diameter of Ring                              1500  mm.
    Material Name                                   SA-240 304
    Height of Section Ring                                   0  mm.
```

```
    Using Custom Stiffener Section                     No

    Element From Node                                  50
    Detail Type                                      Ring
    Detail ID                                      Ring 9
    Dist. from "FROM" Node / Offset dist             2913  mm.
    Inside Diameter of Ring                          1406  mm.
    Thickness of Ring                                  10  mm.
    Outside Diameter of Ring                         1500  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"                             2000  mm.
 Inside Diameter                                     1400  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                           1730  mm.
 Design Length of Cone                               2000  mm.
 Half Apex Angle of Cone                        4.7162204  degrees
 Toriconical (Y/N)                                      N
 Weld is pre-Heated                                    No

    Element From Node                                  60
    Detail Type                                      Ring
    Detail ID                                     Ring 18
    Dist. from "FROM" Node / Offset dist                0  mm.
    Inside Diameter of Ring                          1406  mm.
    Thickness of Ring                                  10  mm.
    Outside Diameter of Ring                         1500  mm.
    Material Name                             SA-240 304
    Height of Section Ring                              0  mm.
    Using Custom Stiffener Section                     No

    Element From Node                                  60
    Detail Type                                      Ring
    Detail ID                                     Ring 23
    Dist. from "FROM" Node / Offset dist             1999  mm.
    Inside Diameter of Ring                        1735.8  mm.
    Thickness of Ring                                  10  mm.
    Outside Diameter of Ring                       1829.8  mm.
    Material Name                             SA-240 304
    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"	800	mm.
Inside Diameter	1730	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 10	
Dist. from "FROM" Node / Offset dist	737	mm.
Inside Diameter of Ring	1736	mm.
Thickness of Ring	10	mm.
Outside Diameter of Ring	1830	mm.
Material Name	SA-240 304	
Height of Section Ring	0	mm.
Using Custom Stiffener Section	No	

Element From Node	70	
Detail Type	Ring	
Detail ID	Ring 11	
Dist. from "FROM" Node / Offset dist	750	mm.
Inside Diameter of Ring	1736	mm.
Thickness of Ring	10	mm.
Outside Diameter of Ring	1830	mm.
Material Name	SA-240 304	
Height of Section Ring	0	mm.
Using Custom Stiffener Section	No	

Element From Node	80	
Element To Node	90	
Element Type	Conical	
Description		
Distance "FROM" to "TO"	1200	mm.
Inside Diameter	1730	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	1400	mm.
Design Length of Cone	1200	mm.
Half Apex Angle of Cone	7.8290772	degrees
Toriconical (Y/N)	N	
Weld is pre-Heated	No	

Element From Node	80	

```
    Detail Type                                        Ring
    Detail ID                                       Ring 24
    Dist. from "FROM" Node / Offset dist                  0  mm.
    Inside Diameter of Ring                            1736  mm.
    Thickness of Ring                                    10  mm.
    Outside Diameter of Ring                         1829.7  mm.
    Material Name                                SA-240 304
    Height of Section Ring                                0  mm.
    Using Custom Stiffener Section                       No

    Element From Node                                    80
    Detail Type                                        Ring
    Detail ID                                       Ring 26
    Dist. from "FROM" Node / Offset dist               1199  mm.
    Inside Diameter of Ring                          1406.3  mm.
    Thickness of Ring                                    10  mm.
    Outside Diameter of Ring                         1499.9  mm.
    Material Name                                SA-240 304
    Height of Section Ring                                0  mm.
    Using Custom Stiffener Section                       No

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

Element From Node                                        90
Element To Node                                         100
Element Type                                       Cylinder
Description
Distance "FROM" to "TO"                                3500  mm.
Inside Diameter                                        1400  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 12
    Dist. from "FROM" Node / Offset dist                375  mm.
    Inside Diameter of Ring                            1406  mm.
    Thickness of Ring                                    10  mm.
    Outside Diameter of Ring                           1500  mm.
    Material Name                                SA-240 304
    Height of Section Ring                                0  mm.
    Using Custom Stiffener Section                       No

    Element From Node                                    90
    Detail Type                                        Ring
    Detail ID                                      Ring 13]
    Dist. from "FROM" Node / Offset dist               1745  mm.
    Inside Diameter of Ring                            1406  mm.
    Thickness of Ring                                    10  mm.
    Outside Diameter of Ring                           1500  mm.
    Material Name                                SA-240 304
    Height of Section Ring                                0  mm.
    Using Custom Stiffener Section                       No

--------------------------------------------------------------------
```

Element From Node	100	
Element To Node	110	
Element Type	Conical	
Description		
Distance "FROM" to "TO"	2000	mm.
Inside Diameter	1400	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	950	mm.
Design Length of Cone	2000	mm.
Half Apex Angle of Cone	6.4187856	degrees
Toriconical (Y/N)	N	
Weld is pre-Heated	No	

Element From Node	100	
Detail Type	Ring	
Detail ID	Ring 22	
Dist. from "FROM" Node / Offset dist	1999	mm.
Inside Diameter of Ring	956.22	mm.
Thickness of Ring	10	mm.
Outside Diameter of Ring	1057.1	mm.
Material Name	SA-240 304	
Height of Section Ring	0	mm.
Using Custom Stiffener Section	No	

Element From Node	100	
Detail Type	Ring	
Detail ID	Ring 28	
Dist. from "FROM" Node / Offset dist	0	mm.
Inside Diameter of Ring	1406	mm.
Thickness of Ring	10	mm.
Outside Diameter of Ring	1506.8	mm.
Material Name	SA-240 304	
Height of Section Ring	0	mm.
Using Custom Stiffener Section	No	

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

XY Coordinate Calculations:

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
10	20	...	8052	...	8052
20	30	...	10052	...	2000
30	40	...	10852	...	800
40	50	...	12052	...	1200
50	60	...	16552	...	4500
60	70	...	18552	...	2000
70	80	...	19352	...	800
80	90	...	20552	...	1200
90	100	...	24052	...	3500
100	110	...	26052	...	2000

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

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	...	1300	104.16
20	30	0.5	3	...	1730	104.16
30	40	0.5	3	...	1730	104.16
40	50	0.5	3	...	1730	104.16
50	60	0.5	3	...	1400	104.16
60	70	0.5	3	...	1730	104.16
70	80	0.5	3	...	1730	104.16
80	90	0.5	3	...	1730	104.16
90	100	0.5	3	...	1400	104.16
100	110	0.5	3	...	1400	104.16

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	4.79375	6.34667	3	1.5
20	30	0.5	3.58411	4.74517	3	1.5
30	40	0.5	3.60472	4.77245	3	1.5
40	50	0.5	3.57118	4.72806	3	1.5
50	60	0.5	4.45222	5.8945	3	1.5
60	70	0.5	3.59254	4.75633	3	1.5
70	80	0.5	3.60472	4.77245	3	1.5
80	90	0.5	3.57118	4.72806	3	1.5
90	100	0.5	4.45222	5.8945	3	1.5
100	110	0.5	4.42438	5.85764	3	1.5
Minimum			3.571	4.728		

MAWP: 3.571 bars, limited by: Cone.

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*650.0)/(104.16*1.0-0.6*0.5)
 = 0.3121 + 0.0000 = 0.3121 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)
 = (104.16*1.0*3.0)/(650.0+0.6*3.0)
 = 4.794 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)/(650.0+0.6*3.0)
```

= 6.347 bars

Actual stress at given pressure and thickness, corroded [Sact]:
```
= (P*(R+0.6*t))/(E*t)
= (0.5*(650.0+0.6*3.0))/(1.0*3.0)
= 10.864 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf)*(1-Rf/Ro) 0.230 %
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*1730.0)/(2*0.9943*(104.16*1.0-0.6*0.5))
= 0.4178 + 0.0000 = 0.4178 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*104.16*1.0*3.0*0.994)/(1730.0+1.2*3.0*0.994)
= 3.584 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*0.9943)/(1730.0+1.2*3.0*0.9943)
= 4.745 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
= (P*(D+1.2*t*cos(a)))/(2*E*t*cos(a))
= (0.5*(1730.0+1.2*3.0*0.9943))/(2*1.0*3.0*0.9943)
= 14.531 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf)*(1-Rf/Ro) 0.230 %
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*865.0)/(104.16*1.0-0.6*0.5)
= 0.4154 + 0.0000 = 0.4154 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)
= (104.16*1.0*3.0)/(865.0+0.6*3.0)
= 3.605 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)/(865.0+0.6*3.0)
  = 4.772 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(R+0.6*t))/(E*t)
  = (0.5*(865.0+0.6*3.0))/(1.0*3.0)
  = 14.448 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf)*(1-Rf/Ro) 0.173 %
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 40 To 50 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*1730.0)/(2*0.9907*(104.16*1.0-0.6*0.5))
  = 0.4193 + 0.0000 = 0.4193 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*104.16*1.0*3.0*0.991)/(1730.0+1.2*3.0*0.991)
  = 3.571 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*0.9907)/(1730.0+1.2*3.0*0.9907)
  = 4.728 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(D+1.2*t*cos(a)))/(2*E*t*cos(a))
  = (0.5*(1730.0+1.2*3.0*0.9907))/(2*1.0*3.0*0.9907)
  = 14.583 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf)*(1-Rf/Ro) 0.214 %
Note: Please Check Requirements of Table UHA-44 for Elongation limits.

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*700.0)/(104.16*1.0-0.6*0.5)
  = 0.3361 + 0.0000 = 0.3361 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)
  = (104.16*1.0*3.0)/(700.0+0.6*3.0)
```

```
  = 4.452 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)/(700.0+0.6*3.0)
  = 5.894 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(R+0.6*t))/(E*t)
  = (0.5*(700.0+0.6*3.0))/(1.0*3.0)
  = 11.697 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf)*(1-Rf/Ro) 0.214 %
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*1730.0)/(2*0.9966*(104.16*1.0-0.6*0.5))
  = 0.4168 + 0.0000 = 0.4168 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*104.16*1.0*3.0*0.997)/(1730.0+1.2*3.0*0.997)
  = 3.593 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*0.9966)/(1730.0+1.2*3.0*0.9966)
  = 4.756 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(D+1.2*t*cos(a)))/(2*E*t*cos(a))
  = (0.5*(1730.0+1.2*3.0*0.9966))/(2*1.0*3.0*0.9966)
  = 14.496 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf)*(1-Rf/Ro) 0.214 %
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*865.0)/(104.16*1.0-0.6*0.5)
  = 0.4154 + 0.0000 = 0.4154 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)
  = (104.16*1.0*3.0)/(865.0+0.6*3.0)
  = 3.605 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)/(865.0+0.6*3.0)
  = 4.772 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(R+0.6*t))/(E*t)
  = (0.5*(865.0+0.6*3.0))/(1.0*3.0)
  = 14.448 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf)*(1-Rf/Ro) 0.173 %
Note: Please Check Requirements of Table UHA-44 for Elongation limits.

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

<u>Conical Section From 80 To 90 SA-240 316 at 170 °C</u>

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*1730.0)/(2*0.9907*(104.16*1.0-0.6*0.5))
  = 0.4193 + 0.0000 = 0.4193 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*104.16*1.0*3.0*0.991)/(1730.0+1.2*3.0*0.991)
  = 3.571 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*0.9907)/(1730.0+1.2*3.0*0.9907)
  = 4.728 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(D+1.2*t*cos(a)))/(2*E*t*cos(a))
  = (0.5*(1730.0+1.2*3.0*0.9907))/(2*1.0*3.0*0.9907)
  = 14.583 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf)*(1-Rf/Ro) 0.214 %
Note: Please Check Requirements of Table UHA-44 for Elongation limits.

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

<u>Cylindrical Shell From 90 To 100 SA-240 316 at 170 °C</u>

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*700.0)/(104.16*1.0-0.6*0.5)
  = 0.3361 + 0.0000 = 0.3361 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)
= (104.16*1.0*3.0)/(700.0+0.6*3.0)
= 4.452 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)/(700.0+0.6*3.0)
= 5.894 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
= (P*(R+0.6*t))/(E*t)
= (0.5*(700.0+0.6*3.0))/(1.0*3.0)
= 11.697 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf)*(1-Rf/Ro) 0.214 %
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 100 To 110 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*1400.0)/(2*0.9937*(104.16*1.0-0.6*0.5))
= 0.3383 + 0.0000 = 0.3383 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*104.16*1.0*3.0*0.994)/(1400.0+1.2*3.0*0.994)
= 4.424 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*0.9937)/(1400.0+1.2*3.0*0.9937)
= 5.858 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
= (P*(D+1.2*t*cos(a)))/(2*E*t*cos(a))
= (0.5*(1400.0+1.2*3.0*0.9937))/(2*1.0*3.0*0.9937)
= 11.771 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf)*(1-Rf/Ro) 0.315 %
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.

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

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	3958	1306	3	0.46719E-04	4.48502
Ring	Ring	1988	1306	3	0.95296E-04	9.14839
Ring	Ring	1993	1306	3	0.95050E-04	9.12477
Ring	Ring	12.9998	1306	3	0.0047922	91.4355
Ring	20	100	1306	3	0.0026	83.9018
20	Ring	1679.94	1306.03	3	0.00011239	10.7893
Ring	30	1752.3	1736.03	3	0.93196E-04	8.94674
30	Ring	No Calc	...	3	No Calc	No Calc
Ring	40	800	1736	3	0.00021156	20.3093
40	Ring	1752.3	1736.06	3	0.92641E-04	8.89351
Ring	Ring	1085.13	1736.06	3	0.00015138	14.5319
Ring	50	0.99994	1406.33	3	0.0041294	89.7316
50	Ring	90	1406	3	0.0029414	85.5356
Ring	Ring	13	1406	3	0.0042047	89.9431
Ring	Ring	1410	1406	3	0.000131	12.5764
Ring	Ring	1400	1406	3	0.00013196	12.6681
Ring	60	1587	1406	3	0.00011601	11.1366
60	Ring	0.99994	1406.02	3	0.004178	89.8686
Ring	Ring	1809.08	1735.86	3	0.90550E-04	8.69271
Ring	70	0.99989	1736.02	3	0.0028755	85.24
70	Ring	737	1736	3	0.00023058	22.1352
Ring	Ring	13	1736	3	0.0028938	85.3229
Ring	80	50	1736	3	0.0028938	85.3229
80	Ring	0.99989	1736.06	3	0.0028434	85.0923
Ring	Ring	1085.13	1736.06	3	0.00015138	14.5319
Ring	90	0.99994	1406.33	3	0.0041294	89.7316
90	Ring	375	1406	3	0.00052804	50.6919
Ring	Ring	1370	1406	3	0.0001349	12.9498
Ring	100	1755	1406	3	0.00010461	10.0421
100	Ring	0.99994	1406.04	3	0.0041551	89.8045
Ring	Ring	1679.26	1406.04	3	0.00010837	10.4036
Ring	110	0.99982	956.263	3	0.0083163	97.0162

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	2.64879	0.1	0.13736
Ring	Ring	3	1.98494	0.1	0.28018
Ring	Ring	3	1.98708	0.1	0.27946
Ring	Ring	3	0.47257	0.1	2.80031
Ring	20	3	0.57319	0.1	2.56958
20	Ring	3	1.86049	0.1	0.32853
Ring	30	3	2.24961	0.1	0.20495
30	Ring	3	No Calc	0.1	No Calc
Ring	40	3	1.62103	0.1	0.46793
40	Ring	3	2.25778	0.1	0.20299
Ring	Ring	3	1.85593	0.1	0.33169
Ring	50	3	0.51366	0.1	2.52828
50	Ring	3	0.56956	0.1	2.4333
Ring	Ring	3	0.50876	0.1	2.55869
Ring	Ring	3	1.80715	0.1	0.35777
Ring	Ring	3	1.80239	0.1	0.36038
Ring	60	3	1.89031	0.1	0.31681

60	Ring	3	0.51049	0.1	2.54788
Ring	Ring	3	2.27117	0.1	0.19962
Ring	70	3	0.6303	0.1	1.95727
70	Ring	3	1.56614	0.1	0.51
Ring	Ring	3	0.62816	0.1	1.96585
Ring	80	3	0.62816	0.1	1.96585
80	Ring	3	0.63409	0.1	1.9422
Ring	Ring	3	1.85593	0.1	0.33169
Ring	90	3	0.51366	0.1	2.52828
90	Ring	3	1.04348	0.1	1.44208
Ring	Ring	3	1.78809	0.1	0.3684
Ring	100	3	1.96728	0.1	0.28568
100	Ring	3	0.51198	0.1	2.53866
Ring	Ring	3	1.94504	0.1	0.2941
Ring	110	3	0.34821	0.1	4.03247
Minimum					0.137

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	3958	5366.66	No Calc	No Calc
Ring	Ring	1988	5367.77	4.74696	17.6358
Ring	Ring	1993	5367.78	3.17821	17.6358
Ring	Ring	12.9998	362.283	1.60148	17.6358
Ring	20	100	3105.85	0.090213	17.6358
20	Ring	1679.94	1679.94	No Calc	No Calc
Ring	30	1752.3	1752.3	2.74012	118.645
30	Ring	No Calc	No Calc	No Calc	No Calc
Ring	40	800	3576.41	1.50003	18.5486
40	Ring	1752.3	1752.3	No Calc	No Calc
Ring	Ring	1085.13	1085.13	5.32031	21.7628
Ring	50	0.99994	0.99994	1.08257	17.7314
50	Ring	90	2782.45	No Calc	No Calc
Ring	Ring	13	332.63	0.1026	17.8679
Ring	Ring	1410	4840.94	1.41706	17.8679
Ring	Ring	1400	4840.92	2.80393	17.8679
Ring	60	1587	4841.33	2.96283	17.8679
60	Ring	0.99994	0.99994	No Calc	No Calc
Ring	Ring	1809.08	1809.08	1.80308	17.8679
Ring	70	0.99989	0.99989	3.39301	18.5482
70	Ring	737	3576.31	No Calc	No Calc
Ring	Ring	13	979.513	1.41118	18.5486
Ring	80	50	1799.98	0.11813	18.5486
80	Ring	0.99989	0.99989	No Calc	No Calc
Ring	Ring	1085.13	1085.13	2.0298	18.381
Ring	90	0.99994	0.99994	1.08257	17.7021
90	Ring	375	4840.98	No Calc	No Calc
Ring	Ring	1370	4840.85	1.73585	17.8679
Ring	100	1755	4841.66	3.11292	17.8679
100	Ring	0.99994	0.99994	No Calc	No Calc
Ring	Ring	1679.26	1679.26	1.67377	21.4269
Ring	110	0.99982	0.99982	0.52653	20.0339

Elements Suitable for External Pressure.

ASME Code, Section VIII Division 1, 2017

Cylindrical Shell From 10 to Ring:[1 of 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	1306.00	3958.00	435.33	3.0306	0.0000467	4.49

EMAP = (4*B)/(3*(D/t)) = (4*4.485)/(3*435.3333) = 0.1374 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
2.649	1306.00	3958.00	493.06	3.0306	0.0000385	3.70

EMAP = (4*B)/(3*(D/t)) = (4*3.6983)/(3*493.0556) = 0.1 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	1306.00	5366.66	435.33	4.1092	0.0000340	3.27

EMAP = (4*B)/(3*(D/t)) = (4*3.268)/(3*435.3333) = 0.1001 bars

Cylindrical Shell From Ring:[1 of 1] to Ring:[2 of 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	1306.00	1988.00	435.33	1.5222	0.0000953	9.15

EMAP = (4*B)/(3*(D/t)) = (4*9.1484)/(3*435.3333) = 0.2802 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
1.985	1306.00	1988.00	657.96	1.5222	0.0000514	4.94

EMAP = (4*B)/(3*(D/t)) = (4*4.9351)/(3*657.9558) = 0.1 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	1306.00	5367.77	435.33	4.1101	0.0000340	3.27

EMAP = (4*B)/(3*(D/t)) = (4*3.2673)/(3*435.3333) = 0.1001 bars

Cylindrical Shell From Ring:[2 of 2] to Ring:[3 of 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
3.000	1306.00	1993.00	435.33	1.5260	0.0000951	9.12

EMAP = (4*B)/(3*(D/t)) = (4*9.1248)/(3*435.3333) = 0.2795 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
1.987	1306.00	1993.00	657.25	1.5260	0.0000514	4.93

EMAP = (4*B)/(3*(D/t)) = (4*4.9298)/(3*657.2463) = 0.1 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	1306.00	5367.78	435.33	4.1101	0.0000340	3.27

EMAP = (4*B)/(3*(D/t)) = (4*3.2673)/(3*435.3333) = 0.1001 bars

Cone From Ring 16 to 30 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
2.983	1736.03	1752.30	582.01	1.0094	0.0000932	8.95

EMAP = (4*B)/(3*(D/t)) = (4*8.9467)/(3*582.0123) = 0.2049 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
2.237	1736.03	1752.30	776.15	1.0094	0.0000606	5.82

EMAP = (4*B)/(3*(D/t)) = (4*5.8216)/(3*776.1512) = 0.1 bars

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

Cylindrical Shell From Ring5 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	1736.00	800.00	578.67	0.4608	0.0002116	20.31

EMAP = (4*B)/(3*(D/t)) = (4*20.3093)/(3*578.6667) = 0.4679 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
1.621	1736.00	800.00	1070.92	0.4608	0.0000837	8.03

EMAP = (4*B)/(3*(D/t)) = (4*8.0326)/(3*1070.9225) = 0.1 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	1736.00	3576.41	578.67	2.0601	0.0000452	4.34

EMAP = (4*B)/(3*(D/t)) = (4*4.3427)/(3*578.6667) = 0.1001 bars

Cone From Ring 21 to Ring:17 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
2.972	1736.06	1085.13	584.13	0.6251	0.0001514	14.53

EMAP = (4*B)/(3*(D/t)) = (4*14.5319)/(3*584.1302) = 0.3317 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
1.839	1736.06	1085.13	944.21	0.6251	0.0000738	7.08

EMAP = (4*B)/(3*(D/t)) = (4*7.0822)/(3*944.2127) = 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:17 to 50 Ext. Chart: HA-2 at 50 °C

Cylindrical Shell From Ring 7 to Ring 8 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	1406.00	1410.00	468.67	1.0028	0.0001310	12.58

EMAP = (4*B)/(3*(D/t)) = (4*12.5764)/(3*468.6667) = 0.3578 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
1.807	1406.00	1410.00	778.02	1.0028	0.0000608	5.84

EMAP = (4*B)/(3*(D/t)) = (4*5.8358)/(3*778.0202) = 0.1 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	1406.00	4840.94	468.67	3.4431	0.0000366	3.52

EMAP = (4*B)/(3*(D/t)) = (4*3.5182)/(3*468.6667) = 0.1001 bars

Cylindrical Shell From Ring 8 to Ring 9 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	1406.00	1400.00	468.67	0.9957	0.0001320	12.67

EMAP = (4*B)/(3*(D/t)) = (4*12.6681)/(3*468.6667) = 0.3604 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
1.802	1406.00	1400.00	780.07	0.9957	0.0000610	5.85

EMAP = (4*B)/(3*(D/t)) = (4*5.8512)/(3*780.0737) = 0.1 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	1406.00	4840.92	468.67	3.4430	0.0000366	3.52

EMAP = (4*B)/(3*(D/t)) = (4*3.5182)/(3*468.6667) = 0.1001 bars

Cylindrical Shell From Ring 9 to 60 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	1406.00	1587.00	468.67	1.1287	0.0001160	11.14

EMAP = (4*B)/(3*(D/t)) = (4*11.1366)/(3*468.6667) = 0.3168 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
1.890	1406.00	1587.00	743.79	1.1287	0.0000581	5.58

EMAP = (4*B)/(3*(D/t)) = (4*5.5789)/(3*743.7935) = 0.1 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	1406.00	4841.33	468.67	3.4433	0.0000366	3.52

EMAP = (4*B)/(3*(D/t)) = (4*3.5179)/(3*468.6667) = 0.1001 bars

Cone From Ring 18 to Ring 23 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
2.990	1735.86	1809.08	580.58	1.0422	0.0000905	8.69

EMAP = (4*B)/(3*(D/t)) = (4*8.6927)/(3*580.5842) = 0.1996 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
2.263	1735.86	1809.08	766.90	1.0422	0.0000599	5.75

EMAP = (4*B)/(3*(D/t)) = (4*5.7522)/(3*766.8951) = 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 23 to 70 Ext. Chart: HA-2 at 50 °C

Cylindrical Shell From 70 to Ring 10 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	1736.00	737.00	578.67	0.4245	0.0002306	22.14

EMAP = (4*B)/(3*(D/t)) = (4*22.1352)/(3*578.6667) = 0.51 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
1.566	1736.00	737.00	1108.46	0.4245	0.0000866	8.31

EMAP = (4*B)/(3*(D/t)) = (4*8.3142)/(3*1108.459) = 0.1 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	1736.00	3576.31	578.67	2.0601	0.0000452	4.34

EMAP = (4*B)/(3*(D/t)) = (4*4.3428)/(3*578.6667) = 0.1001 bars

Cone From Ring 24 to Ring 26 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
2.972	1736.06	1085.13	584.13	0.6251	0.0001514	14.53

EMAP = (4*B)/(3*(D/t)) = (4*14.5319)/(3*584.1302) = 0.3317 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
1.839	1736.06	1085.13	944.21	0.6251	0.0000738	7.08

EMAP = (4*B)/(3*(D/t)) = (4*7.0822)/(3*944.2127) = 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 26 to 90 Ext. Chart: HA-2 at 50 °C

Cylindrical Shell From 90 to Ring 12 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	1406.00	375.00	468.67	0.2667	0.0005280	50.69

EMAP = (4*B)/(3*(D/t)) = (4*50.6919)/(3*468.6667) = 1.4421 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
1.043	1406.00	375.00	1347.41	0.2667	0.0001053	10.11

EMAP = (4*B)/(3*(D/t)) = (4*10.1068)/(3*1347.4142) = 0.1 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	1406.00	4840.98	468.67	3.4431	0.0000366	3.52

EMAP = (4*B)/(3*(D/t)) = (4*3.5182)/(3*468.6667) = 0.1001 bars

Cylindrical Shell From Ring 12 to Ring 13] 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	1406.00	1370.00	468.67	0.9744	0.0001349	12.95

EMAP = (4*B)/(3*(D/t)) = (4*12.9498)/(3*468.6667) = 0.3684 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
1.788	1406.00	1370.00	786.31	0.9744	0.0000614	5.90

EMAP = (4*B)/(3*(D/t)) = (4*5.898)/(3*786.3148) = 0.1 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	1406.00	4840.85	468.67	3.4430	0.0000366	3.52

EMAP = (4*B)/(3*(D/t)) = (4*3.5183)/(3*468.6667) = 0.1001 bars

Cylindrical Shell From Ring 13] to 100 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	1406.00	1755.00	468.67	1.2482	0.0001046	10.04

EMAP = (4*B)/(3*(D/t)) = (4*10.0421)/(3*468.6667) = 0.2857 bars

Results for Required Thickness (Tca):

Tca	OD	SLEN	D/t	L/D	Factor A	B
1.967	1406.00	1755.00	714.69	1.2482	0.0000558	5.36

EMAP = (4*B)/(3*(D/t)) = (4*5.3608)/(3*714.6927) = 0.1 bars

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
3.000	1406.00	4841.66	468.67	3.4436	0.0000366	3.52

EMAP = (4*B)/(3*(D/t)) = (4*3.5177)/(3*468.6667) = 0.1001 bars

Cone From Ring 28 to Ring 22 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
2.981	1406.04	1679.26	471.64	1.1943	0.0001084	10.40

EMAP = (4*B)/(3*(D/t)) = (4*10.4036)/(3*471.6358) = 0.2941 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
1.933	1406.04	1679.26	727.44	1.1943	0.0000568	5.46

EMAP = (4*B)/(3*(D/t)) = (4*5.4564)/(3*727.4449) = 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 22 to the end: Ext. Chart: HA-2 at 50 °C

Stiffening Ring Calcs for : Ring:[1 of 1] , SA-240 316 , Bar Ring: 47 x 10 mm.

Effective Length of Shell: 69 mm.

	Area (cm²)	Distance (mm.)	Area*Dist

Shell:	2.066	1.5000	3.098
Ring :	4.700	26.5000	124.550
Total:	6.766		127.648

Centroid of Ring plus Shell: 19 mm.

	Inertia	Distance	A*Dist²
Shell:	0.015	17.3673	623.030
Ring :	8.652	-7.6327	273.815
Total:	8.667		896.845

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

Required Stress in Ring plus Shell Breq 3.10 N./mm²
Required Strain in Ring plus Shell Areq 0.0000323

Required Moment of Inertia, Ring plus Shell:
= (OD² * Slen(Tca + Aring/Slen)Areq)/10.9
= (1306.0²*2973.0002(3.0+4.7/2973.0002)0.000032)/10.9
= 5 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	3.03	Kgf/mm.
The Radial Shear Load	V	39.59	Kgf
The First Moment of the Area (Ring + Shell)	Q	3587.38	mm.³
Weld Shear Flow due to Rad. Shear Load	VQ/I	0.81	Kgf/mm.
The Weld Allowable Stress	0.55*S	73.59	N./mm²
Minimum Weld Leg Size Min(6mm, t, tw)	Wldmin	3.00	mm.
The Weld Allowable Load	2* WLeg*0.55*S	45.03	Kgf/mm.
The Combined Weld Load	SRSS of VQ/I and Pext*Slen	3.14	Kgf/mm.

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

Effective Length of Shell: 69 mm.

	Area (cm²)	Distance (mm.)	Area*Dist
Shell:	2.066	1.5000	3.098
Ring :	4.700	26.5000	124.550
Total:	6.766		127.648

Centroid of Ring plus Shell: 19 mm.

	Inertia	Distance	A*Dist²
Shell:	0.015	17.3673	623.030
Ring :	8.652	-7.6327	273.815
Total:	8.667		896.845

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

Required Stress in Ring plus Shell Breq 3.03 N./mm²
Required Strain in Ring plus Shell Areq 0.0000315

Required Moment of Inertia, Ring plus Shell:
= (OD² * Slen(Tca + Aring/Slen)Areq)/10.9
= (1306.0²*1990.5(3.0+4.7/1990.5)0.000032)/10.9
= 3 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	2.03	Kgf/mm.	
The Radial Shear Load	V	26.51	Kgf	
The First Moment of the Area (Ring + Shell)	Q	3587.38	$mm.^3$	
Weld Shear Flow due to Rad. Shear Load	VQ/I	0.54	Kgf/mm.	
The Weld Allowable Stress	0.55*S	73.59	$N./mm^2$	
Minimum Weld Leg Size Min(6mm, t, tw)	Wldmin	3.00	mm.	
The Weld Allowable Load 2*	WLeg*0.55*S	45.03	Kgf/mm.	
The Combined Weld Load SRSS of VQ/I and Pext*Slen		2.10	Kgf/mm.	

Stiffening Ring Calcs for : Ring:[3 of 3] , SA-240 316 , Bar Ring: 47 x 10 mm.

Effective Length of Shell: 69 mm.

	Area (cm^2)	Distance (mm.)	Area*Dist
Shell:	2.066	1.5000	3.098
Ring :	4.700	26.5000	124.550
Total:	6.766		127.648

Centroid of Ring plus Shell: 19 mm.

	Inertia	Distance	A*Dist²
Shell:	0.015	17.3673	623.030
Ring :	8.652	-7.6327	273.815
Total:	8.667		896.845

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

Required Stress in Ring plus Shell Breq 2.82 $N./mm^2$
Required Strain in Ring plus Shell Areq 0.0000294

Required Moment of Inertia, Ring plus Shell:

= (OD² * Slen(Tca + Aring/Slen)Areq)/10.9
= (1306.0²*1003.0(3.0+4.7/1003.0)0.000029)/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	1.02	Kgf/mm.
The Radial Shear Load	V	13.36	Kgf
The First Moment of the Area (Ring + Shell)	Q	3587.38	$mm.^3$
Weld Shear Flow due to Rad. Shear Load	VQ/I	0.27	Kgf/mm.
The Weld Allowable Stress	0.55*S	73.59	$N./mm^2$
Minimum Weld Leg Size Min(6mm, t, tw)	Wldmin	3.00	mm.
The Weld Allowable Load 2*	WLeg*0.55*S	45.03	Kgf/mm.
The Combined Weld Load SRSS of VQ/I and Pext*Slen		1.06	Kgf/mm.

Stiffening Ring Calcs for : Ring:[4 of 4] , SA-240 316 , Bar Ring: 47 x 10 mm.

Effective Length of Shell: 69 mm.

	Area (cm^2)	Distance (mm.)	Area*Dist
Shell:	2.066	1.5000	3.098
Ring :	4.700	26.5000	124.550
Total:	6.766		127.648

Centroid of Ring plus Shell: 19 mm.

	Inertia	Distance	A*Dist²

Shell:	0.015	17.3673	623.030
Ring :	8.652	-7.6327	273.815
Total:	8.667		896.845

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

Required Stress in Ring plus Shell Breq 0.87 N./mm²
Required Strain in Ring plus Shell Areq 0.0000090

Required Moment of Inertia, Ring plus Shell:
= (OD² * Slen(Tca + Aring/Slen)Areq)/10.9
= (1306.0²*56.5(3.0+4.7/56.5)0.000009)/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	0.06	Kgf/mm.
The Radial Shear Load	V	0.75	Kgf
The First Moment of the Area (Ring + Shell)	Q	3587.38	mm.³
Weld Shear Flow due to Rad. Shear Load	VQ/I	0.02	Kgf/mm.
The Weld Allowable Stress	0.55*S	73.59	N./mm²
Minimum Weld Leg Size Min(6mm, t, tw)	Wldmin	3.00	mm.
The Weld Allowable Load	2* WLeg*0.55*S	45.03	Kgf/mm.
The Combined Weld Load	SRSS of VQ/I and Pext*Slen	0.06	Kgf/mm.

<u>Stiffening Ring Calcs for : Ring 16 , SA-240 304 , Bar Ring: 97 x 10 mm.</u>

Effective Length of Shell: 69 mm.

	Area (cm²)	Distance (mm.)	Area*Dist
Shell:	2.066	1.5000	3.098
Ring :	9.700	51.5000	499.550
Total:	11.766		502.648

Centroid of Ring plus Shell: 43 mm.

	Inertia	Distance	A*Dist²
Shell:	0.015	41.2219	3509.954
Ring :	76.056	-8.7781	747.439
Total:	76.071		4257.393

Available Moment of Inertia, Ring plus Shell: 119 cm**4

Required Stress in Ring plus Shell Breq 2.75 N./mm²
Required Strain in Ring plus Shell Areq 0.0000286

Required Moment of Inertia, Ring plus Shell:
= (OD² * Slen(Tca + Aring/Slen)Areq)/10.9
= (1306.0²*1716.1235(3.0+9.7/1716.1235)0.000029)/10.9
= 3 cm**4

<u>Stiffening Ring Calcs for : Ring5 , SA-240 304 , Bar Ring: 47 x 10 mm.</u>

Effective Length of Shell: 79 mm.

	Area (cm²)	Distance (mm.)	Area*Dist
Shell:	2.381	1.5000	3.572
Ring :	4.700	26.5000	124.550
Total:	7.081		128.122

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

                 Inertia       Distance        A*Dist²
 --------------------------------------------------------
 Shell:            0.018        16.5926        655.656
 Ring :            8.652        -8.4075        332.221
 Total:            8.670                       987.878
 --------------------------------------------------------
 Available Moment of Inertia, Ring plus Shell:        19 cm**4

 Required Stress in Ring plus Shell      Breq        3.12 N./mm²
 Required Strain in Ring plus Shell      Areq   0.0000325
```

Required Moment of Inertia, Ring plus Shell:

```
  = ( OD² * Slen(Tca + Aring/Slen)Areq )/10.9
  = (1736.0²*400.0(3.0+4.7/400.0)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                   CONTINUOUS
 Location of Stiffening Ring                          EXTERNAL
 Radial Pressure Load                      Pext*Slen      0.41  Kgf/mm.
 The Radial Shear Load                             V      7.08  Kgf
 The First Moment of the Area ( Ring + Shell )     Q   3951.51  mm.³
 Weld Shear Flow due to Rad. Shear Load         VQ/I      0.15  Kgf/mm.
 The Weld Allowable Stress                    0.55*S     73.09  N./mm²
 Minimum Weld Leg Size Min( 6mm, t, tw )      Wldmin      3.00  mm.
 The Weld Allowable Load             2*   WLeg*0.55*S     44.72  Kgf/mm.
 The Combined Weld Load   SRSS of VQ/I and Pext*Slen      0.43  Kgf/mm.
```

Stiffening Ring Calcs for : Ring 21 , SA-240 304 , Bar Ring: 50 x 10 mm.

```
 Effective Length of Shell:                         79 mm.

                Area (cm²)   Distance (mm.)    Area*Dist
 --------------------------------------------------------
 Shell:            2.381         1.5000          3.572
 Ring :            5.000        28.0000        140.000
 Total:            7.381                       143.572
 --------------------------------------------------------
 Centroid of Ring plus Shell:                       19 mm.

                 Inertia       Distance        A*Dist²
 --------------------------------------------------------
 Shell:            0.018        17.9503        767.347
 Ring :           10.417        -8.5497        365.487
 Total:           10.434                      1132.833
 --------------------------------------------------------
 Available Moment of Inertia, Ring plus Shell:        22 cm**4

 Required Stress in Ring plus Shell      Breq        3.88 N./mm²
 Required Strain in Ring plus Shell      Areq   0.0000405
```

Required Moment of Inertia, Ring plus Shell:

```
  = ( OD² * Slen(Tca + Aring/Slen)Areq )/10.9
  = (1736.0²*1418.7195(3.0+5.0/1418.7195)0.00004)/10.9
  = 5 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      1.45  Kgf/mm.
```

```
 The Radial Shear Load                              V     25.12  Kgf
 The First Moment of the Area ( Ring + Shell )      Q   4274.85  mm.³
 Weld Shear Flow due to Rad. Shear Load          VQ/I      0.49  Kgf/mm.
 The Weld Allowable Stress                     0.55*S     73.09  N./mm²
 Minimum Weld Leg Size Min( 6mm, t, tw )       Wldmin      3.00  mm.
 The Weld Allowable Load            2*   WLeg*0.55*S     44.72  Kgf/mm.
 The Combined Weld Load   SRSS of VQ/I and Pext*Slen      1.53  Kgf/mm.
```

Stiffening Ring Calcs for : Ring:17 , SA-240 304 , Bar Ring: 47 x 10 mm.

Effective Length of Shell: 71 mm.

	Area (cm²)	Distance (mm.)	Area*Dist
Shell:	2.143	1.5000	3.215
Ring :	4.686	26.4300	123.851
Total:	6.829		127.066

Centroid of Ring plus Shell: 19 mm.

	Inertia	Distance	A*Dist²
Shell:	0.016	17.1057	627.176
Ring :	8.575	-7.8243	286.878
Total:	8.591		914.053

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

```
 Required Stress in Ring plus Shell      Breq        2.73 N./mm²
 Required Strain in Ring plus Shell      Areq   0.0000284
```

Required Moment of Inertia, Ring plus Shell:

```
  = ( OD² * Slen(Tca + Aring/Slen)Areq )/10.9
  = (1406.275²*543.0673(3.0+4.686/543.0673)0.000028)/10.9
  = 1 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      0.55  Kgf/mm.
 The Radial Shear Load                              V      7.79  Kgf
 The First Moment of the Area ( Ring + Shell )      Q   3666.48  mm.³
 Weld Shear Flow due to Rad. Shear Load          VQ/I      0.16  Kgf/mm.
 The Weld Allowable Stress                     0.55*S     73.09  N./mm²
 Minimum Weld Leg Size Min( 6mm, t, tw )       Wldmin      3.00  mm.
 The Weld Allowable Load            2*   WLeg*0.55*S     44.72  Kgf/mm.
 The Combined Weld Load   SRSS of VQ/I and Pext*Slen      0.58  Kgf/mm.
```

Stiffening Ring Calcs for : Ring 6 , SA-240 304 , Bar Ring: 47 x 10 mm.

Effective Length of Shell: 71 mm.

	Area (cm²)	Distance (mm.)	Area*Dist
Shell:	2.143	1.5000	3.215
Ring :	4.700	26.5000	124.550
Total:	6.843		127.765

Centroid of Ring plus Shell: 19 mm.

	Inertia	Distance	A*Dist²
Shell:	0.016	17.1703	631.861
Ring :	8.652	-7.8297	288.132

```
 Total:            8.668                          919.992
 --------------------------------------------------------
 Available Moment of Inertia, Ring plus Shell:         18 cm**4

 Required Stress in Ring plus Shell      Breq        0.87 N./mm²
 Required Strain in Ring plus Shell      Areq   0.0000091
```

Required Moment of Inertia, Ring plus Shell:

```
  = ( OD² * Slen(Tca + Aring/Slen)Areq )/10.9
  = (1406.0²*51.5(3.0+4.7/51.5)0.000009)/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      0.05  Kgf/mm.
 The Radial Shear Load                             V      0.74  Kgf
 The First Moment of the Area ( Ring + Shell )     Q   3679.97  mm.³
 Weld Shear Flow due to Rad. Shear Load         VQ/I      0.02  Kgf/mm.
 The Weld Allowable Stress                    0.55*S     73.09  N./mm²
 Minimum Weld Leg Size Min( 6mm, t, tw )      Wldmin      3.00  mm.
 The Weld Allowable Load            2*   WLeg*0.55*S     44.72  Kgf/mm.
 The Combined Weld Load   SRSS of VQ/I and Pext*Slen      0.05  Kgf/mm.
```

<u>Stiffening Ring Calcs for : Ring 7 , SA-240 304 , Bar Ring: 47 x 10 mm.</u>

```
 Effective Length of Shell:                               71 mm.

                Area (cm²)   Distance (mm.)    Area*Dist
 --------------------------------------------------------
 Shell:            2.143         1.5000            3.215
 Ring :            4.700        26.5000          124.550
 Total:            6.843                         127.765
 --------------------------------------------------------
 Centroid of Ring plus Shell:                             19 mm.

                 Inertia        Distance         A*Dist²
 --------------------------------------------------------
 Shell:            0.016        17.1703          631.861
 Ring :            8.652        -7.8297          288.132
 Total:            8.668                         919.992
 --------------------------------------------------------
 Available Moment of Inertia, Ring plus Shell:         18 cm**4

 Required Stress in Ring plus Shell      Breq        2.88 N./mm²
 Required Strain in Ring plus Shell      Areq   0.0000300
```

Required Moment of Inertia, Ring plus Shell:

```
  = ( OD² * Slen(Tca + Aring/Slen)Areq )/10.9
  = (1406.0²*711.5(3.0+4.7/711.5)0.00003)/10.9
  = 1 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      0.73  Kgf/mm.
 The Radial Shear Load                             V     10.20  Kgf
 The First Moment of the Area ( Ring + Shell )     Q   3679.97  mm.³
 Weld Shear Flow due to Rad. Shear Load         VQ/I      0.21  Kgf/mm.
 The Weld Allowable Stress                    0.55*S     73.09  N./mm²
 Minimum Weld Leg Size Min( 6mm, t, tw )      Wldmin      3.00  mm.
 The Weld Allowable Load            2*   WLeg*0.55*S     44.72  Kgf/mm.
 The Combined Weld Load   SRSS of VQ/I and Pext*Slen      0.76  Kgf/mm.
```

Stiffening Ring Calcs for : Ring 8 , SA-240 304 , Bar Ring: 47 x 10 mm.

Effective Length of Shell: 71 mm.

	Area (cm²)	Distance (mm.)	Area*Dist
Shell:	2.143	1.5000	3.215
Ring :	4.700	26.5000	124.550
Total:	6.843		127.765

Centroid of Ring plus Shell: 19 mm.

	Inertia	Distance	A*Dist²
Shell:	0.016	17.1703	631.861
Ring :	8.652	-7.8297	288.132
Total:	8.668		919.992

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

Required Stress in Ring plus Shell Breq 3.16 N./mm²
Required Strain in Ring plus Shell Areq 0.0000330

Required Moment of Inertia, Ring plus Shell:

= (OD² * Slen(Tca + Aring/Slen)Areq)/10.9
= (1406.0²*1405.0(3.0+4.7/1405.0)0.000033)/10.9
= 3 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	1.43	Kgf/mm.
The Radial Shear Load	V	20.14	Kgf
The First Moment of the Area (Ring + Shell)	Q	3679.97	mm.³
Weld Shear Flow due to Rad. Shear Load	VQ/I	0.41	Kgf/mm.
The Weld Allowable Stress	0.55*S	73.09	N./mm²
Minimum Weld Leg Size Min(6mm, t, tw)	Wldmin	3.00	mm.
The Weld Allowable Load	2* WLeg*0.55*S	44.72	Kgf/mm.
The Combined Weld Load	SRSS of VQ/I and Pext*Slen	1.49	Kgf/mm.

Stiffening Ring Calcs for : Ring 9 , SA-240 304 , Bar Ring: 47 x 10 mm.

Effective Length of Shell: 71 mm.

	Area (cm²)	Distance (mm.)	Area*Dist
Shell:	2.143	1.5000	3.215
Ring :	4.700	26.5000	124.550
Total:	6.843		127.765

Centroid of Ring plus Shell: 19 mm.

	Inertia	Distance	A*Dist²
Shell:	0.016	17.1703	631.861
Ring :	8.652	-7.8297	288.132
Total:	8.668		919.992

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

Required Stress in Ring plus Shell Breq 3.18 N./mm²
Required Strain in Ring plus Shell Areq 0.0000330

Required Moment of Inertia, Ring plus Shell:

```
= ( OD² * Slen(Tca + Aring/Slen)Areq )/10.9
= (1406.0²*1493.5001(3.0+4.7/1493.5001)0.000033)/10.9
= 3 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      1.52  Kgf/mm.
The Radial Shear Load                             V     21.41  Kgf
The First Moment of the Area ( Ring + Shell )     Q   3679.97  mm.³
Weld Shear Flow due to Rad. Shear Load         VQ/I      0.44  Kgf/mm.
The Weld Allowable Stress                    0.55*S     73.09  N./mm²
Minimum Weld Leg Size Min( 6mm, t, tw )      Wldmin      3.00  mm.
The Weld Allowable Load            2*   WLeg*0.55*S     44.72  Kgf/mm.
The Combined Weld Load   SRSS of VQ/I and Pext*Slen      1.59  Kgf/mm.
```

Stiffening Ring Calcs for : Ring 18 , SA-240 304 , Bar Ring: 47 x 10 mm.

Effective Length of Shell: 71 mm.

	Area (cm²)	Distance (mm.)	Area*Dist
Shell:	2.143	1.5000	3.215
Ring :	4.700	26.5000	124.550
Total:	6.843		127.765

Centroid of Ring plus Shell: 19 mm.

	Inertia	Distance	A*Dist²
Shell:	0.016	17.1703	631.861
Ring :	8.652	-7.8297	288.132
Total:	8.668		919.992

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

```
Required Stress in Ring plus Shell      Breq       3.00 N./mm²
Required Strain in Ring plus Shell      Areq   0.0000312
```

Required Moment of Inertia, Ring plus Shell:

```
= ( OD² * Slen(Tca + Aring/Slen)Areq )/10.9
= (1406.0²*905.0399(3.0+4.7/905.0399)0.000031)/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      0.92  Kgf/mm.
The Radial Shear Load                             V     12.98  Kgf
The First Moment of the Area ( Ring + Shell )     Q   3679.97  mm.³
Weld Shear Flow due to Rad. Shear Load         VQ/I      0.27  Kgf/mm.
The Weld Allowable Stress                    0.55*S     73.09  N./mm²
Minimum Weld Leg Size Min( 6mm, t, tw )      Wldmin      3.00  mm.
The Weld Allowable Load            2*   WLeg*0.55*S     44.72  Kgf/mm.
The Combined Weld Load   SRSS of VQ/I and Pext*Slen      0.96  Kgf/mm.
```

Stiffening Ring Calcs for : Ring 23 , SA-240 304 , Bar Ring: 47 x 10 mm.

Effective Length of Shell: 79 mm.

	Area (cm²)	Distance (mm.)	Area*Dist

Shell:	2.381	1.5000	3.572
Ring :	4.700	26.5000	124.550
Total:	7.081		128.122

Centroid of Ring plus Shell: 18 mm.

	Inertia	Distance	A*Dist²
Shell:	0.018	16.5928	655.646
Ring :	8.652	-8.4072	332.200
Total:	8.670		987.847

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

Required Stress in Ring plus Shell Breq 3.70 N./mm²
Required Strain in Ring plus Shell Areq 0.0000385

Required Moment of Inertia, Ring plus Shell:
= (OD² * Slen(Tca + Aring/Slen)Areq)/10.9
= (1735.8351²*905.0399(3.0+4.7/905.0399)0.000039)/10.9
= 3 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	0.92	Kgf/mm.
The Radial Shear Load	V	16.02	Kgf
The First Moment of the Area (Ring + Shell)	Q	3951.38	mm.³
Weld Shear Flow due to Rad. Shear Load	VQ/I	0.34	Kgf/mm.
The Weld Allowable Stress	0.55*S	73.09	N./mm²
Minimum Weld Leg Size Min(6mm, t, tw)	Wldmin	3.00	mm.
The Weld Allowable Load	2* WLeg*0.55*S	44.72	Kgf/mm.
The Combined Weld Load	SRSS of VQ/I and Pext*Slen	0.98	Kgf/mm.

Stiffening Ring Calcs for : Ring 10 , SA-240 304 , Bar Ring: 47 x 10 mm.

Effective Length of Shell: 79 mm.

	Area (cm²)	Distance (mm.)	Area*Dist
Shell:	2.381	1.5000	3.572
Ring :	4.700	26.5000	124.550
Total:	7.081		128.122

Centroid of Ring plus Shell: 18 mm.

	Inertia	Distance	A*Dist²
Shell:	0.018	16.5926	655.656
Ring :	8.652	-8.4075	332.221
Total:	8.670		987.878

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

Required Stress in Ring plus Shell Breq 3.06 N./mm²
Required Strain in Ring plus Shell Areq 0.0000320

Required Moment of Inertia, Ring plus Shell:
= (OD² * Slen(Tca + Aring/Slen)Areq)/10.9
= (1736.0²*375.0(3.0+4.7/375.0)0.000032)/10.9
= 1 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      0.38  Kgf/mm.
The Radial Shear Load                              V      6.64  Kgf
The First Moment of the Area ( Ring + Shell )      Q   3951.51  mm.³
Weld Shear Flow due to Rad. Shear Load          VQ/I      0.14  Kgf/mm.
The Weld Allowable Stress                     0.55*S     73.09  N./mm²
Minimum Weld Leg Size Min( 6mm, t, tw )       Wldmin      3.00  mm.
The Weld Allowable Load           2*   WLeg*0.55*S     44.72  Kgf/mm.
The Combined Weld Load   SRSS of VQ/I and Pext*Slen      0.41  Kgf/mm.
```

Stiffening Ring Calcs for : Ring 11 , SA-240 304 , Bar Ring: 47 x 10 mm.

Effective Length of Shell: 79 mm.

	Area (cm²)	Distance (mm.)	Area*Dist
Shell:	2.381	1.5000	3.572
Ring :	4.700	26.5000	124.550
Total:	7.081		128.122

Centroid of Ring plus Shell: 18 mm.

	Inertia	Distance	A*Dist²
Shell:	0.018	16.5926	655.656
Ring :	8.652	-8.4075	332.221
Total:	8.670		987.878

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

```
Required Stress in Ring plus Shell      Breq        0.73 N./mm²
Required Strain in Ring plus Shell      Areq   0.0000076
```

Required Moment of Inertia, Ring plus Shell:

```
= ( OD² * Slen(Tca + Aring/Slen)Areq )/10.9
= (1736.0²*31.5(3.0+4.7/31.5)0.000008)/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      0.56  Kgf
The First Moment of the Area ( Ring + Shell )      Q   3951.51  mm.³
Weld Shear Flow due to Rad. Shear Load          VQ/I      0.01  Kgf/mm.
The Weld Allowable Stress                     0.55*S     73.09  N./mm²
Minimum Weld Leg Size Min( 6mm, t, tw )       Wldmin      3.00  mm.
The Weld Allowable Load           2*   WLeg*0.55*S     44.72  Kgf/mm.
The Combined Weld Load   SRSS of VQ/I and Pext*Slen      0.03  Kgf/mm.
```

Stiffening Ring Calcs for : Ring 24 , SA-240 304 , Bar Ring: 47 x 10 mm.

Effective Length of Shell: 79 mm.

	Area (cm²)	Distance (mm.)	Area*Dist
Shell:	2.381	1.5000	3.572
Ring :	4.684	26.4175	123.727
Total:	7.065		127.299

Centroid of Ring plus Shell: 18 mm.

	Inertia	Distance	A*Dist²

	Inertia	Distance	A*Dist²
Shell:	0.018	16.5182	649.795
Ring :	8.561	-8.3993	330.411
Total:	8.579		980.207

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
= (1736.0²*543.0673(3.0+4.6835/543.0673)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	0.55	Kgf/mm.
The Radial Shear Load	V	9.61	Kgf
The First Moment of the Area (Ring + Shell)	Q	3933.81	mm.³
Weld Shear Flow due to Rad. Shear Load	VQ/I	0.21	Kgf/mm.
The Weld Allowable Stress	0.55*S	73.09	N./mm²
Minimum Weld Leg Size Min(6mm, t, tw)	Wldmin	3.00	mm.
The Weld Allowable Load	2* WLeg*0.55*S	44.72	Kgf/mm.
The Combined Weld Load	SRSS of VQ/I and Pext*Slen	0.59	Kgf/mm.

Stiffening Ring Calcs for : Ring 26 , SA-240 304 , Bar Ring: 47 x 10 mm.

Effective Length of Shell: 71 mm.

	Area (cm²)	Distance (mm.)	Area*Dist
Shell:	2.143	1.5000	3.215
Ring :	4.683	26.4150	123.701
Total:	6.826		126.916

Centroid of Ring plus Shell: 19 mm.

	Inertia	Distance	A*Dist²
Shell:	0.016	17.0919	626.168
Ring :	8.558	-7.8231	286.600
Total:	8.574		912.769

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

Required Stress in Ring plus Shell Breq 2.73 N./mm²
Required Strain in Ring plus Shell Areq 0.0000284

Required Moment of Inertia, Ring plus Shell:
= (OD² * Slen(Tca + Aring/Slen)Areq)/10.9
= (1406.275²*543.0673(3.0+4.683/543.0673)0.000028)/10.9
= 1 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	0.55	Kgf/mm.
The Radial Shear Load	V	7.79	Kgf
The First Moment of the Area (Ring + Shell)	Q	3663.53	mm.³
Weld Shear Flow due to Rad. Shear Load	VQ/I	0.16	Kgf/mm.
The Weld Allowable Stress	0.55*S	73.09	N./mm²

```
 Minimum Weld Leg Size Min( 6mm, t, tw )      Wldmin      3.00  mm.
 The Weld Allowable Load            2*   WLeg*0.55*S     44.72  Kgf/mm.
 The Combined Weld Load   SRSS of VQ/I and Pext*Slen      0.58  Kgf/mm.
```

Stiffening Ring Calcs for : Ring 12 , SA-240 304 , Bar Ring: 47 x 10 mm.

```
 Effective Length of Shell:                                71 mm.

                Area (cm²)   Distance (mm.)    Area*Dist
 --------------------------------------------------------
 Shell:            2.143         1.5000           3.215
 Ring :            4.700        26.5000         124.550
 Total:            6.843                        127.765
 --------------------------------------------------------
 Centroid of Ring plus Shell:                              19 mm.

                 Inertia        Distance         A*Dist²
 --------------------------------------------------------
 Shell:            0.016        17.1703         631.861
 Ring :            8.652        -7.8297         288.132
 Total:            8.668                        919.992
 --------------------------------------------------------
 Available Moment of Inertia, Ring plus Shell:         18 cm**4

 Required Stress in Ring plus Shell      Breq        2.98 N./mm²
 Required Strain in Ring plus Shell      Areq   0.0000310
```

Required Moment of Inertia, Ring plus Shell:

```
  = ( OD² * Slen(Tca + Aring/Slen)Areq )/10.9
  = (1406.0²*872.5(3.0+4.7/872.5)0.000031)/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      0.89  Kgf/mm.
 The Radial Shear Load                            V     12.51  Kgf
 The First Moment of the Area ( Ring + Shell )    Q   3679.97  mm.³
 Weld Shear Flow due to Rad. Shear Load        VQ/I      0.26  Kgf/mm.
 The Weld Allowable Stress                   0.55*S     73.09  N./mm²
 Minimum Weld Leg Size Min( 6mm, t, tw )      Wldmin      3.00  mm.
 The Weld Allowable Load            2*   WLeg*0.55*S     44.72  Kgf/mm.
 The Combined Weld Load   SRSS of VQ/I and Pext*Slen      0.93  Kgf/mm.
```

Stiffening Ring Calcs for : Ring 13] , SA-240 304 , Bar Ring: 47 x 10 mm.

```
 Effective Length of Shell:                                71 mm.

                Area (cm²)   Distance (mm.)    Area*Dist
 --------------------------------------------------------
 Shell:            2.143         1.5000           3.215
 Ring :            4.700        26.5000         124.550
 Total:            6.843                        127.765
 --------------------------------------------------------
 Centroid of Ring plus Shell:                              19 mm.

                 Inertia        Distance         A*Dist²
 --------------------------------------------------------
 Shell:            0.016        17.1703         631.861
 Ring :            8.652        -7.8297         288.132
 Total:            8.668                        919.992
 --------------------------------------------------------
 Available Moment of Inertia, Ring plus Shell:         18 cm**4
```

```
 Required Stress in Ring plus Shell      Breq        3.19 N./mm²
 Required Strain in Ring plus Shell      Areq   0.0000333
```

Required Moment of Inertia, Ring plus Shell:

```
  = ( OD² * Slen(Tca + Aring/Slen)Areq )/10.9
  = (1406.0²*1562.5(3.0+4.7/1562.5)0.000033)/10.9
  = 3 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      1.59  Kgf/mm.
 The Radial Shear Load                             V     22.40  Kgf
 The First Moment of the Area ( Ring + Shell )     Q   3679.97  mm.³
 Weld Shear Flow due to Rad. Shear Load         VQ/I      0.46  Kgf/mm.
 The Weld Allowable Stress                    0.55*S     73.09  N./mm²
 Minimum Weld Leg Size Min( 6mm, t, tw )      Wldmin      3.00  mm.
 The Weld Allowable Load            2*   WLeg*0.55*S     44.72  Kgf/mm.
 The Combined Weld Load   SRSS of VQ/I and Pext*Slen      1.66  Kgf/mm.
```

<u>Stiffening Ring Calcs for : Ring 28 , SA-240 304 , Bar Ring: 50 x 10 mm.</u>

```
 Effective Length of Shell:                               71 mm.

                Area (cm²)   Distance (mm.)    Area*Dist
 --------------------------------------------------------
 Shell:            2.143         1.5000            3.215
 Ring :            5.042        28.2100          142.235
 Total:            7.185                         145.450
 --------------------------------------------------------
 Centroid of Ring plus Shell:                             20 mm.

                 Inertia        Distance         A*Dist²
 --------------------------------------------------------
 Shell:            0.016        18.7429          752.904
 Ring :           10.681        -7.9671          320.040
 Total:           10.697                        1072.945
 --------------------------------------------------------
 Available Moment of Inertia, Ring plus Shell:         21 cm**4

 Required Stress in Ring plus Shell      Breq        2.93 N./mm²
 Required Strain in Ring plus Shell      Areq   0.0000305
```

Required Moment of Inertia, Ring plus Shell:

```
  = ( OD² * Slen(Tca + Aring/Slen)Areq )/10.9
  = (1406.0²*840.1315(3.0+5.042/840.1315)0.000031)/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      0.86  Kgf/mm.
 The Radial Shear Load                             V     12.05  Kgf
 The First Moment of the Area ( Ring + Shell )     Q   4017.02  mm.³
 Weld Shear Flow due to Rad. Shear Load         VQ/I      0.23  Kgf/mm.
 The Weld Allowable Stress                    0.55*S     73.09  N./mm²
 Minimum Weld Leg Size Min( 6mm, t, tw )      Wldmin      3.00  mm.
 The Weld Allowable Load            2*   WLeg*0.55*S     44.72  Kgf/mm.
 The Combined Weld Load   SRSS of VQ/I and Pext*Slen      0.89  Kgf/mm.
```

<u>Stiffening Ring Calcs for : Ring 22 , SA-240 304 , Bar Ring: 50 x 10 mm.</u>

```
 Effective Length of Shell:                               59 mm.
```

	Area (cm^2)	Distance (mm.)	Area*Dist
Shell:	1.767	1.5000	2.651
Ring :	5.042	28.2113	142.248
Total:	6.810		144.899

Centroid of Ring plus Shell: 21 mm.

	Inertia	Distance	A*Dist²
Shell:	0.013	19.7783	691.404
Ring :	10.683	-6.9330	242.361
Total:	10.696		933.765

Available Moment of Inertia, Ring plus Shell: 20 cm**4

Required Stress in Ring plus Shell Breq 1.99 N./mm²
Required Strain in Ring plus Shell Areq 0.0000208

Required Moment of Inertia, Ring plus Shell:

= (OD² * Slen(Tca + Aring/Slen)Areq)/10.9
= (956.225²*840.1315(3.0+5.0423/840.1315)0.000021)/10.9
= 1 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	0.86	Kgf/mm.
The Radial Shear Load	V	8.19	Kgf
The First Moment of the Area (Ring + Shell)	Q	3495.77	mm.³
Weld Shear Flow due to Rad. Shear Load	VQ/I	0.14	Kgf/mm.
The Weld Allowable Stress	0.55*S	73.09	N./mm²
Minimum Weld Leg Size Min(6mm, t, tw)	Wldmin	3.00	mm.
The Weld Allowable Load	2* WLeg*0.55*S	44.72	Kgf/mm.
The Combined Weld Load	SRSS of VQ/I and Pext*Slen	0.87	Kgf/mm.

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

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	793.769	10689519	793.769	10689519	...
20	30	231.016	3630184	231.016	3630184	...
30	40	104.889	1880831	104.889	1880831	...
40	50	143.693	2317308	143.693	2317308	...
50	60	477.657	6928454	477.657	6928454	...
60	70	238.06	3862180	238.06	3862180	...
70	80	104.889	1880831	104.889	1880831	...
80	90	143.693	2317308	143.693	2317308	...
90	100	371.509	5388796	371.509	5388796	...
100	110	179.371	2195581	179.371	2195581	...
Total		2788	41090996.00	2788	41090996.00	0

Weight of Details:

From	Type	Weight of Detail kg.	X Offset, Dtl. Cent. mm.	Y Offset, Dtl. Cent. mm.	Description
10	Ring	16.0367	...	3958	Ring:[1 of 1]
10	Ring	16.0367	...	5946	Ring:[2 of 2]
10	Ring	16.0367	...	7939	Ring:[3 of 3]
10	Ring	16.0367	...	7952	Ring:[4 of 4]
20	Ring	34.3201	...	...	Ring 16
30	Ring	21.1334	...	...	Ring5
40	Ring	17.1723	...	1199	Ring:17
40	Ring	22.5201	...	...	Ring 21
50	Ring	17.222	...	90	Ring 6
50	Ring	17.222	...	103	Ring 7
50	Ring	17.222	...	1513	Ring 8
50	Ring	17.222	...	2913	Ring 9
60	Ring	17.222	...	...	Ring 18
60	Ring	21.1315	...	1999	Ring 23
70	Ring	21.1334	...	737	Ring 10
70	Ring	21.1334	...	750	Ring 11
80	Ring	21.0573	...	...	Ring 24
80	Ring	17.161	...	1199	Ring 26
90	Ring	17.222	...	375	Ring 12
90	Ring	17.222	...	1745	Ring 13]
100	Ring	12.8003	...	1999	Ring 22
100	Ring	18.5186	...	...	Ring 28

Total Weight of Each Detail Type:

Stiffeners	412.8
Sum of the Detail Weights	412.8 kg.

Weight Summation Results: (kg.)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	2788.5	2788.5	2788.5	2788.5	2788.5	2788.5
Stif. Rings	412.8	412.8	412.8	412.8	412.8	412.8
Test Liquid	...	41065.9	...	...	...	...
Totals	3201.3	44267.2	3201.3	3201.3	3201.3	3201.3

Weight Summary:

Fabricated Wt.	- Bare Weight without Removable Internals	3201.3 kg.
Shop Test Wt.	- Fabricated Weight + Water (Full)	44267.2 kg.
Shipping Wt.	- Fab. Weight + removable Intls.+ Shipping App.	3201.3 kg.
Erected Wt.	- Fab. Wt + or - loose items (trays,platforms etc.)	3201.3 kg.
Ope. Wt. no Liq	- Fab. Weight + Internals. + Details + Weights	3201.3 kg.
Operating Wt.	- Empty Weight + Operating Liq. Uncorroded	3201.3 kg.
Field Test Wt.	- Empty Weight + Water (Full)	44267.2 kg.
Mass of the Upper 1/3 of the Vertical Vessel		1107.8 kg.

Outside Surface Areas of Elements:

From	To	Surface Area cm²
10	20	330367
20	30	96120.1
30	40	43630.4
40	50	59784.7
50	60	198769
60	70	99045.5
70	80	43630.4
80	90	59784.7
90	100	154598
100	110	74674.9

Total 1160404.250 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	857.916	857.916	857.916	...	857.916
20	30	265.336	265.336	265.336	...	265.336
30	40	126.022	126.022	126.022	...	126.022
40	50	183.386	183.386	183.386	...	183.386
50	60	546.545	546.545	546.545	...	546.545
60	70	276.413	276.413	276.413	...	276.413
70	80	147.156	147.156	147.156	...	147.156
80	90	181.912	181.912	181.912	...	181.912
90	100	405.953	405.953	405.953	...	405.953
100	110	210.689	210.689	210.689	...	210.689

Cumulative Vessel Weight

From	To	Cumulative Ope Wgt. No Liquid kg.	Cumulative Oper. Wgt. kg.	Cumulative Hydro. Wgt. kg.
10	20	3201.33	3201.33	3201.33
20	30	2343.41	2343.41	2343.41
30	40	2078.08	2078.08	2078.08
40	50	1952.05	1952.05	1952.05
50	60	1768.67	1768.67	1768.67
60	70	1222.12	1222.12	1222.12
70	80	945.71	945.71	945.71
80	90	798.554	798.554	798.554
90	100	616.643	616.643	616.643
100	110	210.689	210.689	210.689

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	...	...	...
100	110	...	...	...

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

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    12.7573  mm.
Maximum Centroid Reinforcement Distance Small End    11.0651  mm.
```

<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      0.00048
Large end max. half apex angle w/o reinforcement      11.000  degrees
Large end actual half apex angle                       6.136  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       0.187  degrees
Large end actual half apex angle                       6.136  degrees
```

Intermediate Value [k]:

```
= max( Y / ( Srl * Erl ), 1 )
= max( 0.25813E+11/( 132.9 * 0.19291E+09 ), 1 )
= 1.0068
```

where [Y] is:

```
= Large End All. Stress * Large End Elastic Modulus (Ext. temp.)
= 133.8 * 0.19291E+09
= 25812725760.0 N./mm²^2
```

```
Allowable Stress of Large End Material (Ext. Temp)   133.8  N./mm²
Allowable Stress of Cone Material (Ext. Temp)        133.8  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)
= (1.0068*0.4426*868.0*0.107/(134*1.0))*
  (1-1/4((0.1*868.0-0.443)/0.443)*(0.187/6.136)
= 0.0302 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( 868.0/2 ) + 0.0/(pi(1736.0 - 3.0)) +
  0.0/(pi(868.0 - 3.0/2)(868.0 - 3.0/2))
= 0.443 Kgf/mm.
```

Available Area of Reinforcement, Large End, External [Ael]:
```
= 0.55*( Dl*ts )½ * ( ts + tc/cos(alpha) )
= 0.55 * ( 1736.0 * 3.0 )½ * ( 3.0 + 3.0/0.994 )
= 2.3884 cm²
```

Summary of Reinforcement Area, Large End, External Pressure:

Area of reinforcement required per App. 1-8(1)	0.0302	cm²
Area of reinforcement in shell per App. 1-8(2)	2.3884	cm²
Area of reinforcement in stiffening ring	4.7000	cm²

Intermediate Results, Large End, External Pressure:

Area Available in Cone, Shell, and Reinforcement	46.87	cm²
Force per Unit Length on Shell / Cone Junction	1.55	Kgf/mm.
Actual Buckling Stress associated with this Force	4.23	N./mm²
Material Strain associated with this stress	0.000044	

Required Moment of Inertia, Large End, External Pressure [I's]:
```
= A * Dl² * Atl / 10.9
= 0.438E-04 * 1736.0 * 1736.0 * 46.87/10.9
= 56786.08 mm.⁴
```

Available Moment of Inertia, Large End, External Pressure:

	Area	Centroid	Ar*Ce	Dist	I	Ar*Di²
Shl	1.191	0.0000	0.000	16.2161	0.009	313.119
Con	1.198	-2.1334	-2.555	18.3495	0.027	403.238
Sec	4.700	25.0000	117.500	-8.7840	8.652	362.643
TOT	7.088		114.945		8.688	1079.001
Centroid of Section			16.2161	Moment of Inertia		19.48

Summary of Large End Inertia Calculations

Available Moment of Inertia (Large End)	19.478	cm**4
Required Moment of Inertia (Large End)	5.679	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	0.00048	
Small end max. half apex angle w/o reinforcement	4.000	degrees
Small end actual half apex angle	6.136	degrees

Intermediate Value [k]:
```
= max( Y / ( Sr * Ers ), 1 )
= max( 0.19226E+11/( 100.3 * 0.18458E+09 ), 1 )
= 1.0386
```

where [Y] is:
```
= Cone Allowable Stress * Cone Elastic Modulus (Int. temp.)
= 104.2 * 0.18458E+09
= 19225886720.0 N./mm²^2
```

Decay Length, Cone Small End:
```
= 1.4 * sqrt( Rs( ts - ca ) )
= 1.4 * sqrt( 650.0( 3.0 - 0.0 ) )
= 61.822 mm.
```

Required Area of Reinforcement, Small End, Internal [Ars]:
```
= k*QS*Rs/(Ss*E1)*(1-delta/alpha)*tan(alpha)
= 1.04 * 1.6571 * 650.0/( 104 * 1.0 ) *
```

```
    ( 1 - 4.0/6.14 ) 0.1075
  = 0.0394 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( 650.0/2 ) - 0.0/(pi(1300.0 + 3.0)) +
    0.0/(pi(650.0 + 3.0/2)(650.0 + 3.0/2))
  = 1.657 Kgf/mm.
```

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

```
  = 0.78(Rs*Ts)½*((Ts-t)+(Tc-Tr)/cos(alpha) ))
  = 0.78(650.0*3.0)½*(( 3.0- 0.312 )+( 3.0- 0.314 )/0.99)
  = 1.8563 cm²
```

Summary of Reinforcement Area, Small End, Internal Pressure:

Area of reinforcement required per App. 1-5(3)	0.0394	cm²
Area of reinforcement in shell per App. 1-5(4)	1.8563	cm²
Area of reinforcement in stiffening ring	9.7000	cm²

Required Area of Reinforcement for Small End Under External Pressure

Allowable Stress of Small End Material (Ext. Temp)	133.8	N./mm²
Allowable Stress of Cone Material (Ext. Temp)	133.8	N./mm²

Intermediate Value [k]:

```
  = max( Y / ( Srs * Ers ), 1 )
  = max( 0.25813E+11/( 132.9 * 0.19291E+09 ), 1 )
  = 1.0068
```

where [Y] is:

```
    = Cone Allowable Stress * Cone Elastic Modulus (Ext. temp.)
    = 133.8 * 0.19291E+09
    = 25812725760.0 N./mm²^2
```

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

```
  = k * QS * Rs * tan(alpha) / ( Ss * E1 )
  = (1.0068*0.333*653.0*0.1075/(134*1.0))
  = 0.0172 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( 653.0/2 ) + 0.0/(pi(1306.0 - 3.0)) +
    0.0/(pi(653.0 - 3.0/2)(653.0 - 3.0/2))
  = 0.333 Kgf/mm.
```

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

```
  = 0.55*(Ds*ts)½*[(ts-t)+(tc-tr)/cos(alpha))]
  = 0.55*(1306.0*3.0)½*[(3.0-0.573)+(3.0-1.893)/0.994]
  = 1.2188 cm²
```

Summary of Reinforcement Area, Small End, External Pressure:

Area of reinforcement required per App. 1-8(3)	0.0172	cm²
Area of reinforcement in shell per App. 1-8(4)	1.2188	cm²
Area of reinforcement in stiffening ring	9.7000	cm²

Intermediate Results, Small End, External Pressure:

Area Available in Cone, Shell, and Reinforcement	41.37	cm²
Force per Unit Length on Shell / Cone Junction	0.88	Kgf/mm.
Actual Buckling Stress associated with this Force	2.04	N./mm²
Material Strain associated with this stress	0.000021	

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

```
  = A * Ds² * Ats / 10.9
  = 0.211E-04 * 1306.0 * 1306.0 * 41.37/10.9
  = 13689.88 mm.⁴
```

Available Moment of Inertia, Small End, External Pressure:

	Area	Centroid	Ar*Ce	Dist	I	Ar*Di²
Shl	1.033	0.0000	0.000	41.3643	0.008	1767.127
Con	1.039	1.8504	1.922	39.5139	0.020	1621.850
Sec	9.700	50.0000	485.000	-8.6357	76.056	723.377
TOT	11.772		486.922		76.083	4112.354
Centroid of Section			41.3643	Moment of Inertia		117.21

Summary of Small End Inertia Calculations

Available Moment of Inertia (Small End)	0.1172E+03	cm**4
Required Moment of Inertia (Small End)	0.1369E+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	15.45	312.47	Small Cyl. Long.
Compres. Stress	-4.60	-312.47	Small Cyl. Long.
Membrane Stress	16.38	-156.24	Small End Tang.
Tensile Stress	15.49	312.47	Cone Longitudinal
Compres. Stress	-4.56	-312.47	Cone Longitudinal
Compres Stress	16.44	-156.24	Cone Tangential
Tensile Stress	22.60	312.47	Large Cyl. Long.
Compres. Stress	-8.16	-312.47	Large Cyl. Long.
Membrane Stress	5.98	-156.24	Large End Tang.
Tensile Stress	22.64	312.47	Cone Longitudinal
Compres. Stress	-8.11	-312.47	Cone Longitudinal
Compres Stress	6.06	-156.24	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	3.584	Thickness due to internal pressure, Cone Large End
MAPnc	4.745	Thickness due to internal pressure, Cone Large End

These pressures were determined by iteration.

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

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

Conical Section From 40 To 50 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    12.7573  mm.
Maximum Centroid Reinforcement Distance Small End    11.4810  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      0.00048
Large end max. half apex angle w/o reinforcement      11.000  degrees
Large end actual half apex angle                       7.829  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       0.187  degrees
Large end actual half apex angle                       7.829  degrees
```

Intermediate Value [k]:

```
= max( Y / ( Srl * Erl ), 1 )
= max( 0.25813E+11/( 132.9 * 0.19291E+09 ), 1 )
= 1.0068
```

where [Y] is:

```
= Cone Allowable Stress * Cone Elastic Modulus (Ext. temp.)
= 133.8 * 0.19291E+09
= 25812725760.0 N./mm²^2

Allowable Stress of Large End Material (Ext. Temp)   133.8  N./mm²
Allowable Stress of Cone Material (Ext. Temp)        133.8  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)
= (1.0068*0.4426*868.0*0.138/(134*1.0))*
  (1-1/4((0.1*868.0-0.443)/0.443)*(0.187/7.829)
= 0.0387 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( 868.0/2 ) + 0.0/(pi(1736.0 - 3.0)) +
  0.0/(pi(868.0 - 3.0/2)(868.0 - 3.0/2))
= 0.443 Kgf/mm.
```

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

```
= 0.55*( Dl*ts )½ * ( ts + tc/cos(alpha) )
= 0.55 * ( 1736.0 * 3.0 )½ * ( 3.0 + 3.0/0.991 )
= 2.3927 cm²
```

Summary of Reinforcement Area, Large End, External Pressure:

Area of reinforcement required per App. 1-8(1)	0.0387	cm²
Area of reinforcement in shell per App. 1-8(2)	2.3927	cm²
Area of reinforcement in stiffening ring	5.0000	cm²

Intermediate Results, Large End, External Pressure:

Area Available in Cone, Shell, and Reinforcement	35.17	cm²
Force per Unit Length on Shell / Cone Junction	1.09	Kgf/mm.
Actual Buckling Stress associated with this Force	3.94	N./mm²
Material Strain associated with this stress	0.000041	

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

```
= A * Dl² * Atl / 10.9
= 0.408E-04 * 1736.0 * 1736.0 * 35.17/10.9
= 39720.57 mm.⁴
```

Available Moment of Inertia, Large End, External Pressure:

	Area	Centroid	Ar*Ce	Dist	I	Ar*Di²
Shl	1.191	0.0000	0.000	17.4794	0.009	363.808
Con	1.202	-2.7288	-3.280	20.2082	0.039	490.842
Sec	5.000	26.5000	132.500	-9.0206	10.417	406.853
TOT	7.393		129.220		10.465	1261.504
Centroid of Section			17.4794	Moment of Inertia		23.08

Summary of Large End Inertia Calculations

Available Moment of Inertia (Large End)	23.080	cm**4
Required Moment of Inertia (Large End)	3.972	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	0.00048	
Small end max. half apex angle w/o reinforcement	4.000	degrees
Small end actual half apex angle	7.829	degrees

Intermediate Value [k]:

```
= max( Y / ( Sr * Ers ), 1 )
= max( 0.19226E+11/( 100.3 * 0.18458E+09 ), 1 )
= 1.0386
```

where [Y] is:

```
= Cone Allowable Stress * Cone Elastic Modulus (Int. temp.)
= 104.2 * 0.18458E+09
= 19225886720.0 N./mm²^2
```

Decay Length, Cone Small End:

```
= 1.4 * sqrt( Rs( ts - ca ) )
= 1.4 * sqrt( 700.0( 3.0 - 0.0 ) )
= 64.156 mm.
```

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

```
= k*QS*Rs/(Ss*E1)*(1-delta/alpha)*tan(alpha)
= 1.04 * 1.7846 * 700.0/( 104 * 1.0 ) *
```

```
    ( 1 - 4.0/7.83 ) 0.1375
  = 0.0822 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( 700.0/2 ) - 0.0/(pi(1400.0 + 3.0)) +
    0.0/(pi(700.0 + 3.0/2)(700.0 + 3.0/2))
  = 1.785 Kgf/mm.
```

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

```
  = 0.78(Rs*Ts)½*((Ts-t)+(Tc-Tr)/cos(alpha) ))
  = 0.78(700.0*3.0)½*(( 3.0- 0.336 )+( 3.0- 0.339 )/0.99)
  = 1.9122 cm²
```

Summary of Reinforcement Area, Small End, Internal Pressure:

Area of reinforcement required per App. 1-5(3)	0.0822	cm²
Area of reinforcement in shell per App. 1-5(4)	1.9122	cm²
Area of reinforcement in stiffening ring	4.6860	cm²

Required Area of Reinforcement for Small End Under External Pressure

Allowable Stress of Small End Material (Ext. Temp)	133.8	N./mm²
Allowable Stress of Cone Material (Ext. Temp)	133.8	N./mm²

Intermediate Value [k]:

```
  = max( Y / ( Srs * Ers ), 1 )
  = max( 0.25813E+11/( 132.9 * 0.19291E+09 ), 1 )
  = 1.0068
```

where [Y] is:

```
   = Cone Allowable Stress * Cone Elastic Modulus (Ext. temp.)
   = 133.8 * 0.19291E+09
   = 25812725760.0 N./mm²^2
```

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

```
  = k * QS * Rs * tan(alpha) / ( Ss * E1 )
  = (1.0068*0.3584*703.0*0.1375/(134*1.0))
  = 0.0256 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( 703.0/2 ) + 0.0/(pi(1406.0 - 3.0)) +
    0.0/(pi(703.0 - 3.0/2)(703.0 - 3.0/2))
  = 0.358 Kgf/mm.
```

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

```
  = 0.55*(Ds*ts)½*[(ts-t)+(tc-tr)/cos(alpha))]
  = 0.55*(1406.0*3.0)½*[(3.0-0.57)+(3.0-0.514)/0.991]
  = 1.7647 cm²
```

Summary of Reinforcement Area, Small End, External Pressure:

Area of reinforcement required per App. 1-8(3)	0.0256	cm²
Area of reinforcement in shell per App. 1-8(4)	1.7647	cm²
Area of reinforcement in stiffening ring	4.6860	cm²

Intermediate Results, Small End, External Pressure:

Area Available in Cone, Shell, and Reinforcement	24.21	cm²
Force per Unit Length on Shell / Cone Junction	0.55	Kgf/mm.
Actual Buckling Stress associated with this Force	2.35	N./mm²
Material Strain associated with this stress	0.000024	

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

```
  = A * Ds² * Ats / 10.9
  = 0.244E-04 * 1406.0 * 1406.0 * 24.21/10.9
  = 10712.14 mm.⁴
```

Available Moment of Inertia, Small End, External Pressure:

	Area	Centroid	Ar*Ce	Dist	I	Ar*Di²
Shl	1.072	0.0000	0.000	17.4694	0.008	327.033
Con	1.082	2.4558	2.656	15.0136	0.030	243.822
Sec	4.686	24.9300	116.822	-7.4606	8.575	260.827
TOT	6.839		119.478		8.613	831.682
Centroid of Section			17.4694	Moment of Inertia		16.93

Summary of Small End Inertia Calculations

Available Moment of Inertia (Small End)	0.1693E+02	cm**4
Required Moment of Inertia (Small End)	0.1071E+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	20.16	312.47	Small Cyl. Long.
Compres. Stress	-8.47	-312.47	Small Cyl. Long.
Membrane Stress	19.57	-156.24	Small End Tang.
Tensile Stress	20.22	312.47	Cone Longitudinal
Compres. Stress	-8.41	-312.47	Cone Longitudinal
Compres Stress	19.68	-156.24	Cone Tangential
Tensile Stress	26.87	312.47	Large Cyl. Long.
Compres. Stress	-12.43	-312.47	Large Cyl. Long.
Membrane Stress	3.63	-156.24	Large End Tang.
Tensile Stress	26.94	312.47	Cone Longitudinal
Compres. Stress	-12.36	-312.47	Cone Longitudinal
Compres Stress	3.76	-156.24	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	3.571	Thickness due to internal pressure, Cone Large End
MAPnc	4.728	Thickness due to internal pressure, Cone Large End

These pressures were determined by iteration.

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

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	12.7573	mm.
Maximum Centroid Reinforcement Distance Small End	11.4810	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	0.00048	
Large end max. half apex angle w/o reinforcement	11.000	degrees
Large end actual half apex angle	4.716	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	0.187	degrees
Large end actual half apex angle	4.716	degrees

Intermediate Value [k]:
= max(Y / (Srl * Erl), 1)
= max(0.25813E+11/(132.9 * 0.19291E+09), 1)
= 1.0068

where [Y] is:
= Cone Allowable Stress * Cone Elastic Modulus (Ext. temp.)
= 133.8 * 0.19291E+09
= 25812725760.0 N./mm²^2

Allowable Stress of Large End Material (Ext. Temp)	133.8	N./mm²
Allowable Stress of Cone Material (Ext. Temp)	133.8	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)
= (1.0068*0.4426*868.0*0.082/(134*1.0))*
(1-1/4((0.1*868.0-0.443)/0.443)*(0.187/4.716)
= 0.0232 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( 868.0/2 ) + 0.0/(pi(1736.0 - 3.0)) +
    0.0/(pi(868.0 - 3.0/2)(868.0 - 3.0/2))
  = 0.443 Kgf/mm.
```

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

```
  = 0.55*( Dl*ts )½ * ( ts + tc/cos(alpha) )
  = 0.55 * ( 1736.0 * 3.0 )½ * ( 3.0 + 3.0/0.997 )
  = 2.3855 cm²
```

Summary of Reinforcement Area, Large End, External Pressure:

Area of reinforcement required per App. 1-8(1)	0.0232	cm²
Area of reinforcement in shell per App. 1-8(2)	2.3855	cm²
Area of reinforcement in stiffening ring	4.7000	cm²

Intermediate Results, Large End, External Pressure:

Area Available in Cone, Shell, and Reinforcement	45.86	cm²
Force per Unit Length on Shell / Cone Junction	1.57	Kgf/mm.
Actual Buckling Stress associated with this Force	4.37	N./mm²
Material Strain associated with this stress	0.000045	

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

```
  = A * Dl² * Atl / 10.9
  = 0.453E-04 * 1736.0 * 1736.0 * 45.86/10.9
  = 57448.63 mm.⁴
```

Available Moment of Inertia, Large End, External Pressure:

	Area	Centroid	Ar*Ce	Dist	I	Ar*Di²
Shl	1.191	0.0000	0.000	16.3070	0.009	316.641
Con	1.195	-1.6373	-1.956	17.9443	0.020	384.720
Sec	4.700	25.0000	117.500	-8.6930	8.652	355.172
TOT	7.086		115.544		8.681	1056.534
Centroid of Section			16.3070	Moment of Inertia		19.25

Summary of Large End Inertia Calculations

Available Moment of Inertia (Large End)	19.246	cm**4
Required Moment of Inertia (Large End)	5.745	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	0.00048	
Small end max. half apex angle w/o reinforcement	4.000	degrees
Small end actual half apex angle	4.716	degrees

Intermediate Value [k]:

```
  = max( Y / ( Sr * Ers ), 1 )
  = max( 0.19226E+11/( 100.3 * 0.18458E+09 ), 1 )
  = 1.0386
```

where [Y] is:

```
  = Cone Allowable Stress * Cone Elastic Modulus (Int. temp.)
  = 104.2 * 0.18458E+09
  = 19225886720.0 N./mm²^2
```

Decay Length, Cone Small End:

```
  = 1.4 * sqrt( Rs( ts - ca ) )
  = 1.4 * sqrt( 700.0( 3.0 - 0.0 ) )
  = 64.156 mm.
```

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

```
  = k*QS*Rs/(Ss*E1)*(1-delta/alpha)*tan(alpha)
  = 1.04 * 1.7846 * 700.0/( 104 * 1.0 ) *
```

```
    ( 1 - 4.0/4.72 ) 0.0825
  = 0.0153 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( 700.0/2 ) - 0.0/(pi(1400.0 + 3.0)) +
    0.0/(pi(700.0 + 3.0/2)(700.0 + 3.0/2))
  = 1.785 Kgf/mm.
```

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

```
  = 0.78(Rs*Ts)½*((Ts-t)+(Tc-Tr)/cos(alpha) ))
  = 0.78(700.0*3.0)½*(( 3.0- 0.336 )+( 3.0- 0.337 )/1.)
  = 1.9072 cm²
```

Summary of Reinforcement Area, Small End, Internal Pressure:

Area of reinforcement required per App. 1-5(3)	0.0153	cm²
Area of reinforcement in shell per App. 1-5(4)	1.9072	cm²
Area of reinforcement in stiffening ring	4.7000	cm²

Required Area of Reinforcement for Small End Under External Pressure

Allowable Stress of Small End Material (Ext. Temp)	133.8	N./mm²
Allowable Stress of Cone Material (Ext. Temp)	133.8	N./mm²

Intermediate Value [k]:

```
  = max( Y / ( Srs * Ers ), 1 )
  = max( 0.25813E+11/( 132.9 * 0.19291E+09 ), 1 )
  = 1.0068
```

where [Y] is:

```
   = Cone Allowable Stress * Cone Elastic Modulus (Ext. temp.)
   = 133.8 * 0.19291E+09
   = 25812725760.0 N./mm²^2
```

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

```
  = k * QS * Rs * tan(alpha) / ( Ss * E1 )
  = (1.0068*0.3584*703.0*0.0825/(134*1.0))
  = 0.0153 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( 703.0/2 ) + 0.0/(pi(1406.0 - 3.0)) +
    0.0/(pi(703.0 - 3.0/2)(703.0 - 3.0/2))
  = 0.358 Kgf/mm.
```

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

```
  = 0.55*(Ds*ts)½*[(ts-t)+(tc-tr)/cos(alpha))]
  = 0.55*(1406.0*3.0)½*[(3.0-1.89)+(3.0-2.0)/0.997]
  = 0.7552 cm²
```

Summary of Reinforcement Area, Small End, External Pressure:

Area of reinforcement required per App. 1-8(3)	0.0153	cm²
Area of reinforcement in shell per App. 1-8(4)	0.7552	cm²
Area of reinforcement in stiffening ring	4.7000	cm²

Intermediate Results, Small End, External Pressure:

Area Available in Cone, Shell, and Reinforcement	58.61	cm²
Force per Unit Length on Shell / Cone Junction	1.60	Kgf/mm.
Actual Buckling Stress associated with this Force	2.82	N./mm²
Material Strain associated with this stress	0.000029	

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

```
  = A * Ds² * Ats / 10.9
  = 0.292E-04 * 1406.0 * 1406.0 * 58.61/10.9
  = 31077.31 mm.⁴
```

Available Moment of Inertia, Small End, External Pressure:

	Area	Centroid	Ar*Ce	Dist	I	Ar*Di²
Shl	1.072	0.0000	0.000	17.3925	0.008	324.163
Con	1.075	1.4735	1.584	15.9191	0.016	272.487
Sec	4.700	25.0000	117.500	-7.6075	8.652	272.005
TOT	6.847		119.084		8.676	868.655
Centroid of Section			17.3925	Moment of Inertia		17.36

Summary of Small End Inertia Calculations

Available Moment of Inertia (Small End)	0.1736E+02	cm**4
Required Moment of Inertia (Small End)	0.3108E+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	14.45	312.47	Small Cyl. Long.
Compres. Stress	-2.76	-312.47	Small Cyl. Long.
Membrane Stress	16.43	-156.24	Small End Tang.
Tensile Stress	14.47	312.47	Cone Longitudinal
Compres. Stress	-2.74	-312.47	Cone Longitudinal
Compres Stress	16.47	-156.24	Cone Tangential
Tensile Stress	19.03	312.47	Large Cyl. Long.
Compres. Stress	-4.59	-312.47	Large Cyl. Long.
Membrane Stress	7.94	-156.24	Large End Tang.
Tensile Stress	19.05	312.47	Cone Longitudinal
Compres. Stress	-4.56	-312.47	Cone Longitudinal
Compres Stress	7.99	-156.24	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	3.592	Thickness due to internal pressure, Cone Large End
MAPnc	4.756	Thickness due to internal pressure, Cone Large End

These pressures were determined by iteration.

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

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

Conical Section From 80 To 90 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    12.7573  mm.
 Maximum Centroid Reinforcement Distance Small End    11.4810  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      0.00048
 Large end max. half apex angle w/o reinforcement      11.000  degrees
 Large end actual half apex angle                       7.829  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       0.187  degrees
 Large end actual half apex angle                       7.829  degrees
```

Intermediate Value [k]:

```
  = max( Y / ( Srl * Erl ), 1 )
  = max( 0.25813E+11/( 132.9 * 0.19291E+09 ), 1 )
  = 1.0068
```

where [Y] is:

```
   = Cone Allowable Stress * Cone Elastic Modulus (Ext. temp.)
   = 133.8 * 0.19291E+09
   = 25812725760.0 N./mm²^2

 Allowable Stress of Large End Material (Ext. Temp)   133.8  N./mm²
 Allowable Stress of Cone Material (Ext. Temp)        133.8  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)
  = (1.0068*0.4426*868.0*0.138/(134*1.0))*
    (1-1/4((0.1*868.0-0.443)/0.443)*(0.187/7.829)
  = 0.0387 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( 868.0/2 ) + 0.0/(pi(1736.0 - 3.0)) +
  0.0/(pi(868.0 - 3.0/2)(868.0 - 3.0/2))
= 0.443 Kgf/mm.
```

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

```
= 0.55*( Dl*ts )½ * ( ts + tc/cos(alpha) )
= 0.55 * ( 1736.0 * 3.0 )½ * ( 3.0 + 3.0/0.991 )
= 2.3927 cm²
```

Summary of Reinforcement Area, Large End, External Pressure:

Area of reinforcement required per App. 1-8(1)	0.0387	cm²
Area of reinforcement in shell per App. 1-8(2)	2.3927	cm²
Area of reinforcement in stiffening ring	4.6835	cm²

Intermediate Results, Large End, External Pressure:

Calculate Cylinder Decay Length:

```
= 2 * sqrt( RL * ts )
= 2*sqrt(868.0*3.0)
= 102.0588 mm.
```

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

Area Available in Cone, Shell, and Reinforcement	22.85	cm²
Force per Unit Length on Shell / Cone Junction	0.68	Kgf/mm.
Actual Buckling Stress associated with this Force	3.78	N./mm²
Material Strain associated with this stress	0.000039	

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

```
= A * Dl² * Atl / 10.9
= 0.392E-04 * 1736.0 * 1736.0 * 22.85/10.9
= 24792.07 mm.⁴
```

Available Moment of Inertia, Large End, External Pressure:

	Area	Centroid	Ar*Ce	Dist	I	Ar*Di²
Shl	1.191	0.0000	0.000	16.0286	0.009	305.921
Con	1.202	-2.7288	-3.280	18.7574	0.039	422.893
Sec	4.684	24.9175	116.701	-8.8889	8.561	370.059
TOT	7.076		113.421		8.609	1098.873
Centroid of Section			16.0286	Moment of Inertia		19.60

Summary of Large End Inertia Calculations

Available Moment of Inertia (Large End)	19.598	cm**4
Required Moment of Inertia (Large End)	2.479	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	0.00048	
Small end max. half apex angle w/o reinforcement	4.000	degrees
Small end actual half apex angle	7.829	degrees

Intermediate Value [k]:

```
= max( Y / ( Sr * Ers ), 1 )
= max( 0.19226E+11/( 100.3 * 0.18458E+09 ), 1 )
= 1.0386
```

where [Y] is:

```
= Cone Allowable Stress * Cone Elastic Modulus (Int. temp.)
= 104.2 * 0.18458E+09
= 19225886720.0 N./mm²^2
```

Decay Length, Cone Small End:
```
  = 1.4 * sqrt( Rs( ts - ca ) )
  = 1.4 * sqrt( 700.0( 3.0 - 0.0 ) )
  = 64.156 mm.
```

Required Area of Reinforcement, Small End, Internal [Ars]:
```
  = k*QS*Rs/(Ss*E1)*(1-delta/alpha)*tan(alpha)
  = 1.04 * 1.7846 * 700.0/( 104 * 1.0 ) *
    ( 1 - 4.0/7.83 ) 0.1375
  = 0.0822 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( 700.0/2 ) - 0.0/(pi(1400.0 + 3.0)) +
    0.0/(pi(700.0 + 3.0/2)(700.0 + 3.0/2))
  = 1.785 Kgf/mm.
```

Area of Reinforcement Available in Small End Shell [Aes]:
```
  = 0.78(Rs*Ts)½*((Ts-t)+(Tc-Tr)/cos(alpha) ))
  = 0.78(700.0*3.0)½*(( 3.0- 0.336 )+( 3.0- 0.339 )/0.99)
  = 1.9122 cm²
```

Summary of Reinforcement Area, Small End, Internal Pressure:

Area of reinforcement required per App. 1-5(3)	0.0822	cm²
Area of reinforcement in shell per App. 1-5(4)	1.9122	cm²
Area of reinforcement in stiffening ring	4.6830	cm²

Required Area of Reinforcement for Small End Under External Pressure

Allowable Stress of Small End Material (Ext. Temp)	133.8	N./mm²
Allowable Stress of Cone Material (Ext. Temp)	133.8	N./mm²

Intermediate Value [k]:
```
  = max( Y / ( Srs * Ers ), 1 )
  = max( 0.25813E+11/( 132.9 * 0.19291E+09 ), 1 )
  = 1.0068
```

where [Y] is:
```
  = Cone Allowable Stress * Cone Elastic Modulus (Ext. temp.)
  = 133.8 * 0.19291E+09
  = 25812725760.0 N./mm²^2
```

Area of Reinforcement Required in Small End Shell [Ars]:
```
  = k * QS * Rs * tan(alpha) / ( Ss * E1 )
  = (1.0068*0.3584*703.0*0.1375/(134*1.0))
  = 0.0256 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( 703.0/2 ) + 0.0/(pi(1406.0 - 3.0)) +
    0.0/(pi(703.0 - 3.0/2)(703.0 - 3.0/2))
  = 0.358 Kgf/mm.
```

Area of Reinforcement Available in Small End Shell [Aes]:
```
  = 0.55*(Ds*ts)½*[(ts-t)+(tc-tr)/cos(alpha))]
  = 0.55*(1406.0*3.0)½*[(3.0-1.043)+(3.0-0.514)/0.991]
  = 1.5954 cm²
```

Summary of Reinforcement Area, Small End, External Pressure:

Area of reinforcement required per App. 1-8(3)	0.0256	cm²
Area of reinforcement in shell per App. 1-8(4)	1.5954	cm²
Area of reinforcement in stiffening ring	4.6830	cm²

Intermediate Results, Small End, External Pressure:

Area Available in Cone, Shell, and Reinforcement	28.48	cm²

Force per Unit Length on Shell / Cone Junction	0.70	Kgf/mm.
Actual Buckling Stress associated with this Force	2.53	N./mm²
Material Strain associated with this stress	0.000026	

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

= A * Ds² * Ats / 10.9
= 0.262E-04 * 1406.0 * 1406.0 * 28.48/10.9
= 13537.53 mm.⁴

Available Moment of Inertia, Small End, External Pressure:

	Area	Centroid	Ar*Ce	Dist	I	Ar*Di²
Shl	1.072	0.0000	0.000	17.4558	0.008	326.525
Con	1.082	2.4558	2.656	15.0000	0.030	243.382
Sec	4.683	24.9150	116.677	-7.4592	8.558	260.558
TOT	6.836		119.333		8.596	830.465
Centroid of Section			17.4558	Moment of Inertia		16.90

Summary of Small End Inertia Calculations

Available Moment of Inertia (Small End)	0.1690E+02	cm**4
Required Moment of Inertia (Small End)	0.1354E+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	20.16	312.47	Small Cyl. Long.
Compres. Stress	-8.47	-312.47	Small Cyl. Long.
Membrane Stress	19.57	-156.24	Small End Tang.
Tensile Stress	20.22	312.47	Cone Longitudinal
Compres. Stress	-8.41	-312.47	Cone Longitudinal
Compres Stress	19.68	-156.24	Cone Tangential
Tensile Stress	26.87	312.47	Large Cyl. Long.
Compres. Stress	-12.43	-312.47	Large Cyl. Long.
Membrane Stress	3.63	-156.24	Large End Tang.
Tensile Stress	26.94	312.47	Cone Longitudinal
Compres. Stress	-12.36	-312.47	Cone Longitudinal
Compres Stress	3.76	-156.24	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	3.571	Thickness due to internal pressure, Cone Large End
MAPnc	4.728	Thickness due to internal pressure, Cone Large End

These pressures were determined by iteration.

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

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

Conical Section From 100 To 110 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	11.4810	mm.
Maximum Centroid Reinforcement Distance Small End	9.4670	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	0.00048	
Large end max. half apex angle w/o reinforcement	11.000	degrees
Large end actual half apex angle	6.419	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	0.187	degrees
Large end actual half apex angle	6.419	degrees

Intermediate Value [k]:
= max(Y / (Srl * Erl), 1)
= max(0.25813E+11/(132.9 * 0.19291E+09), 1)
= 1.0068

where [Y] is:
= Cone Allowable Stress * Cone Elastic Modulus (Ext. temp.)
= 133.8 * 0.19291E+09
= 25812725760.0 N./mm²^2

Allowable Stress of Large End Material (Ext. Temp)	133.8	N./mm²
Allowable Stress of Cone Material (Ext. Temp)	133.8	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)
= (1.0068*0.3584*703.0*0.112/(134*1.0))*
(1-1/4((0.1*703.0-0.358)/0.358)*(0.187/6.419)
= 0.0208 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( 703.0/2 ) + 0.0/(pi(1406.0 - 3.0)) +
  0.0/(pi(703.0 - 3.0/2)(703.0 - 3.0/2))
= 0.358 Kgf/mm.
```

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

```
= 0.55*( Dl*ts )½ * ( ts + tc/cos(alpha) )
= 0.55 * ( 1406.0 * 3.0 )½ * ( 3.0 + 3.0/0.994 )
= 2.1500 cm²
```

Summary of Reinforcement Area, Large End, External Pressure:

Area of reinforcement required per App. 1-8(1)	0.0208	cm²
Area of reinforcement in shell per App. 1-8(2)	2.1500	cm²
Area of reinforcement in stiffening ring	5.0420	cm²

Intermediate Results, Large End, External Pressure:

Area Available in Cone, Shell, and Reinforcement	61.56	cm²
Force per Unit Length on Shell / Cone Junction	2.00	Kgf/mm.
Actual Buckling Stress associated with this Force	3.35	N./mm²
Material Strain associated with this stress	0.000035	

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

```
= A * Dl² * Atl / 10.9
= 0.348E-04 * 1406.0 * 1406.0 * 61.56/10.9
= 38820.20 mm.⁴
```

Available Moment of Inertia, Large End, External Pressure:

	Area	Centroid	Ar*Ce	Dist	I	Ar*Di²
Shl	1.072	0.0000	0.000	18.4240	0.008	363.751
Con	1.078	-2.0093	-2.167	20.4333	0.023	450.240
Sec	5.042	26.7100	134.672	-8.2860	10.681	346.172
TOT	7.192		132.505		10.712	1160.163
Centroid of Section			18.4240	Moment of Inertia		22.31

Summary of Large End Inertia Calculations

Available Moment of Inertia (Large End)	22.314	cm**4
Required Moment of Inertia (Large End)	3.882	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	17.57	312.47	Large Cyl. Long.
Compres. Stress	-5.87	-312.47	Large Cyl. Long.
Membrane Stress	5.24	-156.24	Large End Tang.
Tensile Stress	17.60	312.47	Cone Longitudinal
Compres. Stress	-5.84	-312.47	Cone Longitudinal
Compres Stress	5.31	-156.24	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	4.424	Thickness due to internal pressure, Cone Large End

```
     MAPnc         5.857     Thickness due to internal pressure, Cone Large End
```

These pressures were determined by iteration.

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

Shop/Field Installation Options :

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

Center of Gravity of Stiffening Rings	14631.545 mm.
Center of Gravity of Bare Shell New and Cold	13151.735 mm.
Center of Gravity of Bare Shell Corroded	13151.735 mm.
Vessel CG in the Operating Condition	13342.544 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition	13342.544 mm.

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

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						
	[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.

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

ASME Code, Section VIII Division 1, 2017

```
Diameter Spec : 1300.000 x 1730.000 x 1400.000 x 1730.000 x 1400.000 mm. ID
Vessel Design Length, Tangent to Tangent         26052.00  mm.

Distance of Bottom Tangent above Grade            8052.00  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                  3.571  bars
External Max. Allowable Working Pressure            0.137  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
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	4.794	0.0000	N/A	No
Conical	0.500	0.10	3.584	0.0000	N/A	No
Cylinder	0.500	0.10	3.605	0.0000	N/A	No
Conical	0.500	0.10	3.571	0.0000	N/A	No
Cylinder	0.500	0.10	4.452	0.0000	N/A	No
Conical	0.500	0.10	3.593	0.0000	N/A	No
Cylinder	0.500	0.10	3.605	0.0000	N/A	No
Conical	0.500	0.10	3.571	0.0000	N/A	No
Cylinder	0.500	0.10	4.452	0.0000	N/A	No
Conical	0.500	0.10	4.424	0.0000	N/A	No

Stiffener Ring Specifications:

Elevation mm.	Selected Type	User Description
3958.00	Bar 47.0 x 10.	Ring:[1 of 1]
5946.00	Bar 47.0 x 10.	Ring:[2 of 2]
7939.00	Bar 47.0 x 10.	Ring:[3 of 3]
7952.00	Bar 47.0 x 10.	Ring:[4 of 4]
8052.00	Bar 97.0 x 10.	Ring 16
10052.00	Bar 47.0 x 10.	Ring5
12051.00	Bar 46.9 x 10.	Ring:17

10852.00	Bar	50.0 x 10.	Ring 21
12142.00	Bar	47.0 x 10.	Ring 6
12155.00	Bar	47.0 x 10.	Ring 7
13565.00	Bar	47.0 x 10.	Ring 8
14965.00	Bar	47.0 x 10.	Ring 9
16552.00	Bar	47.0 x 10.	Ring 18
18551.00	Bar	47.0 x 10.	Ring 23
19289.00	Bar	47.0 x 10.	Ring 10
19302.00	Bar	47.0 x 10.	Ring 11
19352.00	Bar	46.8 x 10.	Ring 24
20551.00	Bar	46.8 x 10.	Ring 26
20927.00	Bar	47.0 x 10.	Ring 12
22297.00	Bar	47.0 x 10.	Ring 13]
26051.00	Bar	50.4 x 10.	Ring 22
24052.00	Bar	50.4 x 10.	Ring 28

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	8052.0	8052.0	3.0	3.0	1.5	...	1.00	1.00
Conical	10052.0	2000.0	3.0	3.0	1.5	...	1.00	1.00
Cylinder	10852.0	800.0	3.0	3.0	1.5	...	1.00	1.00
Conical	12052.0	1200.0	3.0	3.0	1.5	...	1.00	1.00
Cylinder	16552.0	4500.0	3.0	3.0	1.5	...	1.00	1.00
Conical	18552.0	2000.0	3.0	3.0	1.5	...	1.00	1.00
Cylinder	19352.0	800.0	3.0	3.0	1.5	...	1.00	1.00
Conical	20552.0	1200.0	3.0	3.0	1.5	...	1.00	1.00
Cylinder	24052.0	3500.0	3.0	3.0	1.5	...	1.00	1.00
Conical	26052.0	2000.0	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	2.64879	0.1	0.13736
Ring	Ring	3	1.98494	0.1	0.28018
Ring	Ring	3	1.98708	0.1	0.27946
Ring	Ring	3	0.47257	0.1	2.80031
Ring	20	3	0.57319	0.1	2.56958
20	Ring	3	1.86049	0.1	0.32853
Ring	30	3	2.24961	0.1	0.20495
30	Ring	3	No Calc	0.1	No Calc
Ring	40	3	1.62103	0.1	0.46793
40	Ring	3	2.25778	0.1	0.20299
Ring	Ring	3	1.85593	0.1	0.33169
Ring	50	3	0.51366	0.1	2.52828
50	Ring	3	0.56956	0.1	2.4333
Ring	Ring	3	0.50876	0.1	2.55869
Ring	Ring	3	1.80715	0.1	0.35777
Ring	Ring	3	1.80239	0.1	0.36038
Ring	60	3	1.89031	0.1	0.31681
60	Ring	3	0.51049	0.1	2.54788
Ring	Ring	3	2.27117	0.1	0.19962
Ring	70	3	0.6303	0.1	1.95727
70	Ring	3	1.56614	0.1	0.51
Ring	Ring	3	0.62816	0.1	1.96585
Ring	80	3	0.62816	0.1	1.96585
80	Ring	3	0.63409	0.1	1.9422
Ring	Ring	3	1.85593	0.1	0.33169
Ring	90	3	0.51366	0.1	2.52828
90	Ring	3	1.04348	0.1	1.44208

Ring	Ring	3	1.78809	0.1	0.3684
Ring	100	3	1.96728	0.1	0.28568
100	Ring	3	0.51198	0.1	2.53866
Ring	Ring	3	1.94504	0.1	0.2941
Ring	110	3	0.34821	0.1	4.03247

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	3958	5366.66	No Calc	No Calc
Ring	Ring	1988	5367.77	4.74696	17.6358
Ring	Ring	1993	5367.78	3.17821	17.6358
Ring	Ring	12.9998	362.283	1.60148	17.6358
Ring	20	100	3105.85	0.090213	17.6358
20	Ring	1679.94	1679.94	No Calc	No Calc
Ring	30	1752.3	1752.3	2.74012	118.645
30	Ring	No Calc	No Calc	No Calc	No Calc
Ring	40	800	3576.41	1.50003	18.5486
40	Ring	1752.3	1752.3	No Calc	No Calc
Ring	Ring	1085.13	1085.13	5.32031	21.7628
Ring	50	0.99994	0.99994	1.08257	17.7314
50	Ring	90	2782.45	No Calc	No Calc
Ring	Ring	13	332.63	0.1026	17.8679
Ring	Ring	1410	4840.94	1.41706	17.8679
Ring	Ring	1400	4840.92	2.80393	17.8679
Ring	60	1587	4841.33	2.96283	17.8679
60	Ring	0.99994	0.99994	No Calc	No Calc
Ring	Ring	1809.08	1809.08	1.80308	17.8679
Ring	70	0.99989	0.99989	3.39301	18.5482
70	Ring	737	3576.31	No Calc	No Calc
Ring	Ring	13	979.513	1.41118	18.5486
Ring	80	50	1799.98	0.11813	18.5486
80	Ring	0.99989	0.99989	No Calc	No Calc
Ring	Ring	1085.13	1085.13	2.0298	18.381
Ring	90	0.99994	0.99994	1.08257	17.7021
90	Ring	375	4840.98	No Calc	No Calc
Ring	Ring	1370	4840.85	1.73585	17.8679
Ring	100	1755	4841.66	3.11292	17.8679
100	Ring	0.99994	0.99994	No Calc	No Calc
Ring	Ring	1679.26	1679.26	1.67377	21.4269
Ring	110	0.99982	0.99982	0.52653	20.0339

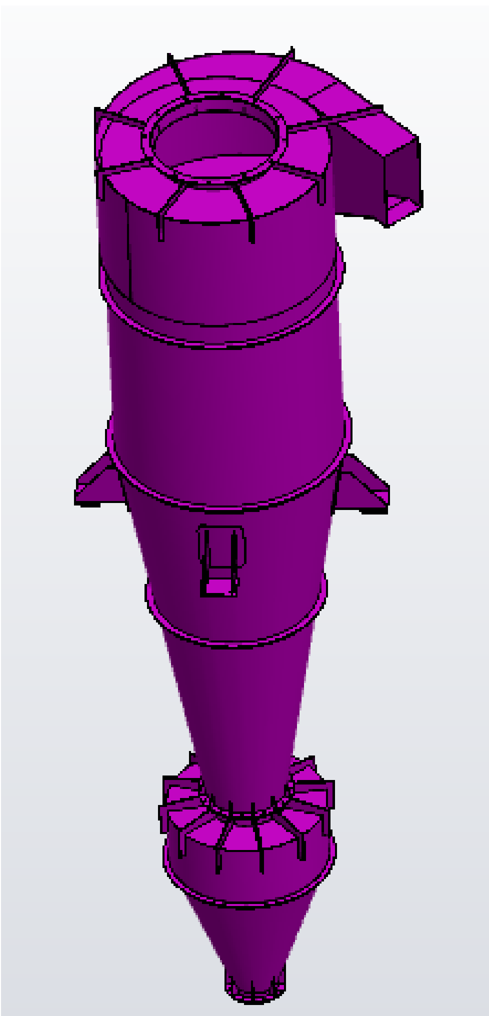
Factored Loads:

Un-Factored Loads:

Weights:

Fabricated	- Bare W/O Removable Internals	3201.3	kg.
Shop Test	- Fabricated + Water (Full)	44267.2	kg.
Shipping	- Fab. + Rem. Intls.+ Shipping App.	3201.3	kg.
Erected	- Fab. + Rem. Intls.+ Insul. (etc)	3201.3	kg.
Empty	- Fab. + Intls. + Details + Wghts.	3201.3	kg.
Operating	- Empty + Operating Liquid (No CA)	3201.3	kg.
Field Test	- Empty Weight + Water (Full)	44267.2	kg.

APPENDIX 2
CALCULATION
CYCLONES- ZONE 4



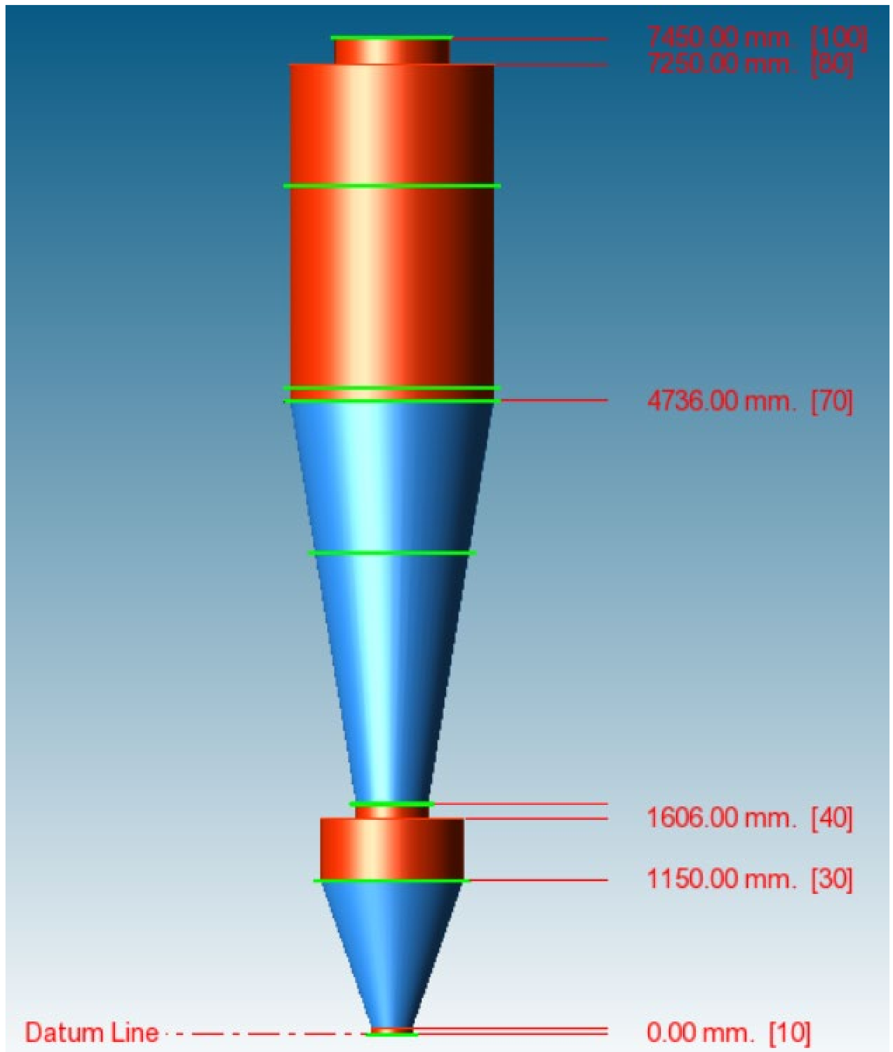


Figure B- Cyclones - Zone 4

Table of Contents

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 is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

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

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

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.

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

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.

ASME Code, Section VIII Division 1, 2017

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

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

Effective Length of Shell: 34 mm.

	Area (cm^2)	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	$A*Dist^2$
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./mm^2
Required Strain in Ring plus Shell Areq 0.0000012

Required Moment of Inertia, Ring plus Shell:
= (OD^2 * Slen(Tca + Aring/Slen)Areq)/10.9
= (327.0^2*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./mm^2
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.

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

Effective Length of Shell: 64 mm.

	Area (cm^2)	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	$A*Dist^2$
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./mm^2
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

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

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

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

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	$A*Dist^2$
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:

= (OD^2 * Slen(Tca + Aring/Slen)Areq)/10.9
= (1610.2754^2*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.

Stiffening Ring Calcs for : Ring 7-1 , 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	$A*Dist^2$
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:

= (OD^2 * Slen(Tca + Aring/Slen)Areq)/10.9
= (1612.0^2*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

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

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|        ... |        ... |       ... |
 -------------------------------------------------
```

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

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

Conical Section From 20 To 30 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    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.

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                      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*Di²
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./mm²^2
```

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 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( 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 cm²
```

Summary of Reinforcement Area, Small End, Internal Pressure:

Area of reinforcement required per App. 1-5(3)	0.0138	cm²
Area of reinforcement in shell per App. 1-5(4)	1.0385	cm²
Area of reinforcement in stiffening ring	0.0000	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*0.0834*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
```

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

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
```

<u>Available Moment of Inertia, Small End, External Pressure:</u>

	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

<u>Summary of Small End Inertia Calculations</u>

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.

<u>Results for Discontinuity Stresses per Bednar p. 236 2nd Edition</u>

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.

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

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
```

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

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
```

<u>Available Moment of Inertia, Large End, External Pressure:</u>

	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

<u>Summary of Large End Inertia Calculations</u>

Available Moment of Inertia (Large End)	20.656	cm**4
Required Moment of Inertia (Large End)	4.010	cm**4

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

Required Area of Reinforcement for Small End under Internal Pressure

Small end ratio of pressure to allowable stress	0.00037	
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 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(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 cm^2

<u>Summary of Reinforcement Area, Small End, Internal Pressure:</u>

Area of reinforcement required per App. 1-5(3)	0.0150	cm^2
Area of reinforcement in shell per App. 1-5(4)	1.3257	cm^2
Area of reinforcement in stiffening ring	4.9000	cm^2

<u>Required Area of Reinforcement for Small End Under External Pressure</u>

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./mm^2^2

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 cm^2

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 cm^2

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

Area of reinforcement required per App. 1-8(3)	0.0051	cm^2
Area of reinforcement in shell per App. 1-8(4)	1.2805	cm^2
Area of reinforcement in stiffening ring	4.9000	cm^2

Intermediate Results, Small End, External Pressure:

Area Available in Cone, Shell, and Reinforcement	52.41	cm^2
Force per Unit Length on Shell / Cone Junction	2.04	Kgf/mm.
Actual Buckling Stress associated with this Force	1.63	N./mm^2
Material Strain associated with this stress	0.000017	

Required Moment of Inertia, Small End, External Pressure [I's]:
= A * Ds^2 * 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.

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

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.

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

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.

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

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.

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

APPENDIX 3
CALCULATION
RECTANGULAR SECTION
ZONE 2

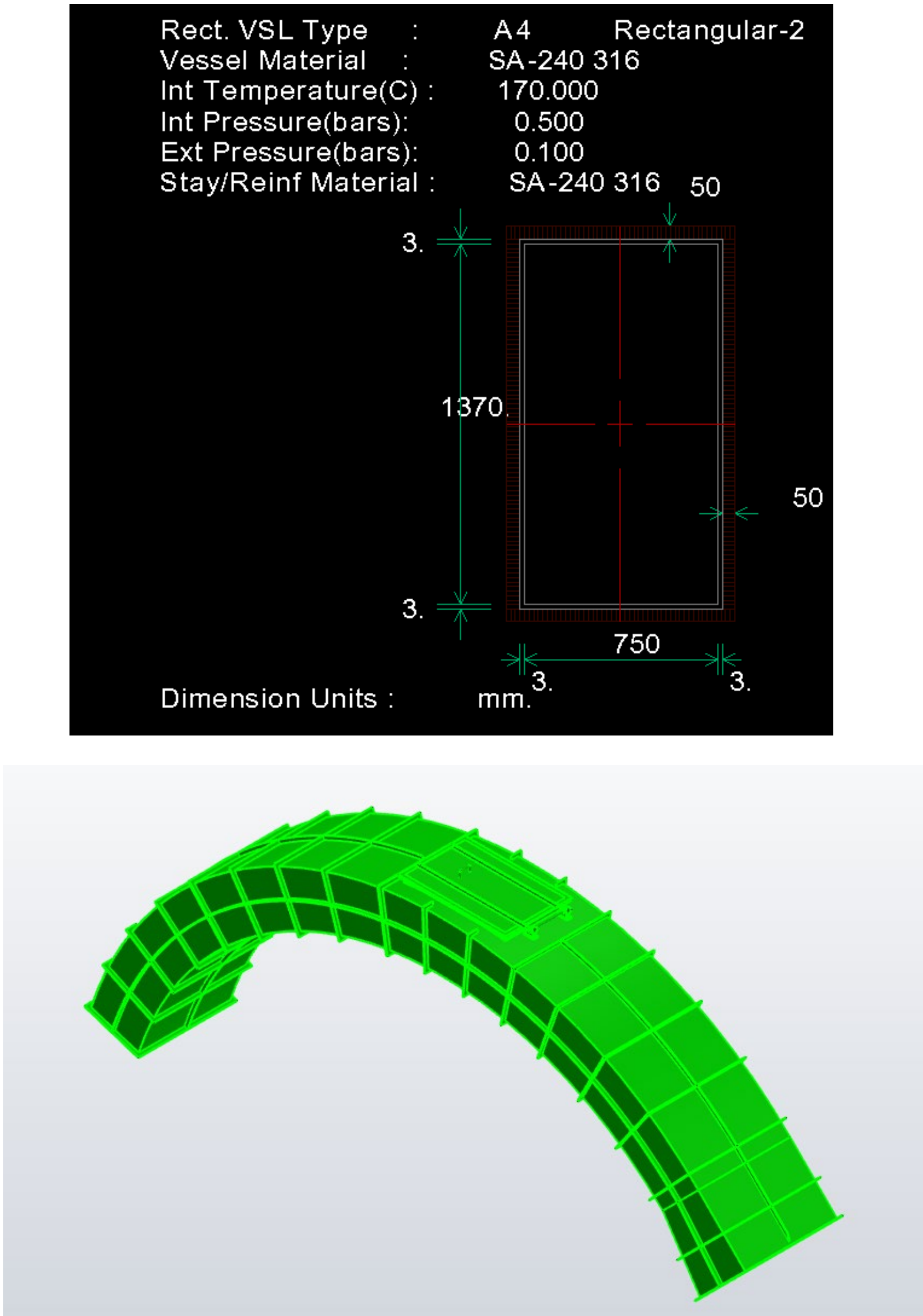


Figure C- Rectangular Duct - Zone 2

Table of Contents

MICROTEC
Rectangular Duct for Flash Dryer - Section 1

DESIGN CALCULATION

ASME Code Version : 2017

Analysis Performed by : SL Client

Job File : D:\2-PAYAM\1-Projects\Microtec Project\13-Microtec -Flash Dryer-5204\5204-Eng

Date of Analysis : Feb 20,2026

PV Elite 2019 , January 2019

Note:
PV Elite performs all calculations internally in U.S. Customary Units
to remain compliant with the ASME Code and any built in assumptions in
the ASME Code formulae. Finalized results are converted to the user set of
selected units using conversion constants with adequate significant digits.

Input Echo, COMPONENT 1, Description: Rectangular-2

```
Figure Number Analyzed                                        A4

Design Internal Pressure                 P         0.5000  bars
Design External Pressure              Pext         0.1000  bars
Design Temperature                    Temp       170.0000  C

VESSEL MATERIAL DATA:
Material Specification                         SA-240 316
Shell Allowable Stress at Design Temp    S       136.0672  N./mm^2
Shell Allowable Stress at Ambient       SA       137.9000  N./mm^2
Shell Yield Stress at Design Temperature  Sy     156.1065  N./mm^2


SHORT-SIDE VESSEL DATA:
Short-side Length Dimension              H       750.0000  mm.
Minimum Thickness of Short-side Plates  t1         3.0000  mm.
Mid-side Joint Efficiency on Short-side  E         1.0000
Corner Joint Efficiency on Short-side   EC         1.0000

LONG-SIDE VESSEL DATA:
Long-side Length Dimension               h      1370.0000  mm.
Minimum Thickness of Long-side Plates   t2         3.0000  mm.
Mid-side Joint Efficiency on Long-side   E         1.0000

REINFORCEMENT MATERIAL DATA:
Reinforcement Material Specification           SA-240 316
Reinf Allowable Stress at Design Temp   Sr       136.0672  N./mm^2
Reinf Allowable Stress at Ambient       SA       137.9000  N./mm^2
Reinf Yield Stress at Design Temp       Sy       156.1065  N./mm^2


C-Factor for Reinforcement  (from UG-47)           2.1000
DELTA (Reinforcement Material Parameter)         485.0000  N./mm^2^0.5

SHORT-SIDE RECTANGULAR BEAM DATA:
Outside Distance from Outside of Vessel           50.0000  mm.
Width of Reinforcing Member                       10.0000  mm.

LONG-SIDE RECTANGULAR BEAM DATA:
Outside Distance from Outside of Vessel           50.0000  mm.
Width of Reinforcing Member                       10.0000  mm.
```

Rectangular Vessel Results, Item number 1, Desc: Rectangular-2
ASME Code, Section VIII, Division 1, 2017 App. 13

Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):

Short-side 1 Calculations

Membrane Ligament Efficiency [Em]:
 = 1.000

Bending Ligament Efficiency [Eb]:
 = 1.000

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:
 = t1 - CA / 2
 = 3.000 - 0.000 / 2
 = 1.500 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:
```
  = -( t1 - CA ) / 2
  = -( 3.000 - 0.000 ) / 2
  = -1.500 mm.
```

Short-side 2 Calculations

Membrane Ligament Efficiency [Em]:
```
  = 1.000
```

Bending Ligament Efficiency [Eb]:
```
  = 1.000
```

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:
```
  = t1 - CA / 2
  = 3.000 - 0.000 / 2
  = 1.500 mm.
```

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:
```
  = -( t1 - CA ) / 2
  = -( 3.000 - 0.000 ) / 2
  = -1.500 mm.
```

Long-side 1 Calculations

Membrane Ligament Efficiency [Em]:
```
  = 1.000
```

Bending Ligament Efficiency [Eb]:
```
  = 1.000
```

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:
```
  = t1 - CA / 2
  = 3.000 - 0.000 / 2
  = 1.500 mm.
```

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:
```
  = -( t1 - CA ) / 2
  = -( 3.000 - 0.000 ) / 2
  = -1.500 mm.
```

Long-side 2 Calculations

Membrane Ligament Efficiency [Em]:
```
  = 1.000
```

Bending Ligament Efficiency [Eb]:
```
  = 1.000
```

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:
```
  = t1 - CA / 2
  = 3.000 - 0.000 / 2
  = 1.500 mm.
```

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:
```
  = -( t1 - CA ) / 2
  = -( 3.000 - 0.000 ) / 2
  = -1.500 mm.
```

Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):

	Em	Eb	Ci	Co
Short-side 1	1.000	1.000	1.500	-1.500

```
            2       1.000       1.000       1.500      -1.500
  Long-side 1       1.000       1.000       1.500      -1.500
            2       1.000       1.000       1.500      -1.500
```

Effective Width of Shell Plate (Section 13-8, Eq. (2))

In Compression [w]:
```
  = Min( Min( t1, t2 ) * Delta / sqrt( Sy ), p )
  = Min( Min( 3.00 , 3.00 ) * 5840.83 / sqrt( 156.11 ), 65.00 )
  = 65.00 mm.
```

In Tension [w]:
```
  = 65.00 mm.
```

Moment of Inertia of a Strip of the Vessel Wall:

```
    Thickness  t1, I1  = 0.0000 cm**4
    Thickness  t2, I2  = 0.0000 cm**4
```

Effective Area of Reinforcement on Shell (t * w):

```
    Short-side Ap = 1.9500 cm^2
    Long-side  Ap = 1.9500 cm^2
```

Moment of Inertia of Effective Area of Reinforcement (w * t3 / 12):**

```
    Short-side Is = 0.0146 cm**4
    Long-side  Il = 0.0146 cm**4
```

Moment of Inertia of Combined Reinforcement and Effective Width:

```
    In Compression I11 = 20.2830 cm**4
                   I21 = 20.2830 cm**4
    In Tension     I11 = 20.2830 cm**4
                   I21 = 20.2830 cm**4
```

Distance from Neutral Axis of Cross Section of Composite Section to the Inside Surface of the Vessel (mm.):

```
                                      Ci            Co
    Short-side, in Compression     20.5647      -32.4353
                in Tension         20.5647      -32.4353
    Long-side,  in Compression     20.5647      -32.4353
                in Tension         20.5647      -32.4353
```

Rectangular Vessel Reinforcement Parameters:

```
    Alpha1 =     H1 / h1      = 0.5652
    k(comp)= (I22/I11)*Alpha1 = 0.5652
    k(tens)= (I22/I11)*Alpha1 = 0.5652
```

Membrane Stress Calculations per Section 13-8

Membrane Stresses at Short-side 1

Membrane Stress at Short-side 1 [Sms]:
```
  = p * h * p / ( 2 * ( A1 + p * t1 ))
  = 0.50 * 1370.00 * 65.00 / ( 2 * ( 500.000 + 65.00 * 3.00 ))
  = 3.20 N./mm^2
```

Membrane Stresses at Short-side 2

Membrane Stress at Short-side 2 [Sms]:
= p * h * p / (2 * (A1 + p * t1))
= 0.50 * 1370.00 * 65.00 / (2 * (500.000 + 65.00 * 3.00))
= 3.20 N./mm^2

Membrane Stresses at Long-side 1

Membrane Stress at Long-side 1 at A[SmlA]:
= p * H * p / (2 * (A2 + p * t2))
= 0.50 * 750.00 * 65.00 / (2 * (5.000 + 65.00 * 3.00))
= 1.75 N./mm^2

Membrane Stresses at Long-side 2

Membrane Stress at Long-side 2 at A[SmlA]:
= p * H * p / (2 * (A2 + p * t2))
= 0.50 * 750.00 * 65.00 / (2 * (5.000 + 65.00 * 3.00))
= 1.75 N./mm^2

Membrane Stresses at Corner sections

Membrane Stress at Short side [Smsc]:
= p * h * p / (2 * (A1 + p * t1))
= 0.50 * 1370.00 * 65.00 / (2 * (5.000 + 65.00 * 3.00))
= 3.20 N./mm^2

Membrane Stress at Long side [Smlc]:
= p * H * p / (2 * (A2 + p * t2))
= 0.50 * 750.00 * 65.00 / (2 * (5.000 + 65.00 * 3.00))
= 1.75 N./mm^2

MEMBRANE STRESSES: Membrane Stress Calculations per Section 13-8, Equations (3) and (4). (N./mm^2) :

STRESS LOCATIONS	Actual	Allowable
Short-side 1	3.20	136.07
Short-side 2	3.20	136.07
Short-side Corner	3.20	136.07
Long-side 1 at A	1.75	136.07
Long-side 2 at A	1.75	136.07
Long-side Corner	1.75	136.07

Bending Stress Calculations per Section 13-8

Bending Stresses at Short-side 1

Bending Stress at Short-side 1 at N Inner[SbsNi]:
= P * p * c / (24 * I11) * [-3 * H^2 + 2 * h^2
* ((1 + Alpha1^2 * k) / (1 + k))]
= 0.5 * 65.0 * 20.56 / (24 * 20.3) * [-3 * 750.00^2 + 2 * 1370.00^2 *
((1 + 0.57^2 * 0.57) / (1 + 0.57))]
= 15.71 N./mm^2

Bending Stress at Short-side 1 at N Outer[SbsNo]:
= P * p * c / (24 * I11) * [-3 * H^2 + 2 * h^2
* ((1 + Alpha1^2 * k) / (1 + k))]
= 0.5 * 65.0 * -32.44 / (24 * 20.3) * [-3 * 750.00^2 + 2 * 1370.00^2 *
((1 + 0.57^2 * 0.57) / (1 + 0.57))]
= -24.77 N./mm^2

Bending Stress at Short-side 1 at Q Inner[SbsQi]:
= P * h^2 * p * c / (12 * I11) *
((1 + Alpha1^2 * k) / (1 + k))

```
  = 0.50 * 1370.00^2 * 65.00 * 20.56 / ( 12 * 20.28 ) *
    (( 1 + 0.57^2 * 0.57 ) / ( 1 + 0.57 ))
  = 38.88 N./mm^2
```

Bending Stress at Short-side 1 at Q Outer[SbsQo]:

```
  = P * h^2 * p * c / ( 12 * I11 ) *
    (( 1 + Alpha1^2 * k ) / ( 1 + k ))
  = 0.50 * 1370.00^2 * 65.00 * -32.44 / ( 12 * 20.28 ) *
    (( 1 + 0.57^2 * 0.57 ) / ( 1 + 0.57 ))
  = -61.32 N./mm^2
```

Bending Stresses at Short-side 2

Bending Stress at Short-side 2 at N Inner[SbsNi]:

```
  = P * p * c / ( 24 * I11 ) * [ -3 * H^2 + 2 * h^2
    * (( 1 + Alpha1^2 * k ) / ( 1 + k ))]
  = 0.5 * 65.0 * 20.56 / ( 24 * 20.3 ) * [ -3 * 750.00^2 + 2 * 1370.00^2 *
    (( 1 + 0.57^2 * 0.57 ) / ( 1 + 0.57 ))]
  = 15.71 N./mm^2
```

Bending Stress at Short-side 2 at N Outer[SbsNo]:

```
  = P * p * c / ( 24 * I11 ) * [ -3 * H^2 + 2 * h^2
    * (( 1 + Alpha1^2 * k ) / ( 1 + k ))]
  = 0.5 * 65.0 * -32.44 / ( 24 * 20.3 ) * [ -3 * 750.00^2 + 2 * 1370.00^2 *
    (( 1 + 0.57^2 * 0.57 ) / ( 1 + 0.57 ))]
  = -24.77 N./mm^2
```

Bending Stress at Short-side 2 at Q Inner[SbsQi]:

```
  = P * h^2 * p * c / ( 12 * I11 ) *
    (( 1 + Alpha1^2 * k ) / ( 1 + k ))
  = 0.50 * 1370.00^2 * 65.00 * 20.56 / ( 12 * 20.28 ) *
    (( 1 + 0.57^2 * 0.57 ) / ( 1 + 0.57 ))
  = 38.88 N./mm^2
```

Bending Stress at Short-side 2 at Q Outer[SbsQo]:

```
  = P * h^2 * p * c / ( 12 * I11 ) *
    (( 1 + Alpha1^2 * k ) / ( 1 + k ))
  = 0.50 * 1370.00^2 * 65.00 * -32.44 / ( 12 * 20.28 ) *
    (( 1 + 0.57^2 * 0.57 ) / ( 1 + 0.57 ))
  = -61.32 N./mm^2
```

Bending Stresses at Long-side 1

Bending Stress at Long-side 1 at M Inner[SblMi]:

```
  = P * h^2 * p * c / ( 24 * I21 ) * [ -3 + 2 *
    (( 1 + Alpha1^2 * k ) / ( 1 + k ))]
  = 0.50 * 1370.00^2 * 65.00 * 20.56 / ( 24 * 20.28 ) * [ -3 + 2 *
    (( 1 + 0.57^2 * 0.57 ) / ( 1 + 0.57 ))]
  = -38.44 N./mm^2
```

Bending Stress at Long-side 1 at M Outer[SblMo]:

```
  = P * h^2 * p * c / ( 24 * I21 ) * [ -3 + 2 *
    (( 1 + Alpha1^2 * k ) / ( 1 + k ))]
  = 0.50 * 1370.00^2 * 65.00 * -32.44 / ( 24 * 20.28 ) * [ -3 + 2 *
    (( 1 + 0.57^2 * 0.57 ) / ( 1 + 0.57 ))]
  = 60.62 N./mm^2
```

Bending Stress at Long-side 1 at Q Inner[SblQi]:

```
  = P * h^2 * p * c / ( 12 * I21 ) *
    (( 1 + Alpha1^2 * k ) / ( 1 + k ))
  = 0.50 * 1370.00^2 * 65.00 * 20.56 / ( 24 * 20.28 ) *
    (( 1 + 0.57^2 * 0.57 ) / ( 1 + 0.57 ))]
  = 38.88 N./mm^2
```

Bending Stress at Long-side 1 at Q Outer[SblQo]:

```
  = P * h² * p * c / ( 12 * I21 ) *
    (( 1 + Alpha1² * k ) / ( 1 + k ))
  = 0.50 * 1370.00² * 65.00 * -32.44 / ( 24 * 20.28 ) *
    (( 1 + 0.57² * 0.57 ) / ( 1 + 0.57 ))]
  = -61.32 N./mm^2
```

Bending Stresses at Long-side 2

Bending Stress at Long-side 2 at M Inner[SblMi]:

```
  = P * h² * p * c / ( 24 * I21 ) * [ -3 + 2 *
    (( 1 + Alpha1² * k ) / ( 1 + k ))]
  = 0.50 * 1370.00² * 65.00 * 20.56 / ( 24 * 20.28 ) * [ -3 + 2 *
    (( 1 + 0.57² * 0.57 ) / ( 1 + 0.57 ))]
  = -38.44 N./mm^2
```

Bending Stress at Long-side 2 at M Outer[SblMo]:

```
  = P * h² * p * c / ( 24 * I21 ) * [ -3 + 2 *
    (( 1 + Alpha1² * k ) / ( 1 + k ))]
  = 0.50 * 1370.00² * 65.00 * -32.44 / ( 24 * 20.28 ) * [ -3 + 2 *
    (( 1 + 0.57² * 0.57 ) / ( 1 + 0.57 ))]
  = 60.62 N./mm^2
```

Bending Stress at Long-side 2 at Q Inner[SblQi]:

```
  = P * h² * p * c / ( 12 * I21 ) *
    (( 1 + Alpha1² * k ) / ( 1 + k ))
  = 0.50 * 1370.00² * 65.00 * 20.56 / ( 24 * 20.28 ) *
    (( 1 + 0.57² * 0.57 ) / ( 1 + 0.57 ))]
  = 38.88 N./mm^2
```

Bending Stress at Long-side 2 at Q Outer[SblQo]:

```
  = P * h² * p * c / ( 12 * I21 ) *
    (( 1 + Alpha1² * k ) / ( 1 + k ))
  = 0.50 * 1370.00² * 65.00 * -32.44 / ( 24 * 20.28 ) *
    (( 1 + 0.57² * 0.57 ) / ( 1 + 0.57 ))]
  = -61.32 N./mm^2
```

BENDING STRESSES: Bending Stress Calculations per Section 13-8, Equations (5-8). (N./mm^2) :

STRESS LOCATIONS	Inner	Outer	Allowable
Short-side 1 at N	15.71	-24.77	104.07
at Q	38.88	-61.32	104.07
Short-side 2 at N	15.71	-24.77	104.07
at Q	38.88	-61.32	104.07
Long-side 1 at M	-38.44	60.62	104.07
at Q	38.88	-61.32	104.07
Long-side 2 at M	-38.44	60.62	104.07
at Q	38.88	-61.32	104.07

Total Stress Calculations per Section 13-8

Total Stresses at Short-side 1

Total Stress at short side 1 at N inner [STS_Ni]:

```
  = Sms + SbsNi
  = 3.20 + 15.71
  = 18.91 N./mm^2
```

Total Stress at short side 1 at N outer [STS_No]:

```
  = Sms + SbsNo
  = 3.20 + -24.77
```

```
  = -21.57 N./mm^2
```

Total Stress at short side 1 at Q inner [STS_Qi]:
```
  = Smsc + SbsQi
  = 3.20 + 38.88
  = 42.08 N./mm^2
```

Total Stress at short side 1 at Q outer [STS_Qo]:
```
  = Smsc + SbsQo
  = 3.20 + -61.32
  = -58.11 N./mm^2
```

Total Stresses at Short-side 2

Total Stress at short side 2 at N inner [STS_Ni]:
```
  = Sms + SbsNi
  = 3.20 + 15.71
  = 18.91 N./mm^2
```

Total Stress at short side 2 at N outer [STS_No]:
```
  = Sms + SbsNo
  = 3.20 + -24.77
  = -21.57 N./mm^2
```

Total Stress at short side 2 at Q inner [STS_Qi]:
```
  = Smsc + SbsQi
  = 3.20 + 38.88
  = 42.08 N./mm^2
```

Total Stress at short side 2 at Q outer [STS_Qo]:
```
  = Smsc + SbsQo
  = 3.20 + -61.32
  = -58.11 N./mm^2
```

Total Stresses at Long-side 1

Total Stress at long side 1 at M inner [STL_Mi]:
```
  = SmlA + SblMi
  = 1.75 + -38.44
  = -36.68 N./mm^2
```

Total Stress at long side 1 at M outer [STL_Mo]:
```
  = SmlA + SblMo
  = 1.75 + 60.62
  = 62.38 N./mm^2
```

Total Stress at long side 1 at Q inner [STL_Qi]:
```
  = Smlc + SblQi
  = 1.75 + 38.88
  = 40.63 N./mm^2
```

Total Stress at long side 1 at Q outer [STL_Qo]:
```
  = Smlc + SblQo
  = 1.75 + -61.32
  = -59.56 N./mm^2
```

Total Stresses at Long-side 2

Total Stress at long side 2 at M inner [STL_Mi]:
```
  = SmlA + SblMi
  = 1.75 + -38.44
  = -36.68 N./mm^2
```

Total Stress at long side 2 at M outer [STL_Mo]:
```
  = SmlA + SblMo
  = 1.75 + 60.62
  = 62.38 N./mm^2
```

Total Stress at long side 2 at Q inner [STL_Qi]:
```
  = Smlc + SblQi
  = 1.75 + 38.88
  = 40.63 N./mm^2
```

Total Stress at long side 2 at Q outer [STL_Qo]:
```
  = Smlc + SblQo
  = 1.75 + -61.32
  = -59.56 N./mm^2
```

TOTAL STRESSES: Total Stress Calculations per Section 13-8, Equations (9-12). (N./mm^2) :

STRESS LOCATIONS		Inner	Outer	Allowable
Short-side 1	at N	18.91	-21.57	104.07
	at Q	42.08	-58.11	104.07
Short-side 2	at N	18.91	-21.57	104.07
	at Q	42.08	-58.11	104.07
Long-side 1	at M	-36.68	62.38	104.07
	at Q	40.63	-59.56	104.07
Long-side 2	at M	-36.68	62.38	104.07
	at Q	40.63	-59.56	104.07

SUMMARY OF RESULTS:

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable)	3.20	N./mm^2
High Stress Percentage	2.35	%
M.A.W.P. for Membrane Stresses	21.24	bars

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable)	-61.32	N./mm^2
High Stress Percentage	58.92	%
M.A.W.P. for Bending Stresses	0.85	bars

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable)	62.38	N./mm^2
High Stress Percentage	59.94	%
M.A.W.P. for Total Stresses	0.83	bars

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

Rectangular Vessel Results For Item 1 : A4

SUMMARY OF RESULTS:

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable)	3.20	N./mm^2
High Stress Percentage	2.35	%
M.A.W.P. for Membrane Stresses	21.24	bars

BENDING STRESS SUMMARY,

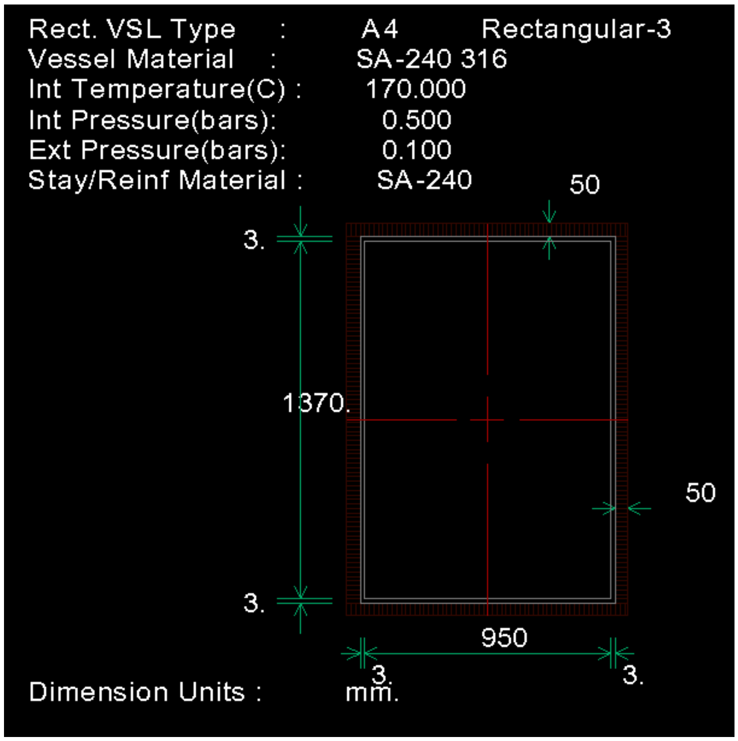
High Stress (Highest % of Allowable)	-61.32	N./mm^2
High Stress Percentage	58.92	%
M.A.W.P. for Bending Stresses	0.85	bars

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable)	62.38	N./mm^2
High Stress Percentage	59.94	%
M.A.W.P. for Total Stresses	0.83	bars

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

APPENDIX 4
CALCULATION
RECTANGULAR SECTION
ZONE 3



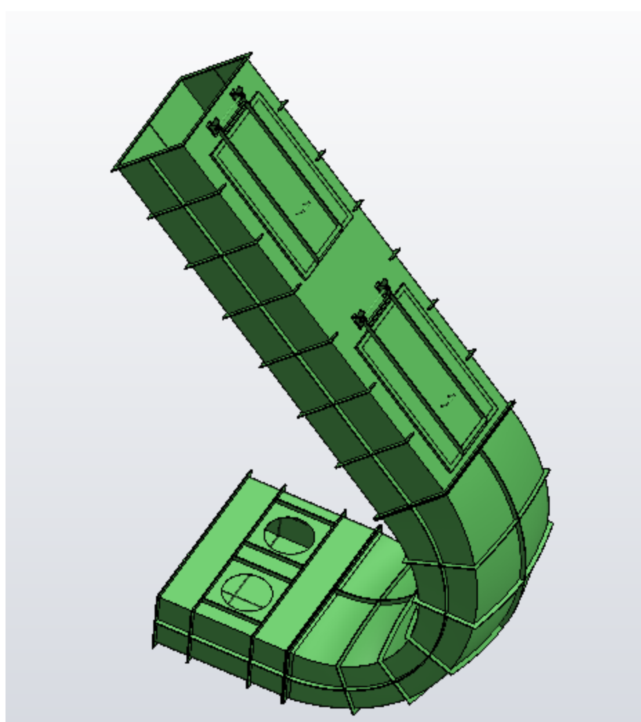


Figure D-Rectangular Duct - Zone 3

Table of Contents

MICROTEC
Rectangular Duct for Flash Dryer - Section 1

DESIGN CALCULATION

ASME Code Version   : 2017

Analysis Performed by : SL Client

Job File   : D:\2-PAYAM\1-Projects\Microtec Project\13-Microtec -Flash Dryer-5204\5204-Eng

Date of Analysis   : Feb 20,2026

PV Elite 2019 , January 2019

Note:
PV Elite performs all calculations internally in U.S. Customary Units
to remain compliant with the ASME Code and any built in assumptions in
the ASME Code formulae. Finalized results are converted to the user set of
selected units using conversion constants with adequate significant digits.

Input Echo, COMPONENT 1, Description: Rectangular-3

```
Figure Number Analyzed                                       A4

Design Internal Pressure                   P          0.5000  bars
Design External Pressure                Pext          0.1000  bars
Design Temperature                      Temp        170.0000  C

VESSEL MATERIAL DATA:
Material Specification                            SA-240 316
Shell Allowable Stress at Design Temp      S        136.0672  N./mm^2
Shell Allowable Stress at Ambient         SA        137.9000  N./mm^2
Shell Yield Stress at Design Temperature  Sy        156.1065  N./mm^2


SHORT-SIDE VESSEL DATA:
Short-side Length Dimension                H        950.0001  mm.
Minimum Thickness of Short-side Plates    t1          3.0000  mm.
Mid-side Joint Efficiency on Short-side    E          1.0000
Corner Joint Efficiency on Short-side     EC          1.0000

LONG-SIDE VESSEL DATA:
Long-side Length Dimension                 h       1370.0000  mm.
Minimum Thickness of Long-side Plates     t2          3.0000  mm.
Mid-side Joint Efficiency on Long-side     E          1.0000

REINFORCEMENT MATERIAL DATA:
Reinforcement Material Specification                  SA-240
Reinf Allowable Stress at Design Temp     Sr        120.0000  N./mm^2
Reinf Allowable Stress at Ambient         SA        153.7585  N./mm^2
Reinf Yield Stress at Design Temp         Sy        166.5450  N./mm^2


C-Factor for Reinforcement  (from UG-47)              2.1000
DELTA (Reinforcement Material Parameter)            485.0000  N./mm^2^0.5

SHORT-SIDE RECTANGULAR BEAM DATA:
Outside Distance from Outside of Vessel              50.0000  mm.
Width of Reinforcing Member                          10.0000  mm.

LONG-SIDE RECTANGULAR BEAM DATA:
Outside Distance from Outside of Vessel              50.0000  mm.
Width of Reinforcing Member                          10.0000  mm.
```

Rectangular Vessel Results, Item number 1, Desc: Rectangular-3
ASME Code, Section VIII, Division 1, 2017 App. 13

Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):

Short-side 1 Calculations

Membrane Ligament Efficiency [Em]:
  = 1.000

Bending Ligament Efficiency [Eb]:
  = 1.000

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:
  = t1 - CA / 2
  = 3.000 - 0.000 / 2
  = 1.500 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:
```
= -( t1 - CA ) / 2
= -( 3.000 - 0.000 ) / 2
= -1.500 mm.
```

Short-side 2 Calculations

Membrane Ligament Efficiency [Em]:
```
= 1.000
```

Bending Ligament Efficiency [Eb]:
```
= 1.000
```

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:
```
= t1 - CA / 2
= 3.000 - 0.000 / 2
= 1.500 mm.
```

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:
```
= -( t1 - CA ) / 2
= -( 3.000 - 0.000 ) / 2
= -1.500 mm.
```

Long-side 1 Calculations

Membrane Ligament Efficiency [Em]:
```
= 1.000
```

Bending Ligament Efficiency [Eb]:
```
= 1.000
```

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:
```
= t1 - CA / 2
= 3.000 - 0.000 / 2
= 1.500 mm.
```

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:
```
= -( t1 - CA ) / 2
= -( 3.000 - 0.000 ) / 2
= -1.500 mm.
```

Long-side 2 Calculations

Membrane Ligament Efficiency [Em]:
```
= 1.000
```

Bending Ligament Efficiency [Eb]:
```
= 1.000
```

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:
```
= t1 - CA / 2
= 3.000 - 0.000 / 2
= 1.500 mm.
```

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:
```
= -( t1 - CA ) / 2
= -( 3.000 - 0.000 ) / 2
= -1.500 mm.
```

Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):

		Em	Eb	Ci	Co
Short-side	1	1.000	1.000	1.500	-1.500
	2	1.000	1.000	1.500	-1.500
Long-side	1	1.000	1.000	1.500	-1.500
	2	1.000	1.000	1.500	-1.500

Effective Width of Shell Plate (Section 13-8, Eq. (2))

In Compression [w]:
```
  = Min( Min( t1, t2 ) * Delta / sqrt( Sy ), p )
  = Min( Min( 3.00 , 3.00 ) * 5840.83 / sqrt( 156.11 ), 65.00 )
  = 65.00 mm.
```

In Tension [w]:
```
  = 65.00 mm.
```

Moment of Inertia of a Strip of the Vessel Wall:

```
    Thickness  t1, I1  = 0.0000 cm**4
    Thickness  t2, I2  = 0.0000 cm**4
```

Effective Area of Reinforcement on Shell (t * w):

```
    Short-side Ap = 1.9500 cm^2
    Long-side  Ap = 1.9500 cm^2
```

Moment of Inertia of Effective Area of Reinforcement (w * t3 / 12):**

```
    Short-side Is = 0.0146 cm**4
    Long-side  Il = 0.0146 cm**4
```

Moment of Inertia of Combined Reinforcement and Effective Width:

```
    In Compression I11 = 20.2830 cm**4
                   I21 = 20.2830 cm**4
    In Tension     I11 = 20.2830 cm**4
                   I21 = 20.2830 cm**4
```

Distance from Neutral Axis of Cross Section of Composite Section to the Inside Surface of the Vessel (mm.):

		Ci	Co
Short-side,	in Compression	20.5647	-32.4353
	in Tension	20.5647	-32.4353
Long-side,	in Compression	20.5647	-32.4353
	in Tension	20.5647	-32.4353

Rectangular Vessel Reinforcement Parameters:

```
    Alpha1 =      H1 / h1      = 0.7055
    k(comp)= (I22/I11)*Alpha1 = 0.7055
    k(tens)= (I22/I11)*Alpha1 = 0.7055
```

Membrane Stress Calculations per Section 13-8

Membrane Stresses at Short-side 1

Membrane Stress at Short-side 1 [Sms]:
```
  = p * h * p / ( 2 * ( A1 + p * t1 ))
  = 0.50 * 1370.00 * 65.00 / ( 2 * ( 500.000 + 65.00 * 3.00 ))
  = 3.20 N./mm^2
```

Membrane Stresses at Short-side 2

Membrane Stress at Short-side 2 [Sms]:
```
  = p * h * p / ( 2 * ( A1 + p * t1 ))
  = 0.50 * 1370.00 * 65.00 / ( 2 * ( 500.000 + 65.00 * 3.00 ))
  = 3.20 N./mm^2
```

Membrane Stresses at Long-side 1

Membrane Stress at Long-side 1 at A[SmlA]:
```
  = p * H * p / ( 2 * ( A2 + p * t2 ))
  = 0.50 * 950.00 * 65.00 / ( 2 * ( 5.000 + 65.00 * 3.00 ))
  = 2.22 N./mm^2
```

Membrane Stresses at Long-side 2

Membrane Stress at Long-side 2 at A[SmlA]:
```
  = p * H * p / ( 2 * ( A2 + p * t2 ))
  = 0.50 * 950.00 * 65.00 / ( 2 * ( 5.000 + 65.00 * 3.00 ))
  = 2.22 N./mm^2
```

Membrane Stresses at Corner sections

Membrane Stress at Short side [Smsc]:
```
  = p * h * p / ( 2 * ( A1 + p * t1 ))
  = 0.50 * 1370.00 * 65.00 / ( 2 * ( 5.000 + 65.00 * 3.00 ))
  = 3.20 N./mm^2
```

Membrane Stress at Long side [Smlc]:
```
  = p * H * p / ( 2 * ( A2 + p * t2 ))
  = 0.50 * 950.00 * 65.00 / ( 2 * ( 5.000 + 65.00 * 3.00 ))
  = 2.22 N./mm^2
```

MEMBRANE STRESSES: Membrane Stress Calculations per Section 13-8, Equations (3) and (4). (N./mm^2) :

STRESS LOCATIONS	Actual	Allowable
Short-side 1	3.20	120.00
Short-side 2	3.20	120.00
Short-side Corner	3.20	120.00
Long-side 1 at A	2.22	120.00
Long-side 2 at A	2.22	120.00
Long-side Corner	2.22	120.00

Bending Stress Calculations per Section 13-8

Bending Stresses at Short-side 1

Bending Stress at Short-side 1 at N Inner[SbsNi]:

$= P * p * c / (24 * I11) * [-3 * H^2 + 2 * h^2 * ((1 + Alpha1^2 * k) / (1 + k))]$

$= 0.5 * 65.0 * 20.56 / (24 * 20.3) * [-3 * 950.00^2 + 2 * 1370.00^2 * ((1 + 0.71^2 * 0.71) / (1 + 0.71))]$

$= 3.66$ N./mm^2

Bending Stress at Short-side 1 at N Outer[SbsNo]:

$= P * p * c / (24 * I11) * [-3 * H^2 + 2 * h^2 * ((1 + Alpha1^2 * k) / (1 + k))]$

$= 0.5 * 65.0 * -32.44 / (24 * 20.3) * [-3 * 950.00^2 + 2 * 1370.00^2 * ((1 + 0.71^2 * 0.71) / (1 + 0.71))]$

$= -5.77$ N./mm^2

Bending Stress at Short-side 1 at Q Inner[SbsQi]:

```
= P * h² * p * c / ( 12 * I11 ) *
  (( 1 + Alpha1² * k ) / ( 1 + k ))
= 0.50 * 1370.00² * 65.00 * 20.56 / ( 12 * 20.28 ) *
  (( 1 + 0.71² * 0.71 ) / ( 1 + 0.71 ))
= 40.83 N./mm^2
```

Bending Stress at Short-side 1 at Q Outer[SbsQo]:

```
= P * h² * p * c / ( 12 * I11 ) *
  (( 1 + Alpha1² * k ) / ( 1 + k ))
= 0.50 * 1370.00² * 65.00 * -32.44 / ( 12 * 20.28 ) *
  (( 1 + 0.71² * 0.71 ) / ( 1 + 0.71 ))
= -64.40 N./mm^2
```

Bending Stresses at Short-side 2

Bending Stress at Short-side 2 at N Inner[SbsNi]:

```
= P * p * c / ( 24 * I11 ) * [ -3 * H² + 2 * h²
  * (( 1 + Alpha1² * k ) / ( 1 + k ))]
= 0.5 * 65.0 * 20.56 / ( 24 * 20.3 ) * [ -3 * 950.00² + 2 * 1370.00² *
  (( 1 + 0.71² * 0.71 ) / ( 1 + 0.71 ))]
= 3.66 N./mm^2
```

Bending Stress at Short-side 2 at N Outer[SbsNo]:

```
= P * p * c / ( 24 * I11 ) * [ -3 * H² + 2 * h²
  * (( 1 + Alpha1² * k ) / ( 1 + k ))]
= 0.5 * 65.0 * -32.44 / ( 24 * 20.3 ) * [ -3 * 950.00² + 2 * 1370.00² *
  (( 1 + 0.71² * 0.71 ) / ( 1 + 0.71 ))]
= -5.77 N./mm^2
```

Bending Stress at Short-side 2 at Q Inner[SbsQi]:

```
= P * h² * p * c / ( 12 * I11 ) *
  (( 1 + Alpha1² * k ) / ( 1 + k ))
= 0.50 * 1370.00² * 65.00 * 20.56 / ( 12 * 20.28 ) *
  (( 1 + 0.71² * 0.71 ) / ( 1 + 0.71 ))
= 40.83 N./mm^2
```

Bending Stress at Short-side 2 at Q Outer[SbsQo]:

```
= P * h² * p * c / ( 12 * I11 ) *
  (( 1 + Alpha1² * k ) / ( 1 + k ))
= 0.50 * 1370.00² * 65.00 * -32.44 / ( 12 * 20.28 ) *
  (( 1 + 0.71² * 0.71 ) / ( 1 + 0.71 ))
= -64.40 N./mm^2
```

Bending Stresses at Long-side 1

Bending Stress at Long-side 1 at M Inner[SblMi]:

```
= P * h² * p * c / ( 24 * I21 ) * [ -3 + 2 *
  (( 1 + Alpha1² * k ) / ( 1 + k ))]
= 0.50 * 1370.00² * 65.00 * 20.56 / ( 24 * 20.28 ) * [ -3 + 2 *
  (( 1 + 0.71² * 0.71 ) / ( 1 + 0.71 ))]
= -36.48 N./mm^2
```

Bending Stress at Long-side 1 at M Outer[SblMo]:

```
= P * h² * p * c / ( 24 * I21 ) * [ -3 + 2 *
  (( 1 + Alpha1² * k ) / ( 1 + k ))]
= 0.50 * 1370.00² * 65.00 * -32.44 / ( 24 * 20.28 ) * [ -3 + 2 *
  (( 1 + 0.71² * 0.71 ) / ( 1 + 0.71 ))]
= 57.54 N./mm^2
```

Bending Stress at Long-side 1 at Q Inner[SblQi]:

```
= P * h² * p * c / ( 12 * I21 ) *
  (( 1 + Alpha1² * k ) / ( 1 + k ))
= 0.50 * 1370.00² * 65.00 * 20.56 / ( 24 * 20.28 ) *
```

```
    (( 1 + 0.71² * 0.71 ) / ( 1 + 0.71 ))]
  = 40.83 N./mm^2
```

Bending Stress at Long-side 1 at Q Outer[SblQo]:

```
  = P * h² * p * c / ( 12 * I21 ) *
    (( 1 + Alpha1² * k ) / ( 1 + k ))
  = 0.50 * 1370.00² * 65.00 * -32.44 / ( 24 * 20.28 ) *
    (( 1 + 0.71² * 0.71 ) / ( 1 + 0.71 ))]
  = -64.40 N./mm^2
```

Bending Stresses at Long-side 2

Bending Stress at Long-side 2 at M Inner[SblMi]:

```
  = P * h² * p * c / ( 24 * I21 ) * [ -3 + 2 *
    (( 1 + Alpha1² * k ) / ( 1 + k ))]
  = 0.50 * 1370.00² * 65.00 * 20.56 / ( 24 * 20.28 ) * [ -3 + 2 *
    (( 1 + 0.71² * 0.71 ) / ( 1 + 0.71 ))]
  = -36.48 N./mm^2
```

Bending Stress at Long-side 2 at M Outer[SblMo]:

```
  = P * h² * p * c / ( 24 * I21 ) * [ -3 + 2 *
    (( 1 + Alpha1² * k ) / ( 1 + k ))]
  = 0.50 * 1370.00² * 65.00 * -32.44 / ( 24 * 20.28 ) * [ -3 + 2 *
    (( 1 + 0.71² * 0.71 ) / ( 1 + 0.71 ))]
  = 57.54 N./mm^2
```

Bending Stress at Long-side 2 at Q Inner[SblQi]:

```
  = P * h² * p * c / ( 12 * I21 ) *
    (( 1 + Alpha1² * k ) / ( 1 + k ))
  = 0.50 * 1370.00² * 65.00 * 20.56 / ( 24 * 20.28 ) *
    (( 1 + 0.71² * 0.71 ) / ( 1 + 0.71 ))]
  = 40.83 N./mm^2
```

Bending Stress at Long-side 2 at Q Outer[SblQo]:

```
  = P * h² * p * c / ( 12 * I21 ) *
    (( 1 + Alpha1² * k ) / ( 1 + k ))
  = 0.50 * 1370.00² * 65.00 * -32.44 / ( 24 * 20.28 ) *
    (( 1 + 0.71² * 0.71 ) / ( 1 + 0.71 ))]
  = -64.40 N./mm^2
```

BENDING STRESSES: Bending Stress Calculations per Section 13-8, Equations (5-8). (N./mm^2) :

STRESS LOCATIONS		Inner	Outer	Allowable
Short-side 1	at N	3.66	-5.77	104.07
	at Q	40.83	-64.40	104.07
Short-side 2	at N	3.66	-5.77	104.07
	at Q	40.83	-64.40	104.07
Long-side 1	at M	-36.48	57.54	104.07
	at Q	40.83	-64.40	104.07
Long-side 2	at M	-36.48	57.54	104.07
	at Q	40.83	-64.40	104.07

Total Stress Calculations per Section 13-8

Total Stresses at Short-side 1

Total Stress at short side 1 at N inner [STS_Ni]:

```
  = Sms + SbsNi
  = 3.20 + 3.66
  = 6.86 N./mm^2
```

Total Stress at short side 1 at N outer [STS_No]:

```
= Sms + SbsNo
= 3.20 + -5.77
= -2.56 N./mm^2
```

Total Stress at short side 1 at Q inner [STS_Qi]:

```
= Smsc + SbsQi
= 3.20 + 40.83
= 44.04 N./mm^2
```

Total Stress at short side 1 at Q outer [STS_Qo]:

```
= Smsc + SbsQo
= 3.20 + -64.40
= -61.20 N./mm^2
```

Total Stresses at Short-side 2

Total Stress at short side 2 at N inner [STS_Ni]:

```
= Sms + SbsNi
= 3.20 + 3.66
= 6.86 N./mm^2
```

Total Stress at short side 2 at N outer [STS_No]:

```
= Sms + SbsNo
= 3.20 + -5.77
= -2.56 N./mm^2
```

Total Stress at short side 2 at Q inner [STS_Qi]:

```
= Smsc + SbsQi
= 3.20 + 40.83
= 44.04 N./mm^2
```

Total Stress at short side 2 at Q outer [STS_Qo]:

```
= Smsc + SbsQo
= 3.20 + -64.40
= -61.20 N./mm^2
```

Total Stresses at Long-side 1

Total Stress at long side 1 at M inner [STL_Mi]:

```
= SmlA + SblMi
= 2.22 + -36.48
= -34.26 N./mm^2
```

Total Stress at long side 1 at M outer [STL_Mo]:

```
= SmlA + SblMo
= 2.22 + 57.54
= 59.76 N./mm^2
```

Total Stress at long side 1 at Q inner [STL_Qi]:

```
= Smlc + SblQi
= 2.22 + 40.83
= 43.05 N./mm^2
```

Total Stress at long side 1 at Q outer [STL_Qo]:

```
= Smlc + SblQo
= 2.22 + -64.40
= -62.18 N./mm^2
```

Total Stresses at Long-side 2

Total Stress at long side 2 at M inner [STL_Mi]:

```
= SmlA + SblMi
= 2.22 + -36.48
```

= -34.26 N./mm^2

Total Stress at long side 2 at M outer [STL_Mo]:
= SmlA + SblMo
= 2.22 + 57.54
= 59.76 N./mm^2

Total Stress at long side 2 at Q inner [STL_Qi]:
= Smlc + SblQi
= 2.22 + 40.83
= 43.05 N./mm^2

Total Stress at long side 2 at Q outer [STL_Qo]:
= Smlc + SblQo
= 2.22 + -64.40
= -62.18 N./mm^2

TOTAL STRESSES: Total Stress Calculations per Section 13-8, Equations (9-12). (N./mm^2) :

STRESS LOCATIONS		Inner	Outer	Allowable
Short-side 1	at N	6.86	-2.56	104.07
	at Q	44.04	-61.20	104.07
Short-side 2	at N	6.86	-2.56	104.07
	at Q	44.04	-61.20	104.07
Long-side 1	at M	-34.26	59.76	104.07
	at Q	43.05	-62.18	104.07
Long-side 2	at M	-34.26	59.76	104.07
	at Q	43.05	-62.18	104.07

Note: The following can be used for outer stress:

Short-side 1 at N, outer allowable	111.03 N./mm^2
Short-side 2 at N, outer allowable	111.03 N./mm^2
Long-side 1 at M, outer allowable	111.03 N./mm^2
Long-side 2 at M, outer allowable	111.03 N./mm^2
At Corner Q, outer allowable	111.03 N./mm^2

SUMMARY OF RESULTS:

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable)	3.20	N./mm^2
High Stress Percentage	2.67	%
M.A.W.P. for Membrane Stresses	18.73	bars

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable)	-64.40	N./mm^2
High Stress Percentage	61.88	%
M.A.W.P. for Bending Stresses	0.81	bars

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable)	-62.18	N./mm^2
High Stress Percentage	59.75	%
M.A.W.P. for Total Stresses	0.84	bars

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

Rectangular Vessel Results For Item 1 : A4

SUMMARY OF RESULTS:

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable)	3.20	N./mm^2
High Stress Percentage	2.67	%
M.A.W.P. for Membrane Stresses	18.73	bars

BENDING STRESS SUMMARY,

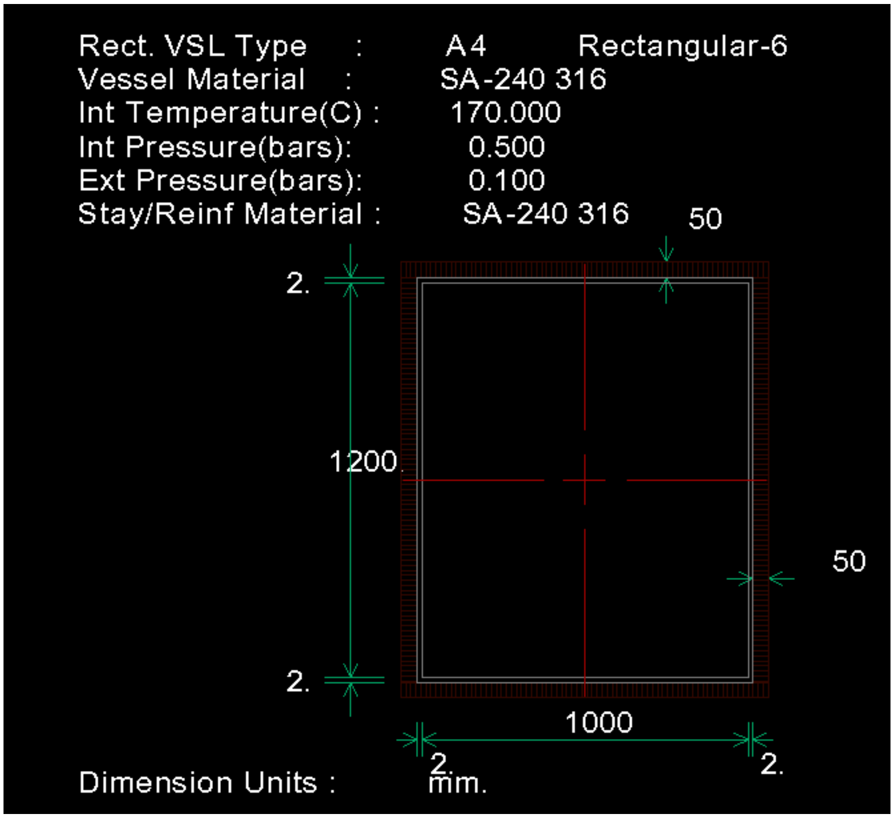
High Stress (Highest % of Allowable)	-64.40	N./mm^2
High Stress Percentage	61.88	%
M.A.W.P. for Bending Stresses	0.81	bars

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable)	-62.18	N./mm^2
High Stress Percentage	59.75	%
M.A.W.P. for Total Stresses	0.84	bars

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

APPENDIX 5
CALCULATION
RECTANGULAR SECTION
ZONE 6



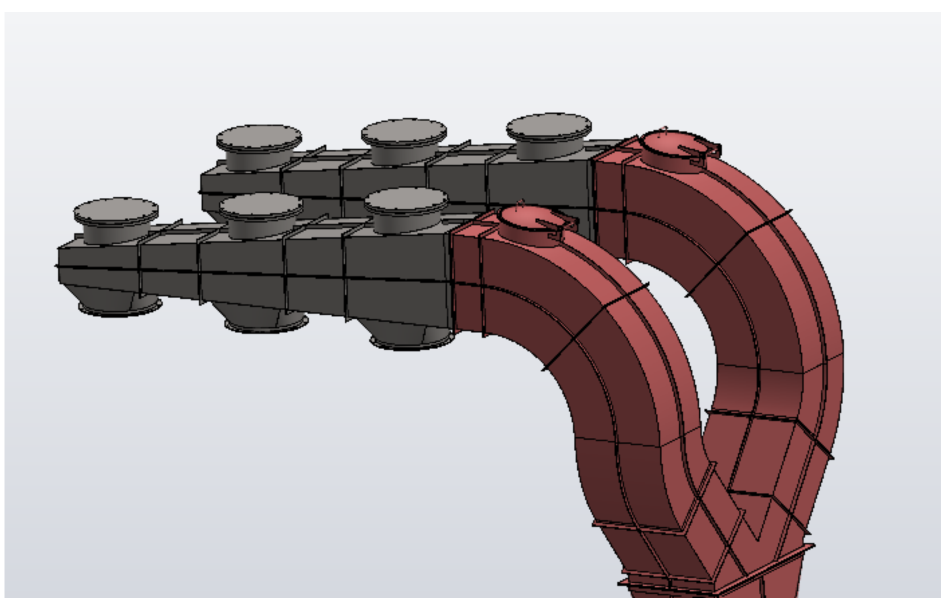


Figure E- Rectangular Duct - Zone 6

Table of Contents

MICROTEC
Rectangular Duct for Flash Dryer - Section 1

DESIGN CALCULATION

ASME Code Version : 2017

Analysis Performed by : SL Client

Job File : D:\2-PAYAM\1-Projects\Microtec Project\13-Microtec -Flash Dryer-5204\5204-Eng

Date of Analysis : Feb 20,2026

PV Elite 2019 , January 2019

Note:
PV Elite performs all calculations internally in U.S. Customary Units to remain compliant with the ASME Code and any built in assumptions in the ASME Code formulae. Finalized results are converted to the user set of selected units using conversion constants with adequate significant digits.

Input Echo, COMPONENT 1, Description: Rectangular-6

```
 Figure Number Analyzed                                        A4

 Design Internal Pressure                 P          0.5000  bars
 Design External Pressure              Pext          0.1000  bars
 Design Temperature                    Temp        170.0000  C

 VESSEL MATERIAL DATA:
 Material Specification                          SA-240 316
 Shell Allowable Stress at Design Temp    S        136.0672  N./mm^2
 Shell Allowable Stress at Ambient       SA        137.9000  N./mm^2
 Shell Yield Stress at Design Temperature Sy       156.1065  N./mm^2


 SHORT-SIDE VESSEL DATA:
 Short-side Length Dimension              H       1000.0000  mm.
 Minimum Thickness of Short-side Plates  t1          3.0000  mm.
 Mid-side Joint Efficiency on Short-side  E          1.0000
 Corner Joint Efficiency on Short-side   EC          1.0000

 LONG-SIDE VESSEL DATA:
 Long-side Length Dimension               h       1200.0000  mm.
 Minimum Thickness of Long-side Plates   t2          3.0000  mm.
 Mid-side Joint Efficiency on Long-side   E          1.0000

 REINFORCEMENT MATERIAL DATA:
 Reinforcement Material Specification            SA-240 316
 Reinf Allowable Stress at Design Temp   Sr        136.0672  N./mm^2
 Reinf Allowable Stress at Ambient       SA        137.9000  N./mm^2
 Reinf Yield Stress at Design Temp       Sy        156.1065  N./mm^2


 C-Factor for Reinforcement  (from UG-47)            2.1000
 DELTA (Reinforcement Material Parameter)          485.0000  N./mm^2^0.5

 SHORT-SIDE RECTANGULAR BEAM DATA:
 Outside Distance from Outside of Vessel            50.0000  mm.
 Width of Reinforcing Member                        10.0000  mm.

 LONG-SIDE RECTANGULAR BEAM DATA:
 Outside Distance from Outside of Vessel            50.0000  mm.
 Width of Reinforcing Member                        10.0000  mm.
```

Rectangular Vessel Results, Item number 1, Desc: Rectangular-6
ASME Code, Section VIII, Division 1, 2017 App. 13

Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):

Short-side 1 Calculations

Membrane Ligament Efficiency [Em]:
 = 1.000

Bending Ligament Efficiency [Eb]:
 = 1.000

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:
 = t1 - CA / 2
 = 3.000 - 0.000 / 2
 = 1.500 mm.

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:
```
  = -( t1 - CA ) / 2
  = -( 3.000 - 0.000 ) / 2
  = -1.500 mm.
```

Short-side 2 Calculations

Membrane Ligament Efficiency [Em]:
```
  = 1.000
```

Bending Ligament Efficiency [Eb]:
```
  = 1.000
```

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:
```
  = t1 - CA / 2
  = 3.000 - 0.000 / 2
  = 1.500 mm.
```

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:
```
  = -( t1 - CA ) / 2
  = -( 3.000 - 0.000 ) / 2
  = -1.500 mm.
```

Long-side 1 Calculations

Membrane Ligament Efficiency [Em]:
```
  = 1.000
```

Bending Ligament Efficiency [Eb]:
```
  = 1.000
```

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:
```
  = t1 - CA / 2
  = 3.000 - 0.000 / 2
  = 1.500 mm.
```

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:
```
  = -( t1 - CA ) / 2
  = -( 3.000 - 0.000 ) / 2
  = -1.500 mm.
```

Long-side 2 Calculations

Membrane Ligament Efficiency [Em]:
```
  = 1.000
```

Bending Ligament Efficiency [Eb]:
```
  = 1.000
```

Dist from Neutral axis of c/s to inside surface of the vesssel [Ci]:
```
  = t1 - CA / 2
  = 3.000 - 0.000 / 2
  = 1.500 mm.
```

Dist from Neutral axis of c/s to extreme outside surface of the section [Co]:
```
  = -( t1 - CA ) / 2
  = -( 3.000 - 0.000 ) / 2
  = -1.500 mm.
```

Ligament Efficiency Calculations (Section 13-6, Equations (1)-(6)):

	Em	Eb	Ci	Co
Short-side 1	1.000	1.000	1.500	-1.500

```
              2       1.000       1.000       1.500      -1.500
    Long-side 1       1.000       1.000       1.500      -1.500
              2       1.000       1.000       1.500      -1.500
```

Effective Width of Shell Plate (Section 13-8, Eq. (2))

In Compression [w]:

```
  = Min( Min( t1, t2 ) * Delta / sqrt( Sy ), p )
  = Min( Min( 3.00 , 3.00 ) * 5840.83 / sqrt( 156.11 ), 80.00 )
  = 80.00 mm.
```

In Tension [w]:

```
  = 80.00 mm.
```

Moment of Inertia of a Strip of the Vessel Wall:

```
    Thickness  t1, I1  = 0.0000 cm**4
    Thickness  t2, I2  = 0.0000 cm**4
```

Effective Area of Reinforcement on Shell (t * w):

```
    Short-side Ap = 2.4000 cm^2
    Long-side  Ap = 2.4000 cm^2
```

Moment of Inertia of Effective Area of Reinforcement (w * t3 / 12):**

```
    Short-side Is = 0.0180 cm**4
    Long-side  Il = 0.0180 cm**4
```

Moment of Inertia of Combined Reinforcement and Effective Width:

```
    In Compression I11 = 21.8225 cm**4
                   I21 = 21.8225 cm**4
    In Tension     I11 = 21.8225 cm**4
                   I21 = 21.8225 cm**4
```

Distance from Neutral Axis of Cross Section of Composite Section to the Inside Surface of the Vessel (mm.):

```
                                         Ci            Co
    Short-side, in Compression        19.4054       -33.5946
                in Tension            19.4054       -33.5946
    Long-side,  in Compression        19.4054       -33.5946
                in Tension            19.4054       -33.5946
```

Rectangular Vessel Reinforcement Parameters:

```
    Alpha1 =      H1 / h1      = 0.8408
    k(comp)= (I22/I11)*Alpha1 = 0.8408
    k(tens)= (I22/I11)*Alpha1 = 0.8408
```

Membrane Stress Calculations per Section 13-8

Membrane Stresses at Short-side 1

Membrane Stress at Short-side 1 [Sms]:

```
  = p * h * p / ( 2 * ( A1 + p * t1 ))
  = 0.50 * 1200.00 * 80.00 / ( 2 * ( 500.000 + 80.00 * 3.00 ))
  = 3.24 N./mm^2
```

Membrane Stresses at Short-side 2

Membrane Stress at Short-side 2 [Sms]:
```
  = p * h * p / ( 2 * ( A1 + p * t1 ))
  = 0.50 * 1200.00 * 80.00 / ( 2 * ( 500.000 + 80.00 * 3.00 ))
  = 3.24 N./mm^2
```

Membrane Stresses at Long-side 1

Membrane Stress at Long-side 1 at A[SmlA]:
```
  = p * H * p / ( 2 * ( A2 + p * t2 ))
  = 0.50 * 1000.00 * 80.00 / ( 2 * ( 5.000 + 80.00 * 3.00 ))
  = 2.70 N./mm^2
```

Membrane Stresses at Long-side 2

Membrane Stress at Long-side 2 at A[SmlA]:
```
  = p * H * p / ( 2 * ( A2 + p * t2 ))
  = 0.50 * 1000.00 * 80.00 / ( 2 * ( 5.000 + 80.00 * 3.00 ))
  = 2.70 N./mm^2
```

Membrane Stresses at Corner sections

Membrane Stress at Short side [Smsc]:
```
  = p * h * p / ( 2 * ( A1 + p * t1 ))
  = 0.50 * 1200.00 * 80.00 / ( 2 * ( 5.000 + 80.00 * 3.00 ))
  = 3.24 N./mm^2
```

Membrane Stress at Long side [Smlc]:
```
  = p * H * p / ( 2 * ( A2 + p * t2 ))
  = 0.50 * 1000.00 * 80.00 / ( 2 * ( 5.000 + 80.00 * 3.00 ))
  = 2.70 N./mm^2
```

MEMBRANE STRESSES: Membrane Stress Calculations per Section 13-8, Equations (3) and (4). (N./mm^2) :

STRESS LOCATIONS	Actual	Allowable
Short-side 1	3.24	136.07
Short-side 2	3.24	136.07
Short-side Corner	3.24	136.07
Long-side 1 at A	2.70	136.07
Long-side 2 at A	2.70	136.07
Long-side Corner	2.70	136.07

Bending Stress Calculations per Section 13-8

Bending Stresses at Short-side 1

Bending Stress at Short-side 1 at N Inner[SbsNi]:

$$= P * p * c / (24 * I11) * [-3 * H^2 + 2 * h^2 * ((1 + Alpha1^2 * k) / (1 + k))]$$

$$= 0.5 * 80.0 * 19.41 / (24 * 21.8) * [-3 * 1000.00^2 + 2 * 1200.00^2 * ((1 + 0.84^2 * 0.84) / (1 + 0.84))]$$

$$= -7.49 \text{ N./mm}^2$$

Bending Stress at Short-side 1 at N Outer[SbsNo]:

$$= P * p * c / (24 * I11) * [-3 * H^2 + 2 * h^2 * ((1 + Alpha1^2 * k) / (1 + k))]$$

$$= 0.5 * 80.0 * -33.59 / (24 * 21.8) * [-3 * 1000.00^2 + 2 * 1200.00^2 * ((1 + 0.84^2 * 0.84) / (1 + 0.84))]$$

$$= 12.97 \text{ N./mm}^2$$

Bending Stress at Short-side 1 at Q Inner[SbsQi]:

$$= P * h^2 * p * c / (12 * I11) * ((1 + Alpha1^2 * k) / (1 + k))$$

$$= 0.50 * 1200.00^2 * 80.00 * 19.41 / (12 * 21.82) *$$

```
    (( 1 + 0.84² * 0.84 ) / ( 1 + 0.84 ))
  = 36.97 N./mm^2
```

Bending Stress at Short-side 1 at Q Outer[SbsQo]:

```
  = P * h² * p * c / ( 12 * I11 ) *
    (( 1 + Alpha1² * k ) / ( 1 + k ))
  = 0.50 * 1200.00² * 80.00 * -33.59 / ( 12 * 21.82 ) *
    (( 1 + 0.84² * 0.84 ) / ( 1 + 0.84 ))
  = -64.00 N./mm^2
```

Bending Stresses at Short-side 2

Bending Stress at Short-side 2 at N Inner[SbsNi]:

```
  = P * p * c / ( 24 * I11 ) * [ -3 * H² + 2 * h²
    * (( 1 + Alpha1² * k ) / ( 1 + k ))]
  = 0.5 * 80.0 * 19.41 / ( 24 * 21.8 ) * [ -3 * 1000.00² + 2 * 1200.00² *
    (( 1 + 0.84² * 0.84 ) / ( 1 + 0.84 ))]
  = -7.49 N./mm^2
```

Bending Stress at Short-side 2 at N Outer[SbsNo]:

```
  = P * p * c / ( 24 * I11 ) * [ -3 * H² + 2 * h²
    * (( 1 + Alpha1² * k ) / ( 1 + k ))]
  = 0.5 * 80.0 * -33.59 / ( 24 * 21.8 ) * [ -3 * 1000.00² + 2 * 1200.00² *
    (( 1 + 0.84² * 0.84 ) / ( 1 + 0.84 ))]
  = 12.97 N./mm^2
```

Bending Stress at Short-side 2 at Q Inner[SbsQi]:

```
  = P * h² * p * c / ( 12 * I11 ) *
    (( 1 + Alpha1² * k ) / ( 1 + k ))
  = 0.50 * 1200.00² * 80.00 * 19.41 / ( 12 * 21.82 ) *
    (( 1 + 0.84² * 0.84 ) / ( 1 + 0.84 ))
  = 36.97 N./mm^2
```

Bending Stress at Short-side 2 at Q Outer[SbsQo]:

```
  = P * h² * p * c / ( 12 * I11 ) *
    (( 1 + Alpha1² * k ) / ( 1 + k ))
  = 0.50 * 1200.00² * 80.00 * -33.59 / ( 12 * 21.82 ) *
    (( 1 + 0.84² * 0.84 ) / ( 1 + 0.84 ))
  = -64.00 N./mm^2
```

Bending Stresses at Long-side 1

Bending Stress at Long-side 1 at M Inner[SblMi]:

```
  = P * h² * p * c / ( 24 * I21 ) * [ -3 + 2 *
    (( 1 + Alpha1² * k ) / ( 1 + k ))]
  = 0.50 * 1200.00² * 80.00 * 19.41 / ( 24 * 21.82 ) * [ -3 + 2 *
    (( 1 + 0.84² * 0.84 ) / ( 1 + 0.84 ))]
  = -27.06 N./mm^2
```

Bending Stress at Long-side 1 at M Outer[SblMo]:

```
  = P * h² * p * c / ( 24 * I21 ) * [ -3 + 2 *
    (( 1 + Alpha1² * k ) / ( 1 + k ))]
  = 0.50 * 1200.00² * 80.00 * -33.59 / ( 24 * 21.82 ) * [ -3 + 2 *
    (( 1 + 0.84² * 0.84 ) / ( 1 + 0.84 ))]
  = 46.84 N./mm^2
```

Bending Stress at Long-side 1 at Q Inner[SblQi]:

```
  = P * h² * p * c / ( 12 * I21 ) *
    (( 1 + Alpha1² * k ) / ( 1 + k ))
  = 0.50 * 1200.00² * 80.00 * 19.41 / ( 24 * 21.82 ) *
    (( 1 + 0.84² * 0.84 ) / ( 1 + 0.84 ))]
  = 36.97 N./mm^2
```

Bending Stress at Long-side 1 at Q Outer[SblQo]:
```
  = P * h² * p * c / ( 12 * I21 ) *
    (( 1 + Alpha1² * k ) / ( 1 + k ))
  = 0.50 * 1200.00² * 80.00 * -33.59 / ( 24 * 21.82 ) *
    (( 1 + 0.84² * 0.84 ) / ( 1 + 0.84 ))]
  = -64.00 N./mm^2
```

Bending Stresses at Long-side 2

Bending Stress at Long-side 2 at M Inner[SblMi]:
```
  = P * h² * p * c / ( 24 * I21 ) * [ -3 + 2 *
    (( 1 + Alpha1² * k ) / ( 1 + k ))]
  = 0.50 * 1200.00² * 80.00 * 19.41 / ( 24 * 21.82 ) * [ -3 + 2 *
    (( 1 + 0.84² * 0.84 ) / ( 1 + 0.84 ))]
  = -27.06 N./mm^2
```

Bending Stress at Long-side 2 at M Outer[SblMo]:
```
  = P * h² * p * c / ( 24 * I21 ) * [ -3 + 2 *
    (( 1 + Alpha1² * k ) / ( 1 + k ))]
  = 0.50 * 1200.00² * 80.00 * -33.59 / ( 24 * 21.82 ) * [ -3 + 2 *
    (( 1 + 0.84² * 0.84 ) / ( 1 + 0.84 ))]
  = 46.84 N./mm^2
```

Bending Stress at Long-side 2 at Q Inner[SblQi]:
```
  = P * h² * p * c / ( 12 * I21 ) *
    (( 1 + Alpha1² * k ) / ( 1 + k ))
  = 0.50 * 1200.00² * 80.00 * 19.41 / ( 24 * 21.82 ) *
    (( 1 + 0.84² * 0.84 ) / ( 1 + 0.84 ))]
  = 36.97 N./mm^2
```

Bending Stress at Long-side 2 at Q Outer[SblQo]:
```
  = P * h² * p * c / ( 12 * I21 ) *
    (( 1 + Alpha1² * k ) / ( 1 + k ))
  = 0.50 * 1200.00² * 80.00 * -33.59 / ( 24 * 21.82 ) *
    (( 1 + 0.84² * 0.84 ) / ( 1 + 0.84 ))]
  = -64.00 N./mm^2
```

BENDING STRESSES: Bending Stress Calculations per Section 13-8, Equations (5-8). (N./mm^2) :

STRESS LOCATIONS		Inner	Outer	Allowable
Short-side 1	at N	-7.49	12.97	104.07
	at Q	36.97	-64.00	104.07
Short-side 2	at N	-7.49	12.97	104.07
	at Q	36.97	-64.00	104.07
Long-side 1	at M	-27.06	46.84	104.07
	at Q	36.97	-64.00	104.07
Long-side 2	at M	-27.06	46.84	104.07
	at Q	36.97	-64.00	104.07

Total Stress Calculations per Section 13-8

Total Stresses at Short-side 1

Total Stress at short side 1 at N inner [STS_Ni]:
```
  = Sms + SbsNi
  = 3.24 + -7.49
  = -4.25 N./mm^2
```

Total Stress at short side 1 at N outer [STS_No]:
```
  = Sms + SbsNo
  = 3.24 + 12.97
  = 16.22 N./mm^2
```

Total Stress at short side 1 at Q inner [STS_Qi]:
```
  = Smsc + SbsQi
  = 3.24 + 36.97
  = 40.21 N./mm^2
```

Total Stress at short side 1 at Q outer [STS_Qo]:
```
  = Smsc + SbsQo
  = 3.24 + -64.00
  = -60.76 N./mm^2
```

Total Stresses at Short-side 2

Total Stress at short side 2 at N inner [STS_Ni]:
```
  = Sms + SbsNi
  = 3.24 + -7.49
  = -4.25 N./mm^2
```

Total Stress at short side 2 at N outer [STS_No]:
```
  = Sms + SbsNo
  = 3.24 + 12.97
  = 16.22 N./mm^2
```

Total Stress at short side 2 at Q inner [STS_Qi]:
```
  = Smsc + SbsQi
  = 3.24 + 36.97
  = 40.21 N./mm^2
```

Total Stress at short side 2 at Q outer [STS_Qo]:
```
  = Smsc + SbsQo
  = 3.24 + -64.00
  = -60.76 N./mm^2
```

Total Stresses at Long-side 1

Total Stress at long side 1 at M inner [STL_Mi]:
```
  = SmlA + SblMi
  = 2.70 + -27.06
  = -24.35 N./mm^2
```

Total Stress at long side 1 at M outer [STL_Mo]:
```
  = SmlA + SblMo
  = 2.70 + 46.84
  = 49.55 N./mm^2
```

Total Stress at long side 1 at Q inner [STL_Qi]:
```
  = Smlc + SblQi
  = 2.70 + 36.97
  = 39.67 N./mm^2
```

Total Stress at long side 1 at Q outer [STL_Qo]:
```
  = Smlc + SblQo
  = 2.70 + -64.00
  = -61.30 N./mm^2
```

Total Stresses at Long-side 2

Total Stress at long side 2 at M inner [STL_Mi]:
```
  = SmlA + SblMi
  = 2.70 + -27.06
  = -24.35 N./mm^2
```

Total Stress at long side 2 at M outer [STL_Mo]:

= SmlA + SblMo
= 2.70 + 46.84
= 49.55 N./mm^2

Total Stress at long side 2 at Q inner [STL_Qi]:
= Smlc + SblQi
= 2.70 + 36.97
= 39.67 N./mm^2

Total Stress at long side 2 at Q outer [STL_Qo]:
= Smlc + SblQo
= 2.70 + -64.00
= -61.30 N./mm^2

TOTAL STRESSES: Total Stress Calculations per Section 13-8, Equations (9-12). (N./mm^2) :

STRESS LOCATIONS		Inner	Outer	Allowable
Short-side 1	at N	-4.25	16.22	104.07
	at Q	40.21	-60.76	104.07
Short-side 2	at N	-4.25	16.22	104.07
	at Q	40.21	-60.76	104.07
Long-side 1	at M	-24.35	49.55	104.07
	at Q	39.67	-61.30	104.07
Long-side 2	at M	-24.35	49.55	104.07
	at Q	39.67	-61.30	104.07

SUMMARY OF RESULTS:

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable)	3.24	N./mm^2
High Stress Percentage	2.38	%
M.A.W.P. for Membrane Stresses	20.98	bars

BENDING STRESS SUMMARY,

High Stress (Highest % of Allowable)	-64.00	N./mm^2
High Stress Percentage	61.50	%
M.A.W.P. for Bending Stresses	0.81	bars

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable)	-61.30	N./mm^2
High Stress Percentage	58.90	%
M.A.W.P. for Total Stresses	0.85	bars

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

Rectangular Vessel Results For Item 1 : A4

SUMMARY OF RESULTS:

MEMBRANE STRESS SUMMARY,

High Stress (Highest % of Allowable)	3.24	N./mm^2
High Stress Percentage	2.38	%
M.A.W.P. for Membrane Stresses	20.98	bars

BENDING STRESS SUMMARY,

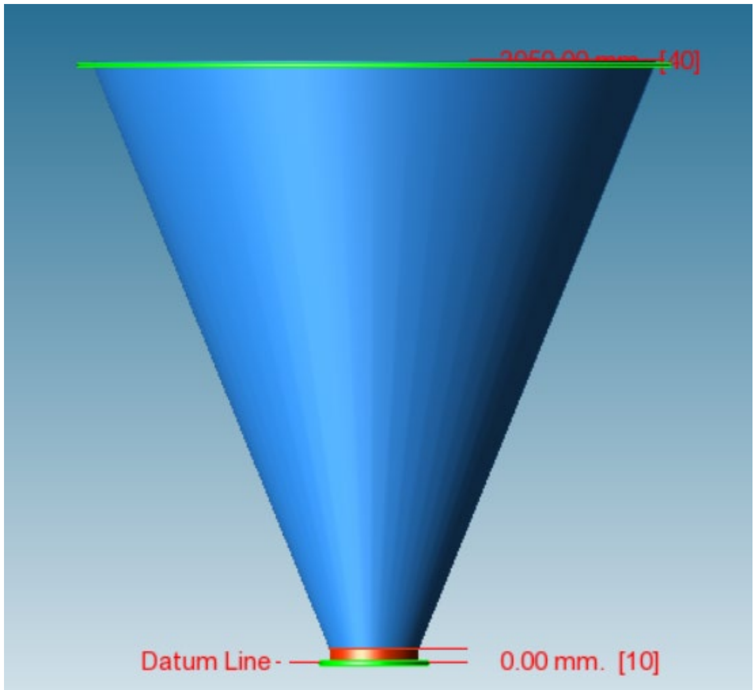
High Stress (Highest % of Allowable)	-64.00	N./mm^2
High Stress Percentage	61.50	%
M.A.W.P. for Bending Stresses	0.81	bars

TOTAL STRESS SUMMARY,

High Stress (Highest % of Allowable)	-61.30	N./mm^2
High Stress Percentage	58.90	%
M.A.W.P. for Total Stresses	0.85	bars

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

APPENDIX 6
CALCULATION HOPPER
ZONE 7



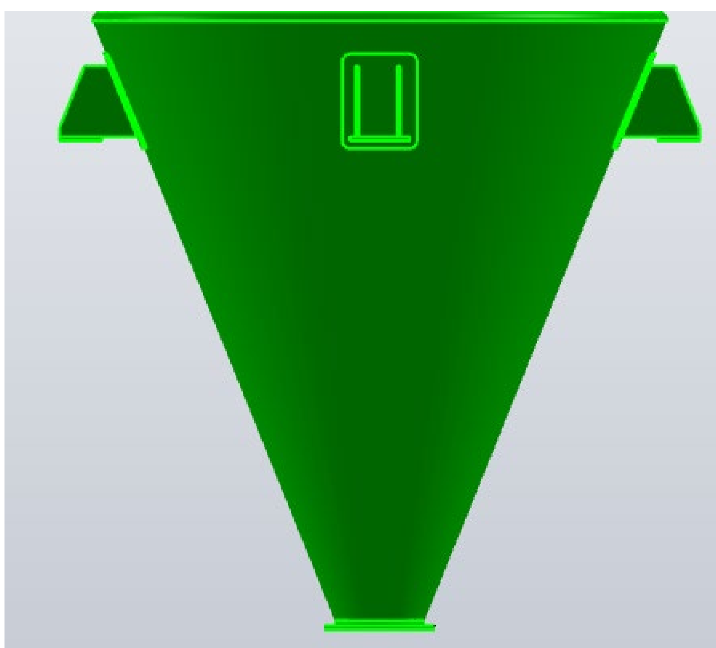


Figure F-Hopper - Zone7

Table of Contents

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   5:10pm

PV Elite 2019 SP1, March 2019
```

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

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

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

There were no geometry errors or warnings.
```

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

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	Horizontal	
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	300	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	136.07	N./mm²
Allowable Stress, Hydrotest	179.27	N./mm²
Material Density	0.008027	kg./cm³
P Number Thickness	0	mm.
Yield Stress, Operating	156.11	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 of 1]	
Dist. from "FROM" Node / Offset dist	0	mm.
Inside Diameter of Ring	306	mm.
Thickness of Ring	14	mm.
Outside Diameter of Ring	370	mm.
Material Name	SA-240 304	
Height of Section Ring	0	mm.
Using Custom Stiffener Section	No	

Element From Node	20
Element To Node	40
Element Type	Conical
Description	

Distance "FROM" to "TO"	2000	mm.
Inside Diameter	300	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	1920	mm.
Design Length of Cone	2000	mm.
Half Apex Angle of Cone	22.047947	degrees
Toriconical (Y/N)	N	
Weld is pre-Heated	No	

Element From Node	20	
Detail Type	Ring	
Detail ID	Flange -1	
Dist. from "FROM" Node / Offset dist	1983	mm.
Inside Diameter of Ring	1912.2	mm.
Thickness of Ring	12	mm.
Outside Diameter of Ring	2020.9	mm.
Material Name	SA-240 304	
Height of Section Ring	0	mm.
Using Custom Stiffener Section	No	

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

XY Coordinate Calculations:

From	To	X (Horiz.) mm.	Y (Vert.) mm.	DX (Horiz.) mm.	DY (Vert.) mm.
10	20	...	50	...	50
20	40	...	2050	...	2000

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

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	...	300	136.07
20	40	0.5	3	...	1920	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	26.8892	27.2514	3	1.5
20	40	0.5	3.93408	3.98707	3	1.5
Minimum			3.934	3.987		

MAWP: 3.934 bars, limited by: Cone.

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*150.0)/(136.07*1.0-0.6*0.5)
= 0.0551 + 0.0000 = 0.0551 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)/(150.0+0.6*3.0)
= 26.889 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)/(150.0+0.6*3.0)
= 27.251 bars

Actual stress at given pressure and thickness, corroded [Sact]:
= (P*(R+0.6*t))/(E*t)
= (0.5*(150.0+0.6*3.0))/(1.0*3.0)
= 2.530 N./mm²

% Elongation per Table UG-79-1 (50*tnom/Rf)*(1-Rf/Ro) 0.990 %
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 40 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*1920.0)/(2*0.9269*(136.07*1.0-0.6*0.5))
  = 0.3807 + 0.0000 = 0.3807 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*0.927)/(1920.0+1.2*3.0*0.927)
  = 3.934 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*0.9269)/(1920.0+1.2*3.0*0.9269)
  = 3.987 bars
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(D+1.2*t*cos(a)))/(2*E*t*cos(a))
  = (0.5*(1920.0+1.2*3.0*0.9269))/(2*1.0*3.0*0.9269)
  = 17.293 N./mm²
```

% Elongation per Table UG-79-1 (50*tnom/Rf)*(1-Rf/Ro) 0.989 %
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

Elements Suitable for Internal Pressure.

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

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	306	3	0.01054	99.0623
20	Ring	1150.16	1912.7	3	0.00012505	12.0049
Ring	40	16.9392	1926.47	3	0.0021617	81.3491

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	0.18486	0.1	12.9486
20	Ring	3	2.15271	0.1	0.23268
Ring	40	3	0.75209	0.1	1.56547
Minimum					0.233

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	5133.63	0.00051345	6.33378
20	Ring	1150.16	1150.16	No Calc	No Calc
Ring	40	16.9392	16.9392	2.92476	30.9459

Elements Suitable for External Pressure.

ASME Code, Section VIII Division 1, 2017

Cone From 20 to Flange -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
   2.781    1912.70     1150.16     687.87     0.6013  0.0001251    12.00
 EMAP = (4*B)/(3*(D/t)) = (4*12.0049)/(3*687.8719) = 0.2327 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
   1.995    1912.70     1150.16     958.61     0.6013  0.0000749     7.19
 EMAP = (4*B)/(3*(D/t)) = (4*7.1904)/(3*958.6123) = 0.1 bars
```

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

Cone From Flange -1 to the end: Ext. Chart: HA-2 at 50 °C

Stiffening Ring Calcs for : Ring:[1 of 1] , SA-240 304 , Bar Ring: 32 x 14 mm.

Effective Length of Shell: 33 mm.

	Area (cm²)	Distance (mm.)	Area*Dist
Shell:	1.000	1.5000	1.500
Ring :	4.480	19.0000	85.120
Total:	5.480		86.620

Centroid of Ring plus Shell: 16 mm.

	Inertia	Distance	A*Dist²
Shell:	0.007	14.3070	204.659
Ring :	3.823	-3.1930	45.676
Total:	3.830		250.335

Available Moment of Inertia, Ring plus Shell: 6 cm**4

Required Stress in Ring plus Shell Breq 0.11 N./mm²
Required Strain in Ring plus Shell Areq 0.0000011

Required Moment of Inertia, Ring plus Shell:
= (OD² * Slen(Tca + Aring/Slen)Areq)/10.9
= (306.0²*25.0(3.0+4.48/25.0)0.000001)/10.9
= 0 cm**4

Stiffening Ring Calcs for : Flange -1 , SA-240 304 , Bar Ring: 54 x 12 mm.

Effective Length of Shell: 83 mm.

	Area (cm²)	Distance (mm.)	Area*Dist
Shell:	2.499	1.5000	3.749
Ring :	6.523	30.1800	196.870
Total:	9.023		200.619

Centroid of Ring plus Shell: 22 mm.

	Inertia	Distance	A*Dist²
Shell:	0.019	20.7351	1074.620
Ring :	16.063	-7.9449	411.755
Total:	16.082		1486.376

Available Moment of Inertia, Ring plus Shell: 31 cm**4

Required Stress in Ring plus Shell Breq 3.48 N./mm²
Required Strain in Ring plus Shell Areq 0.0000363

Required Moment of Inertia, Ring plus Shell:
= (OD² * Slen(Tca + Aring/Slen)Areq)/10.9
= (1912.2301²*583.5508(3.0+6.5232/583.5508)0.000036)/10.9
= 3 cm**4

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

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	1.14618	3534.92	1.14618	3534.92	...
20	40	181.738	2279319	181.738	2279319	...
Total		182	2282854.50	182	2282854.50	0

Weight of Details:

From	Type	Weight of Detail kg.	X Offset, Dtl. Cent. mm.	Y Offset, Dtl. Cent. mm.	Description
10	Ring	3.81869	...	...	Ring:[1 of 1]
20	Ring	32.3515	...	1983	Flange -1

Total Weight of Each Detail Type:

Stiffeners	36.2
Sum of the Detail Weights	36.2 kg.

Weight Summation Results: (kg.)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	182.9	182.9	182.9	182.9	182.9	182.9
Stif. Rings	36.2	36.2	36.2	36.2	36.2	36.2
Test Liquid	...	2281.5	...	...	...	...
Totals	219.1	2500.5	219.1	219.1	219.1	219.1

Weight Summary:

Fabricated Wt.	- Bare Weight without Removable Internals	219.1 kg.
Shop Test Wt.	- Fabricated Weight + Water (Full)	2500.5 kg.
Shipping Wt.	- Fab. Weight + removable Intls.+ Shipping App.	219.1 kg.
Erected Wt.	- Fab. Wt + or - loose items (trays,platforms etc.)	219.1 kg.
Ope. Wt. no Liq	- Fab. Weight + Internals. + Details + Weights	219.1 kg.
Operating Wt.	- Empty Weight + Operating Liq. Uncorroded	219.1 kg.
Field Test Wt.	- Empty Weight + Water (Full)	2500.5 kg.
Mass of the Upper 1/3 of the Vertical Vessel		94.4 kg.

Outside Surface Areas of Elements:

From	To	Surface Area cm²
10	20	480.664
20	40	75684.9
Total		76165.602 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	4.96487	4.96487	4.96487	...	4.96487
20	40	214.09	214.09	214.09	...	214.09

Cumulative Vessel Weight

From	To	Cumulative Ope Wgt. No Liquid kg.	Cumulative Oper. Wgt. kg.	Cumulative Hydro. Wgt. kg.
10	20	219.055	219.055	219.055
20	40	214.09	214.09	214.09

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	40	...	...	...

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

Shop/Field Installation Options :

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

Center of Gravity of Stiffening Rings	1818.365 mm.
Center of Gravity of Bare Shell New and Cold	1285.295 mm.
Center of Gravity of Bare Shell Corroded	1285.295 mm.
Vessel CG in the Operating Condition	1373.315 mm.
Vessel CG in the Fabricated (Shop/Empty) Condition	1373.315 mm.

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

Minimum Design Metal Temperature Results Summary :

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

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019

ASME Code, Section VIII Division 1, 2017

Diameter Spec : 300.000 mm. ID		
Vessel Design Length, Tangent to Tangent	2050.00	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	3.934	bars
External Max. Allowable Working Pressure	0.233	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
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	26.889	0.0000	N/A	No
Conical	0.500	0.10	3.934	0.0000	N/A	No

Stiffener Ring Specifications:

Elevation mm.	Selected Type	User Description
0.00	Bar 32.0 x 14.	Ring:[1 of 1]
2033.00	Bar 54.4 x 12.	Flange -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	2050.0	2000.0	3.0	3.0	1.5	...	1.00	1.00

External Pressure Calculations:

From	To	External Actual T.	External Required T.	External Design Pressure	External M.A.W.P.

		mm.	mm.	bars	bars
10	Ring	3	No Calc	0.1	No Calc
Ring	20	3	0.18486	0.1	12.9486
20	Ring	3	2.15271	0.1	0.23268
Ring	40	3	0.75209	0.1	1.56547

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	5133.63	0.00051345	6.33378
20	Ring	1150.16	1150.16	No Calc	No Calc
Ring	40	16.9392	16.9392	2.92476	30.9459

Factored Loads:

Un-Factored Loads:

Weights:

Fabricated	- Bare W/O Removable Internals	219.1	kg.
Shop Test	- Fabricated + Water (Full)	2500.5	kg.
Shipping	- Fab. + Rem. Intls.+ Shipping App.	219.1	kg.
Erected	- Fab. + Rem. Intls.+ Insul. (etc)	219.1	kg.
Empty	- Fab. + Intls. + Details + Wghts.	219.1	kg.
Operating	- Empty + Operating Liquid (No CA)	219.1	kg.
Field Test	- Empty Weight + Water (Full)	2500.5	kg.

PV Elite is a trademark of Intergraph CADWorx & Analysis Solutions, Inc. 2019