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DESIGN CALCULATION

In Accordance with ASME Section VIII Division 1

ASME Code Version : 2015

Analysis Performed by : JIANGSU SUNPOWER TECHNOLOGY

Job File : G:\伊朗甲醇(17013)\D8502.Pvdb

Date of Analysis : Sep 21,2017 8:36pm

PV Elite 2017 SP1, March 2017

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PV Elite Vessel Analysis Program: Input Data

Design Internal Pressure (for Hydrotest)	1	MPa
Design Internal Temperature	85	C
Type of Hydrotest	UG-99(b)	
Hydrotest Position	Horizontal	
Projection of Nozzle from Vessel Top	0	mm
Projection of Nozzle from Vessel Bottom	0	mm
Minimum Design Metal Temperature	-10	C
Type of Construction	Welded	
Special Service	None	
Degree of Radiography	RT-3	
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	
Is this a Heat Exchanger	No	
User Defined Hydro. Press. (Used if > 0)	0	MPa
User defined MAWP	1	MPa
User defined MAPnc	0	MPa

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

Wind Design Code		ASCE-7 2010	
Wind Load Reduction Scale Factor		0.600	
Basic Wind Speed	[V]	200.3	km/hr
Surface Roughness Category		D: Flat, unobstructed	
Importance Factor		1.0	
Type of Surface		Moderately Smooth	
Base Elevation		0	mm
Percent Wind for Hydrotest		20.0	
Using User defined Wind Press. Vs Elev.		N	
Height of Hill or Escarpment	H or Hh	0	mm
Distance Upwind of Crest	Lh	0	mm
Distance from Crest to the Vessel	x	0	mm
Type of Terrain (Hill, Escarpment)		Flat	
Damping Factor (Beta) for Wind (Ope)		0.0100	
Damping Factor (Beta) for Wind (Empty)		0.0000	
Damping Factor (Beta) for Wind (Filled)		0.0000	

Seismic Design Code	ASCE 7-2010
Seismic Load Reduction Scale Factor	0.700
Importance Factor	1.500
Table Value Fa	1.000

Table Value Fv		1.000
Short Period Acceleration value Ss		1.980
Long Period Acceleration Value Sl		0.705
Moment Reduction Factor Tau		1.000
Force Modification Factor R		3.000
Site Class		B
Component Elevation Ratio	z/h	0.000
Amplification Factor	Ap	2.500
Force Factor		0.000
Consider Vertical Acceleration		Yes
Minimum Acceleration Multiplier		0.000
User Value of Sds (used if > 0)		1.320

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
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

Complete Listing of Vessel Elements and Details:

Element From Node	10	
Element To Node	20	
Element Type	Elliptical	
Description		
Distance "FROM" to "TO"	40	mm
Inside Diameter	600	mm
Element Thickness	7	mm
Internal Corrosion Allowance	3	mm
Nominal Thickness	8	mm
External Corrosion Allowance	0	mm
Design Internal Pressure	1	MPa
Design Temperature Internal Pressure	85	C
Design External Pressure	0	MPa
Design Temperature External Pressure	20	C
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	
Allowable Stress, Ambient	137.9	MPa
Allowable Stress, Operating	137.9	MPa
Allowable Stress, Hydrotest	179.27	MPa
Material Density	0.00775	kg/cm?
P Number Thickness	31.75	mm
Yield Stress, Operating	241.81	MPa
UCS-66 Chart Curve Designation	B	
External Pressure Chart Name	CS-2	
UNS Number	K02700	
Product Form	Plate	
Efficiency, Longitudinal Seam	1.0	
Efficiency, Circumferential Seam	0.85	
Elliptical Head Factor	2.0	

Element From Node	10
Detail Type	Nozzle
Detail ID	Noz N3 Fr10

Dist. from "FROM" Node / Offset dist	0	mm
Nozzle Diameter	60.3	mm
Nozzle Schedule	DIN4.0	
Nozzle Class	150	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0	N
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	

Element From Node	10	
Detail Type	Leg	
Detail ID	LEGS	
Dist. from "FROM" Node / Offset dist	330	mm
Diameter at Leg Centerline	690.93	mm
Leg Orientation	2	
Number of Legs	3	
Section Identifier	I12.6	
Length of Legs	880	mm

Element From Node	20	
Element To Node	30	
Element Type	Cylinder	
Description		
Distance "FROM" to "TO"	1420	mm
Inside Diameter	600	mm
Element Thickness	8	mm
Internal Corrosion Allowance	3	mm
Nominal Thickness	8	mm
External Corrosion Allowance	0	mm
Design Internal Pressure	1	MPa
Design Temperature Internal Pressure	85	C
Design External Pressure	0	MPa
Design Temperature External Pressure	20	C
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	
Efficiency, Longitudinal Seam	0.85	
Efficiency, Circumferential Seam	0.85	

Element From Node	20	
Detail Type	Nozzle	
Detail ID	Noz N1 Fr20	
Dist. from "FROM" Node / Offset dist	360	mm
Nozzle Diameter	114.3	mm
Nozzle Schedule	None	
Nozzle Class	150	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	111.72	N
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	

Element From Node	20	
Detail Type	Nozzle	
Detail ID	Noz H Fr20	
Dist. from "FROM" Node / Offset dist	360	mm
Nozzle Diameter	168.3	mm
Nozzle Schedule	DIN4.0	
Nozzle Class	150	
Layout Angle	180.0	
Blind Flange (Y/N)	Y	
Weight of Nozzle (Used if > 0)	294.65	N
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	

```
    Element From Node                              20
    Detail Type                                Nozzle
    Detail ID                             Noz P Fr20
    Dist. from "FROM" Node / Offset dist         1000  mm
    Nozzle Diameter                              48.3  mm
    Nozzle Schedule                            DIN4.0
    Nozzle Class                                  150
    Layout Angle                                180.0
    Blind Flange (Y/N)                              Y
    Weight of Nozzle ( Used if > 0 )                0  N
    Grade of Attached Flange                   GR 1.1
    Nozzle Matl                              SA-106 B

    Element From Node                              20
    Detail Type                                Nozzle
    Detail ID                             Noz T Fr20
    Dist. from "FROM" Node / Offset dist          760  mm
    Nozzle Diameter                              60.3  mm
    Nozzle Schedule                            DIN4.0
    Nozzle Class                                  150
    Layout Angle                                180.0
    Blind Flange (Y/N)                              Y
    Weight of Nozzle ( Used if > 0 )                0  N
    Grade of Attached Flange                   GR 1.1
    Nozzle Matl                              SA-106 B

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

Element From Node                                  30
Element To Node                                    40
Element Type                               Elliptical
Description
Distance "FROM" to "TO"                            40  mm
Inside Diameter                                   600  mm
Element Thickness                                   7  mm
Internal Corrosion Allowance                        3  mm
Nominal Thickness                                   8  mm
External Corrosion Allowance                        0  mm
Design Internal Pressure                            1  MPa
Design Temperature Internal Pressure               85   C
Design External Pressure                            0  MPa
Design Temperature External Pressure               20   C
Effective Diameter Multiplier                     1.2
Material Name                               SA-516 70
Efficiency, Longitudinal Seam                     1.0
Efficiency, Circumferential Seam                 0.85
Elliptical Head Factor                            2.0

    Element From Node                              30
    Detail Type                                Nozzle
    Detail ID                            Noz N2 Fr30
    Dist. from "FROM" Node / Offset dist            0  mm
    Nozzle Diameter                              88.9  mm
    Nozzle Schedule                              None
    Nozzle Class                                  150
    Layout Angle                                  0.0
    Blind Flange (Y/N)                              N
    Weight of Nozzle ( Used if > 0 )                0  N
    Grade of Attached Flange                   GR 1.1
    Nozzle Matl                              SA-106 B

    Element From Node                              30
    Detail Type                                Nozzle
    Detail ID                             Noz S Fr30
    Dist. from "FROM" Node / Offset dist          200  mm
    Nozzle Diameter                              33.4  mm
    Nozzle Schedule                            DIN4.0
```

Nozzle Class	150	
Layout Angle	45.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0	N
Grade of Attached Flange	GR 1.1	
Nozzle Matl	SA-106 B	

XY Coordinate Calculations:

From	To	X (Horiz.) mm	Y (Vert.) mm	DX (Horiz.) mm	DY (Vert.) mm
10	20	...	40	...	40
20	30	...	1460	...	1420
30	40	...	1500	...	40

Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd MPa	Nominal Thickness mm	Total Corr Allowance mm	Element Diameter mm	Allowable Stress(SE) MPa
10	20	1	8	3	600	137.9
20	30	1	8	3	600	117.22
30	40	1	8	3	600	137.9

Element Required Thickness and MAWP :

From	To	Design Pressure MPa	M.A.W.P. Corroded MPa	M.A.P. New & Cold MPa	Minimum Thickness mm	Required Thickness mm
10	20	1	1.842	3.21018	7	5.17023
20	30	1	1.91528	3.07651	8	5.59829
30	40	1	1.842	3.21018	7	5.17023
Minimum			**1.000**	**1.960**		

Note : The M.A.P.(NC) is Governed by a Flange !

MAWP: 1.000 MPa, limited by: DESIGN (user specified)

Internal Pressure Calculation Results :

ASME Code, Section VIII, Division 1, 2015

Elliptical Head From 10 To 20 SA-516 70 , UCS-66 Crv. B at 85 C

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

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
```
  = (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
  = (1.*606.0*0.987)/(2*137.9*1.0-0.2*1.)
  = 2.1702 + 3.0000 = 5.1702 mm
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
```
  = (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
  = (2*137.9*1.0*4.0)/(0.987*606.0+0.2*4.0)
  = 1.842 MPa
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
  = (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
  = (2*137.9*1.0*7.0)/(1.0*600.0+0.2*7.0)
  = 3.210 MPa
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
  = (P*(Kcor*D+0.2*t))/(2*E*t)
  = (1.*(0.987*606.0+0.2*4.0))/(2*1.0*4.0)
  = 74.864 MPa
```

Straight Flange Required Thickness:
```
  = (P*R)/(S*E-0.6*P) + c    per UG-27 (c)(1)
  = (1.*303.0)/(137.9*1.0-0.6*1.)+3.0
  = 5.207 mm
```

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

```
= (137.9 * 1.0 * 5.0)/(303.0 + 0.6 * 5.0 )
= 2.253 MPa
```

Factor K, corroded condition [Kcor]:

```
= ( 2 + ( Inside Diameter/( 2 * Inside Head Depth ))²)/6
= ( 2 + ( 606.0/( 2 * 153.0 ))²)/6
= 0.986992
```

```
Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro)  5.660 %
```

Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 7.0, tr = 2.17, c = 3.0 mm, E* = 1.0
Stress Ratio = tr * (E*)/(tg - c) = 0.543, Temp. Reduction = 29 C

```
Min Metal Temp. w/o impact per UCS-66, Curve B       -29  C
Min Metal Temp. at Required thickness (UCS 66.1)     -48  C
```

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 8.0, tr = 2.207, c = 3.0 mm, E* = 1.0
Stress Ratio = tr * (E*)/(tg - c) = 0.441, Temp. Reduction = 45 C

```
Min Metal Temp. w/o impact per UCS-66, Curve B       -29  C
Min Metal Temp. at Required thickness (UCS 66.1)     -48  C
```

Cylindrical Shell From 20 To 30 SA-516 70 , UCS-66 Crv. B at 85 C

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

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:

```
= (P*R)/(S*E-0.6*P) per UG-27 (c)(1)
= (1.*303.0)/(137.9*0.85-0.6*1.)
= 2.5983 + 3.0000 = 5.5983 mm
```

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

```
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (137.9*0.85*5.0)/(303.0+0.6*5.0)
= 1.915 MPa
```

Maximum Allowable Pressure, New and Cold [MAPNC]:

```
= (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
= (137.9*0.85*8.0)/(300.0+0.6*8.0)
= 3.077 MPa
```

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

```
= (P*(R+0.6*t))/(E*t)
= (1.*(303.0+0.6*5.0))/(0.85*5.0)
= 72.000 MPa
```

```
% Elongation per Table UG-79-1 (50*tnom/Rf*(1-Rf/Ro))  1.316 %
```

Minimum Design Metal Temperature Results:

Govrn. thk, tg = 8.0, tr = 2.598, c = 3.0 mm, E* = 0.85
Stress Ratio = tr * (E*)/(tg - c) = 0.442, Temp. Reduction = 45 C

```
Min Metal Temp. w/o impact per UCS-66, Curve B       -29  C
Min Metal Temp. at Required thickness (UCS 66.1)     -48  C
```

Elliptical Head From 30 To 40 SA-516 70 , UCS-66 Crv. B at 85 C

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

Material UNS Number: K02700

Required Thickness due to Internal Pressure [tr]:
```
   = (P*D*Kcor)/(2*S*E-0.2*P) Appendix 1-4(c)
   = (1.*606.0*0.987)/(2*137.9*1.0-0.2*1.)
   = 2.1702 + 3.0000 = 5.1702 mm
```

Max. Allowable Working Pressure at given Thickness, corroded [MAWP]:
```
   = (2*S*E*t)/(Kcor*D+0.2*t) per Appendix 1-4 (c)
   = (2*137.9*1.0*4.0)/(0.987*606.0+0.2*4.0)
   = 1.842 MPa
```

Maximum Allowable Pressure, New and Cold [MAPNC]:
```
   = (2*S*E*t)/(K*D+0.2*t) per Appendix 1-4 (c)
   = (2*137.9*1.0*7.0)/(1.0*600.0+0.2*7.0)
   = 3.210 MPa
```

Actual stress at given pressure and thickness, corroded [Sact]:
```
   = (P*(Kcor*D+0.2*t))/(2*E*t)
   = (1.*(0.987*606.0+0.2*4.0))/(2*1.0*4.0)
   = 74.864 MPa
```

Straight Flange Required Thickness:
```
   = (P*R)/(S*E-0.6*P) + c     per UG-27 (c)(1)
   = (1.*303.0)/(137.9*1.0-0.6*1.)+3.0
   = 5.207 mm
```

Straight Flange Maximum Allowable Working Pressure:
```
   = (S*E*t)/(R+0.6*t) per UG-27 (c)(1)
   = (137.9 * 1.0 * 5.0)/(303.0 + 0.6 * 5.0 )
   = 2.253 MPa
```

Factor K, corroded condition [Kcor]:
```
   = ( 2 + ( Inside Diameter/( 2 * Inside Head Depth ))²)/6
   = ( 2 + ( 606.0/( 2 * 153.0 ))²)/6
   = 0.986992
```

```
 Percent Elong. per UCS-79, VIII-1-01-57 (75*tnom/Rf)*(1-Rf/Ro)   5.660 %
```
Note: Please Check Requirements of UCS-79 as Elongation is > 5%.

MDMT Calculations in the Knuckle Portion:

Govrn. thk, tg = 7.0, tr = 2.17, c = 3.0 mm, E* = 1.0
Stress Ratio = tr * (E*)/(tg - c) = 0.543, Temp. Reduction = 29 C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B           -29   C
 Min Metal Temp. at Required thickness (UCS 66.1)         -48   C
```

MDMT Calculations in the Head Straight Flange:

Govrn. thk, tg = 8.0, tr = 2.207, c = 3.0 mm, E* = 1.0
Stress Ratio = tr * (E*)/(tg - c) = 0.441, Temp. Reduction = 45 C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B           -29   C
 Min Metal Temp. at Required thickness (UCS 66.1)         -48   C
```

Hydrostatic Test Pressure Results:

```
 Pressure per UG99b      = 1.3 * M.A.W.P. * Sa/S         1.300  MPa
 Pressure per UG99b[36]  = 1.3 * Design Pres * Sa/S      1.300  MPa
 Pressure per UG99c      = 1.3 * M.A.P. - Head(Hyd)      2.548  MPa
 Pressure per UG100      = 1.1 * M.A.W.P. * Sa/S         1.100  MPa
 Pressure per PED        = 1.43 * MAWP                   1.430  MPa
```

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FileName : D8502
Internal Pressure Calculations: Step: 3 8:36pm Sep 21,2017

Pressure per App 27-4 = 1.3 * M.A.W.P. * Sa/S 1.300 MPa

UG-99(b), Test Pressure Calculation:
= Test Factor * MAWP * Stress Ratio
= 1.3 * 1. * 1.0
= 1.300 MPa

Horizontal Test performed per: UG-99b

Please note that Nozzle, Shell, Head, Flange, etc MAWPs are all considered when determining the hydrotest pressure for those test types that are based on the MAWP of the vessel.

Stresses on Elements due to Test Pressure (MPa):

From	To	Stress	Allowable	Ratio	Pressure
10	20	56.1	179.3	0.313	1.31
20	30	58.5	179.3	0.327	1.31
30	40	56.1	179.3	0.313	1.31

Stress ratios for Nozzle and Pad Materials (MPa):

Description	Pad/Nozzle	Ambient	Operating	Ratio
Noz N3 Fr10	Nozzle	117.90	117.90	1.000
Noz N1 Fr20	Nozzle	117.90	117.90	1.000
Noz H Fr20	Nozzle	117.90	117.90	1.000
Noz P Fr20	Nozzle	117.90	117.90	1.000
Noz T Fr20	Nozzle	117.90	117.90	1.000
Noz N2 Fr30	Nozzle	117.90	117.90	1.000
Noz S Fr30	Nozzle	117.90	117.90	1.000
Minimum				1.000

Stress ratios for Pressurized Vessel Elements (MPa):

Description	Ambient	Operating	Ratio
	137.90	137.90	1.000
	137.90	137.90	1.000
	137.90	137.90	1.000
Minimum			1.000

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

Description	Stress	Allowable	Ratio
Noz N3 Fr10	6.58	153.28	0.043
Noz N1 Fr20	11.87	153.28	0.077
Noz H Fr20	14.93	153.28	0.097
Noz P Fr20	3.89	153.30	0.025
Noz T Fr20	6.58	153.30	0.043
Noz N2 Fr30	10.05	153.28	0.066
Noz S Fr30	2.91	153.28	0.019

Elements Suitable for Internal Pressure.

External Pressure Calculation Results :

External Pressure Calculations:

From	To	Section Length mm	Outside Diameter mm	Corroded Thickness mm	Factor A	Factor B MPa
10	20	No Calc	614	4.00002	0.00090482	82.1653
20	30	1600	616	5	0.00035654	35.6465
30	40	No Calc	614	4.00002	0.00090482	82.1653

External Pressure Calculations:

From	To	External Actual T. mm	External Required T. mm	External Design Pressure MPa	External M.A.W.P. MPa
10	20	7	4.49999	...	0.59476
20	30	8	No Calc	...	0.38579
30	40	7	4.49999	...	0.59476
Minimum					**0.386**

External Pressure Calculations:

From	To	Actual Length Bet. Stiffeners mm	Allowable Length Bet. Stiffeners mm	Ring Inertia Required mm**4	Ring Inertia Available mm**4
10	20	No Calc	No Calc	No Calc	No Calc
20	30	1600	No Calc	No Calc	No Calc
30	40	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

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

Elastic Modulus from Chart: CS-2 at 20 C : 0.200E+06 MPa

Results for Maximum Allowable External Pressure (MAEP):

```
     Tca          OD          D/t      Factor A            B
   4.000      614.00      153.50     0.0009048        82.17
 EMAP = B/(K0*D/t) = 82.1653/( 0.9 *153.4994 ) = 0.5948 MPa
```

*Check the requirements of UG-33(a)(1) using P = 1.67 * External Design pressure for this head.*

Material UNS Number: K02700

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

```
  = ((2*S*E*t)/(Kcor*D+0.2*t))/1.67 per Appendix 1-4 (c)
  = ((2*137.9*1.0*4.0)/(0.987*606.0+0.2*4.0))/1.67
  = 1.103 MPa
```

Maximum Allowable External Pressure [MAEP]:

```
  = min( MAEP, MAWP )
  = min( 0.59, 1.103 )
  = 0.595 MPa
```

Cylindrical Shell From 20 to 30 Ext. Chart: CS-2 at 20 C

Elastic Modulus from Chart: CS-2 at 20 C : 0.200E+06 MPa

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	SLEN	D/t	L/D	Factor A	B
5.000	616.00	1600.00	123.20	2.5974	0.0003565	35.65

EMAP = (4*B)/(3*(D/t)) = (4*35.6465)/(3*123.1996) = 0.3858 MPa

Results for Maximum Stiffened Length (Slen):

Tca	OD	SLEN	D/t	L/D	Factor A	B
5.000	616.00	1600.00	123.20	2.5974	0.0003565	35.65

EMAP = (4*B)/(3*(D/t)) = (4*35.6465)/(3*123.1996) = 0.3858 MPa

Elliptical Head From 30 to 40 Ext. Chart: CS-2 at 20 C

Elastic Modulus from Chart: CS-2 at 20 C : 0.200E+06 MPa

Results for Maximum Allowable External Pressure (MAEP):

Tca	OD	D/t	Factor A	B
4.000	614.00	153.50	0.0009048	82.17

EMAP = B/(K0*D/t) = 82.1653/(0.9 *153.4994) = 0.5948 MPa

*Check the requirements of UG-33(a)(1) using P = 1.67 * External Design pressure for this head.*

Material UNS Number: K02700

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

```
= ((2*S*E*t)/(Kcor*D+0.2*t))/1.67 per Appendix 1-4 (c)
= ((2*137.9*1.0*4.0)/(0.987*606.0+0.2*4.0))/1.67
= 1.103 MPa
```

Maximum Allowable External Pressure [MAEP]:

```
= min( MAEP, MAWP )
= min( 0.59, 1.103 )
= 0.595 MPa
```

Element and Detail Weights:

From	To	Element Metal Wgt. kg	Element ID Volume cm3	Corroded Metal Wgt. kg	Corroded ID Volume cm3	Extra due Misc % kg
10	20	32.17	39591.2	20.1063	40675.5	...
20	30	168.176	401568	105.629	409639	...
30	40	32.17	39591.2	20.1063	40675.5	...
Total		**232**	**480749.91**	**145**	**490989.94**	**0**

Weight of Details:

From	Type	Weight of Detail kg	X Offset, Dtl. Cent. mm	Y Offset, Dtl. Cent. mm	Description
10	Nozl	4.46531	...	-265.006	Noz N3 Fr10
10	Legs	64.1169	...	-110	LEGS
20	Nozl	11.3928	357.15	360	Noz N1 Fr20
20	Nozl	30.0477	384.15	360	Noz H Fr20
20	Nozl	3.63164	324.15	1000	Noz P Fr20
20	Nozl	7.15861	330.15	760	Noz T Fr20
30	Nozl	7.53931	...	265.006	Noz N2 Fr30
30	Nozl	2.06006	141.421	226.81	Noz S Fr30

Total Weight of Each Detail Type

Total Weight of Nozzles	66.3
Total Weight of Legs	64.1
Sum of the Detail Weights	130.4 kg

Weight Summation: kg

Fabricated	Shop Test	Shipping	Erected	Empty	Operating
232.5	362.9	232.5	362.9	232.5	362.9
...	480.5	...	...	...	...
66.3	...	66.3	...	...	...
64.1	...	64.1	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	66.3	...
...	...	...	...	64.1	...
362.9	843.4	362.9	362.9	362.9	362.9

Note:
The shipping total has been modified because some items have been specified as being installed in the shop.

Weight Summary

Fabricated Wt.	- Bare Weight W/O Removable Internals	362.9	kg
Shop Test Wt.	- Fabricated Weight + Water (Full)	843.4	kg
Shipping Wt.	- Fab. Wt + Rem. Intls.+ Shipping App.	362.9	kg
Erected Wt.	- Fab. Wt + Rem. Intls.+ Insul. (etc)	362.9	kg
Ope. Wt. no Liq	- Fab. Wt + Intls. + Details + Wghts.	362.9	kg
Operating Wt.	- Empty Wt + Operating Liq. Uncorroded	362.9	kg
Field Test Wt.	- Empty Weight + Water (Full)	843.4	kg
Mass of the Upper 1/3 of the Vertical Vessel		67.6	kg

Outside Surface Areas of Elements:

From	To	Surface Area mm?
10	20	488734
20	30	2748014
30	40	488734
Total		3725482.000 mm?

Element and Detail Weights:

From	To To	Total Ele. Empty Wgt. kg	Total. Ele. Oper. Wgt. kg	Total. Ele. Hydro. Wgt. kg	Total Dtl. Offset Mom. N-mm	Oper. Wgt. No Liquid kg
10	Legs	302.241	302.241	628.668	...	302.241
Legs	20	-265.605	-265.605	-552.465	...	-265.605
20	30	220.406	220.406	621.729	187884	220.406
30	40	41.7694	41.7694	81.3364	2858	41.7694

Cumulative Vessel Weight

From	To	Cumulative Ope Wgt. No Liquid kg	Cumulative Oper. Wgt. kg	Cumulative Hydro. Wgt. kg
10	Legs	...	...	...
Legs	20	-3.42946	-3.42946	150.6
20	30	262.176	262.176	703.065
30	40	41.7694	41.7694	81.3364

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. N-mm	Cumulative Oper. Mom. N-mm	Cumulative Hydro. Mom. N-mm
10	Legs	...	...	...
Legs	20	190742	190742	190742
20	30	190742	190742	190742
30	40	2858	2858	2858

Nozzle Flange MAWP Results :

Nozzle Description	Flange Rating Operating MPa	Flange Rating Ambient MPa	Temperature C	Class	Grade/Group
Noz N3 Fr10	1.8	2.0	85	150	GR 1.1
Noz N1 Fr20	1.8	2.0	85	150	GR 1.1
Noz H Fr20	1.8	2.0	85	150	GR 1.1
Noz P Fr20	1.8	2.0	85	150	GR 1.1
Noz T Fr20	1.8	2.0	85	150	GR 1.1
Noz N2 Fr30	1.8	2.0	85	150	GR 1.1
Noz S Fr30	1.8	2.0	85	150	GR 1.1
Minimum Rating	1.8	2.0 MPa	(for Core Elements)		

Note: ANSI Ratings are per ANSI/ASME B16.5 2013 Metric Edition

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

The Natural Frequency for the Vessel (Empty.) is 32.0777 Hz.

The Natural Frequency for the Vessel (Ope...) is 32.0777 Hz.

Input Values:

```
Wind Design Code                                          ASCE-7 2010
Wind Load Reduction Scale Factor                                0.600
Basic Wind Speed                         [V]                    200.3  km/hr
Surface Roughness Category                 D: Flat, unobstructed
Importance Factor                                                 1.0
Type of Surface                               Moderately Smooth
Base Elevation                                                      0  mm
Percent Wind for Hydrotest                                       20.0
Using User defined Wind Press. Vs Elev.                             N
Height of Hill or Escarpment      H or Hh                           0  mm
Distance Upwind of Crest               Lh                           0  mm
Distance from Crest to the Vessel       x                           0  mm
Type of Terrain ( Hill, Escarpment )                             Flat
Damping Factor (Beta) for Wind (Ope)                           0.0100
Damping Factor (Beta) for Wind (Empty)                         0.0000
Damping Factor (Beta) for Wind (Filled)                        0.0000
```

Wind Analysis Results

Static Gust-Effect Factor, Operating Case [G]:

```
= min(0.85, 0.925((1 + 1.7 * gQ * Izbar * Q )/( 1 + 1.7 * gV * Izbar)))
= min(0.85,0.925((1+1.7*3.4*0.194*0.98)/(1+1.7*3.4*0.194)))
= min(0.85, 0.915 )
= 0.850
```

```
Natural Frequency of Vessel (Operating)              32.078 Hz
Natural Frequency of Vessel (Empty)                  32.078 Hz
Natural Frequency of Vessel (Test)                   21.020 Hz

Force Coefficient                               [Cf] 0.529
Structure Height to Diameter ratio                   2.747
Height to top of Structure                           1657.000 mm
```

This is classified as a rigid structure. Static analysis performed.

Sample Calculation for the First Element

The ASCE code performs all calculations in Imperial Units only. The wind pressure is therefore computed in these units.

Value of [Alpha] and [Zg]:

```
Exposure Category: D from Table 26.9.1
Alpha = 11.5: Zg = 213359.984 mm
```

Effective Height [z]:

```
= Centroid Height + Vessel Base Elevation
= 111.587 + 0.0 = 111.587 mm
= 0.366 ft. Imperial Units
```

Velocity Pressure coefficient evaluated at height z [Kz]:

Because z (0.366 ft.) < 15 ft.

$= 2.01 * (15 / Zg)^{2 / Alpha}$

$= 2.01 * (15/700.0)^{2/11.5}$

= 1.03

Type of Hill: No Hill

Wind Directionality Factor [Kd]:

```
= 0.95 per Table 26.6-1
```

As there is No Hill Present: [Kzt]:

```
K1 = 0, K2 = 0, K3 = 0
```

Topographical Factor [Kzt]:
= (1 + K1 * K2 * K3)²
= (1 + 0.0* 0.0* 0.0)²
= 1.0

Velocity Pressure evaluated at height z, Imperial Units [qz]:
= min(16, 0.00256 * Kz * Kzt * Kd * V(mph)²)
= min(16, 0.00256 * 1.03 * 1.0 * 0.95 * 124.464²)
= 38.8 psf [189.508] kg/m?

Force on the first element [F]:
= qz * G * Cf * WindArea
= 38.814 * 0.85 * 0.529 * 1.295
= 22.6 lbs. [100.6] N

Element	Hgt (z) mm	K1	K2	K3	Kz	Kzt	qz kg/m?
Node 10 to 20	111.6	0.000	0.000	0.000	1.030	1.000	189.508
Node 20 to 30	900.0	0.000	0.000	0.000	1.030	1.000	189.508
Node 30 to 40	1695.4	0.000	0.000	0.000	1.030	1.000	189.508

Wind Vibration Calculations

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

Nomenclature

```
 Cf  - Correction factor for natural frequency
  D  - Average internal diameter of vessel mm
 Df  - Damping Factor < 0.75 Unstable,  > 0.95 Stable
 Dr  - Average internal diameter of top half of vessel mm
  f  - Natural frequency of vibration (Hertz)
 f1  - Natural frequency of bare vessel based on a unit value of (D/L²)(10⁴)
  L  - Total height of structure mm
 Lc  - Total length of conical section(s) of vessel mm
 tb  - Uncorroded plate thickness at bottom of vessel mm
 V30 - Design Wind Speed provided by user km/hr
 Vc  - Critical wind velocity km/hr
 Vw  - Maximum wind speed at top of structure km/hr
 W   - Total corroded weight of structure N
 Ws  - Cor. vessel weight excl. weight of parts which do not effect stiff. N
  Z  - Maximum amplitude of vibration at top of vessel mm
 Dl  - Logarithmic decrement ( taken as 0.03 for Welded Structures )
 Vp  - Vib. Chance, <= 0.000003 (High); 0.000003 < 0.000004 (Probable)
 P30 - wind pressure 30 feet above the base
```

Check other Conditions and Basic Assumptions:
#1 - Total Cone Length / Total Length < 0.5
0.0/1500.0 = 0.0

#2 - (D / L²) * 10⁴ < 8.0 (English Units)
- (2.02/4.92²) * 10⁴ = 834.33 [Geometry Violation]

Compute the vibration possibility. If Vp > 0.000004 no chance. [Vp]:
= W / (L * Dr²)
= 2709/(1500.0 * 606.0²)
= 0.49177E-05

Since Vp is > 0.000004 no further vibration analysis is required !

The Natural Frequency for the Vessel (Ope...) is 32.0777 Hz.

Wind Load Calculation:

		Wind	Wind	Wind	Wind	Element

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FileName : D8502
Wind Load Calculation: Step: 8 8:36pm Sep 21,2017

From	To	Height mm	Diameter mm	Area mm?	Pressure kg/m?	Wind Load N
10	20	111.587	736.8	120325	189.508	60.3388
20	30	900	739.2	1049664	189.508	526.37
30	40	1695.41	736.8	120325	189.508	60.3388

Note:
The Wind Loads calculated and printed in the Wind Load calculation report have been factored by the input scalar/load reduction factor of: 0.600.

Be sure the wind speed is in accordance with the specified wind design code.

Earthquake Load Calculation:

Input Values:

Seismic Design Code		ASCE 7-2010
Seismic Load Reduction Scale Factor		0.700
Importance Factor		1.500
Table Value Fa		1.000
Table Value Fv		1.000
Short Period Acceleration value Ss		1.980
Long Period Acceleration Value Sl		0.705
Moment Reduction Factor Tau		1.000
Force Modification Factor R		3.000
Site Class		B
Component Elevation Ratio	z/h	0.000
Amplification Factor	Ap	2.500
Force Factor		0.000
Consider Vertical Acceleration		Yes
Minimum Acceleration Multiplier		0.000
User Value of Sds (used if > 0)		1.320

Seismic Analysis Results:

```
Sms = Fa * Ss = 1.0 * 1.98 = 1.98
Sm1 = Fv * S1 = 1.0 * 0.705 = 0.705
Sds = 2/3 * Sms = 2/3 * 1.98 = 1.32

Sds = Max( 0.8*Sds, SdsUser )
    = Max( 1.056, 1.32 )
    = 1.320

Sd1 = 2/3 * Sm1 = 2/3 * 0.705 = 0.47

Sd1 = Max( 0.8*Sd1, Sd1User )
    = Max( 0.376, 0.47 )
    = 0.470
```

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

= Ct * hn^x where Ct = 0.020, x = 0.75 and hn = Structural Height (ft.)
= 0.020 * ($7.2178^{0.75}$)
= 0.088 seconds

The Coefficient Cu from Table 12.8-1 is : 1.400

Fundamental Period (1/Frequency) [T]:

```
= ( 1/Natural Frequency ) = ( 1/32.078 )
= 0.031
```

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

```
= Minimum Value of (1.4 * 0.088, 0.031 ) per 12.8.2
= 0.031
```

As the time period is < 0.06 second, use section 15.4.2.

Compute the Base Shear per equation 15.4-5, [V]:

```
= 0.3 * Sds * W * I
= 0.3 * 1.32 * 2930 * 1.5
= 1740.504 N
```

Vertical load per 12.4-4, [YEq]:

```
= 0.2 * Sds * W
= 0.2 * 1.32 * 2930 = 773.56 N
```

```
Final Base Shear,      V = 1218.35 N
Final Vertical Load, YEq = 541.49 N
```

Distribute the Base shear force to each element according to the equations
Fx = Cvx * V (eqn. 12.8-11) and the vertical distribution factor
Cvx = $Wx*hx^k$/(Sum of $Wi*hi^k$) and k is an exponent which is related
to the period of Vibration.

In this case, the value of k was 1.0.

The Natural Frequency for the Vessel (Ope...) is 32.0777 Hz.

Earthquake Load Calculation:

From	To	Earthquake Height mm	Earthquake Weight N	Element Ope Load N	Element Emp Load N
10	Legs	-290	2963.77	379.257	379.257
Legs	20	-125	-2604.52	-143.658	-143.658
20	30	750	2161.3	715.267	715.267
30	40	1480	409.591	267.487	267.487

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

The following table is for the Operating Case.

Wind/Earthquake Shear, Bending:

From	To	Distance to Support mm	Cumulative Wind Shear N	Earthquake Shear N	Wind Bending N-mm	Earthquake Bending N-mm
10	Legs	165	...	...	...	...
Legs	20	145	149.254	839.096	275819	584009
20	30	420	586.708	982.754	464746	910887
30	40	1215.41	60.3388	267.487	5155.83	22856.2

Note:
The Wind Shears/Moments and the Earthquake Shears/Moments calculated and printed in the Wind/Earthquake Shear and Bending report have been factored by the input Scalar/Load reductions factors of;
Wind: 0.600; Earthquake: 0.700.

Note:
Review the Vessel Design Summary for the cumulative shear force and bending moment on the support.

Wind Deflection Calculations:

The following table is for the Operating Case.

Wind Deflection:

From	To	Cumulative Wind Shear N	Centroid Deflection mm	Elem. End Deflection mm	Elem. Ang. Rotation
10	Legs	...	0.11231	0.11248	0.00019173
Legs	20	149.254	0.11234	0.11232	0.0001901
20	30	586.708	0.11308	0.11474	0.00019284
30	40	60.3388	0.11479	0.11484	0.00019284

Critical Wind Velocity for Tower Vibration:

From	To	1st Crit. Wind Speed km/hr	2nd Crit. Wind Speed km/hr
10	20	424.281	2651.76
20	30	425.664	2660.4
30	40	424.281	2651.76

Allowable deflection at the Tower Top (Ope)(6.000"/100ft. Criteria)
Allowable deflection : 7.500   Actual Deflection : 0.115 mm

Longitudinal Stress Constants:

From	To	Metal Area New mm?	Metal Area Corroded mm?	Section Modulus New mm3	Section Modulus Corroded mm3
10	20	13348.7	7665.53	2002829	1161427
20	30	15280.8	9597.63	2292905	1454235
30	40	13348.7	7665.53	2002829	1161427

Longitudinal Allowable Stresses:

From	To	Tensile MPa	Hydrotest Tensile MPa	Compressive MPa	Hydrotest Compressive MPa
10	Legs	140.658	182.855	-118.659	-133.181
Legs	20	140.658	182.855	-118.659	-133.181
20	30	140.658	182.855	-124.898	-135.92
30	40	140.658	182.855	-118.659	-133.181

Longitudinal Stress Report

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

Longitudinal Pressure Stresses due to:

From	To	Longitudinal Stress Internal Pressure MPa	Longitudinal Stress External Presssure MPa	Longitudinal Stress Hydrotest Presure MPa
10	20	37.6748	...	27.5971
20	30	30.0999	...	24.115
30	40	37.6748	...	27.5971

Longitudinal Stresses due to Weight Loads for these Conditions:

From	To	Wght. Str. Empty MPa	Wght. Str. Operating MPa	Wght. Str. Hydrotest MPa	Wght. Str. Emp. Mom. MPa	Wght. Str. Opr. Mom. MPa
10	Legs	...	...	...	...	...
Legs	20	0.0043875	0.0043875	...	0.16418	0.16418
20	30	-0.26789	-0.26789	...	0.13112	0.13112
30	40	-0.053437	-0.053437	...	0.00246	0.00246

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

From	To	Wght. Str. Hyd. Mom. MPa	Bend. Str. Oper. Wind MPa	Bend. Str. Oper. Equ. MPa	Bend. Str. Hyd. Wind MPa	Bend. Str. Hyd. Equ. MPa
10	Legs	...	...	...	...	...
Legs	20	...	0.23741	0.50268	...	...
20	30	...	0.31948	0.62617	...	...
30	40	...	0.0044378	0.019673	...	...

Longitudinal Stresses due to these Conditions:

From	To	Vortex Shedding Operating Case MPa	Vortex Shedding Empty Case MPa	Vortex Shedding Test Case MPa	Earthquake Empty Case MPa
10	Legs	...	...	...	...
Legs	20	...	...	...	0.50268
20	30	...	...	...	0.62617
30	40	...	...	...	0.019673

Longitudinal Stresses due to Applied Axial Forces:

From	To	Longitudinal Stress Y Forces Wind MPa	Longitudinal Stress Y Forces Seismic MPa
10	Legs	...	-0.071456
Legs	20	...	-0.0008108
20	30	...	0.049506
30	40	...	0.0098752

Longitudinal Stresses due to User Forces and Moments:

From	To	Wind For/Mom Corroded MPa	Earthquake For/Mom Corroded MPa	Wind For/Mom No Corrosion MPa	Earthquake For/Mom No Corrosion MPa
10	Legs	...	...	...	...
Legs	20	...	...	...	...
20	30	...	...	...	...
30	40	...	...	...	...

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FileName : D8502
Stress due to Combined Loads: Step: 15 8:36pm Sep 21,2017

Stress Combination Load Cases for Vertical Vessels:

Load Case Definition Key

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

General Notes:

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

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

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

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

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	140.66	0.00	118.66	0.0000	0.0000
10	0.41	140.66	-0.40	118.66	0.0029	0.0033
20	0.18	140.66	-0.72	124.90	0.0013	0.0058
30		140.66	-0.06	118.66		0.0005

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		140.66	-0.07	118.66		0.0006
10	0.67	140.66	-0.66	118.66	0.0048	0.0056
20	0.54	140.66	-0.98	124.90	0.0038	0.0078
30		140.66	-0.07	118.66		0.0006

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	140.66	0.00	118.66	0.0000	0.0000
10	0.41	140.66	-0.40	118.66	0.0029	0.0033
20	0.18	140.66	-0.72	124.90	0.0013	0.0058
30		140.66	-0.06	118.66		0.0005

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		140.66	-0.07	118.66		0.0006
10	0.67	140.66	-0.66	118.66	0.0048	0.0056
20	0.54	140.66	-0.98	124.90	0.0038	0.0078
30		140.66	-0.07	118.66		0.0006

Analysis of Load Case 5 : NP+HW+HI

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	182.86	0.00	133.18	0.0000	0.0000
10	0.00	182.86	0.00	133.18	0.0000	0.0000
20	0.00	182.86	0.00	135.92	0.0000	0.0000
30	0.00	182.86	0.00	133.18	0.0000	0.0000

Analysis of Load Case 6 : NP+HW+HE

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	182.86	0.00	133.18	0.0000	0.0000
10	0.00	182.86	0.00	133.18	0.0000	0.0000
20	0.00	182.86	0.00	135.92	0.0000	0.0000
30	0.00	182.86	0.00	133.18	0.0000	0.0000

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	37.67	140.66		118.66	0.2678	
10	38.08	140.66		118.66	0.2707	
20	30.28	140.66		124.90	0.2153	
30	37.63	140.66		118.66	0.2675	

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	37.60	140.66		118.66	0.2673	
10	38.35	140.66		118.66	0.2726	
20	30.64	140.66		124.90	0.2178	
30	37.65	140.66		118.66	0.2677	

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	140.66	0.00	118.66	0.0000	0.0000
10	0.41	140.66	-0.40	118.66	0.0029	0.0033
20	0.18	140.66	-0.72	124.90	0.0013	0.0058
30		140.66	-0.06	118.66		0.0005

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		140.66	-0.07	118.66		0.0006
10	0.67	140.66	-0.66	118.66	0.0048	0.0056
20	0.54	140.66	-0.98	124.90	0.0038	0.0078
30		140.66	-0.07	118.66		0.0006

Analysis of Load Case 11 : HP+HW+HI

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	27.60	182.86		133.18	0.1509	
10	27.60	182.86		133.18	0.1509	
20	24.11	182.86		135.92	0.1319	
30	27.60	182.86		133.18	0.1509	

Analysis of Load Case 12 : HP+HW+HE

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	27.60	182.86		133.18	0.1509	
10	27.60	182.86		133.18	0.1509	
20	24.11	182.86		135.92	0.1319	
30	27.60	182.86		133.18	0.1509	

Analysis of Load Case 13 : IP+WE+EW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	37.67	140.66		118.66	0.2678	
10	37.84	140.66		118.66	0.2690	
20	29.96	140.66		124.90	0.2130	
30	37.62	140.66		118.66	0.2675	

Analysis of Load Case 14 : IP+WF+CW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	37.67	140.66		118.66	0.2678	
10	37.68	140.66		118.66	0.2679	
20	29.93	140.66		124.90	0.2128	
30	37.64	140.66		118.66	0.2676	

Analysis of Load Case 15 : IP+VO+OW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	37.67	140.66		118.66	0.2678	
10	37.84	140.66		118.66	0.2690	
20	29.96	140.66		124.90	0.2130	
30	37.62	140.66		118.66	0.2675	

Analysis of Load Case 16 : IP+VE+EW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	37.67	140.66		118.66	0.2678	
10	37.84	140.66		118.66	0.2690	
20	29.96	140.66		124.90	0.2130	
30	37.62	140.66		118.66	0.2675	

Analysis of Load Case 17 : NP+VO+OW

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	0.00	140.66	0.00	118.66	0.0000	0.0000
10	0.17	140.66	-0.16	118.66	0.0012	0.0013
20		140.66	-0.40	124.90		0.0032
30		140.66	-0.06	118.66		0.0005

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10	37.60	140.66		118.66	0.2673	
10	37.84	140.66		118.66	0.2690	
20	30.01	140.66		124.90	0.2134	
30	37.63	140.66		118.66	0.2676	

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

From Node	Tensile Stress	All. Tens. Stress	Comp. Stress	All. Comp. Stress	Tens. Ratio	Comp. Ratio
10		140.66	-0.07	118.66		0.0006
10	0.17	140.66	-0.16	118.66	0.0012	0.0014
20		140.66	-0.35	124.90		0.0028
30		140.66	-0.05	118.66		0.0004

Absolute Maximum of the all of the Stress Ratio's 0.2726

Element From : 10 to : 20
Governing Load Case 8 : IP+OW+EQ+FS+BS

Shop/Field Installation Options :

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

Center of Gravity of Nozzles	624.130 mm
Center of Gravity of Legs	-110.000 mm
Center of Gravity of Bare Shell New and Cold	750.000 mm
Center of Gravity of Bare Shell Corroded	750.000 mm
Vessel CG in the Operating Condition	520.193 mm
Vessel CG in the Fabricated (Shop/Empty) Condition	575.075 mm
Vessel CG in the Test Condition	674.726 mm

RESULTS FOR LEGS : Operating Case Description: LEGS

Legs attached to: node 10

Section Properties : I Beam I12.6

Chinese Structural Steel Data

```
Overall Leg Length                                        880.000  mm
Effective Leg Length                         Leglen       500.000  mm
Distance Leg Up Side of Vessel                            330.000  mm
Number of Legs                               Nleg           3
Cross Sectional Area for I12.6               Aleg      1810.448  mm?
Section Inertia     ( strong axis )                 4887010.000  mm**4
Section Inertia     ( weak   axis )                  469300.469  mm**4
Section Modulus     ( strong axis )                   77468.195  mm ³
Section Modulus     ( weak   axis )                   12667.199  mm ³
Radius of Gyration ( strong axis )                       51.951  mm
Radius of Gyration ( weak   axis )                       16.091  mm
```

Leg Orientation - Weak Axis

```
Overturning Moment at top of Legs                      584009.2  N-mm
Total Weight Load at top of Legs                 W       3471.6  N
Total Shear force at top of Legs                         1505.7  N
Additional force in Leg due to Bracing        Fadd          0.0  N
Occasional Load Factor                      Occfac        1.333
Effective Leg End Condition Factor               k        1.000
```

Note: The Legs are Not Cross Braced
The Leg Shear Force includes Wind and Seismic Effects

```
Pad Width along Circumference                 C11P    225.000  mm
Pad Length along Vessel Axis                  C22P    300.000  mm
Pad Thickness                                 Tpad      8.000  mm
```

Maximum Shear at top of one Leg [Vleg]:

```
  = ( max( Wind, Seismic ) + applied forces )( Imax / Itot )
  = ( 1505.7 )( 4886154/5823664 )
  = 1263.28 N
```

Axial Compression, Leg furthest from the Neutral Axis [Sma]:

```
  = ((W/Nleg)+(Mleg/(Nlegm*Rn)))/Aleg)
  = ((3472/3) + (584009/( 1 * 345.47 )))/1810.448 )
  = 1.57 MPa
```

Axial Compression, Leg closest to the Neutral Axis [Sva]:

```
  = ( W / Nleg ) / Aleg
  = ( 3472/3 )/1810.448
  = 0.64 MPa
```

Allowable Comp. for the Selected Leg (KL/r < Cc) [Sa]:

```
  = Occfac * ( 1-(kl/r)²/(2*Cc²))*Fy /
   ( 5/3+3*(Kl/r)/(8*Cc)-(Kl/r³)/(8*Cc³)
  = 1.33 * ( 1-( 31.07 )²/(2 * 127.18² )) * 248/
    ( 5/3+3*( 31.07 )/(8* 127.18 )-( 31.07³)/(8* 127.18³)
  = 182.75 MPa
```

Bending at the Bottom of the Leg closest to the N.A. [S]:

```
  = ( Vleg * Leglen / Smdwa )
  = ( 1263.28 * 500.0/12667.2 )
  = 49.87 MPa
```

Allowable Bending Stress[Sb]:

```
  = ( 0.6 * Fy * Occfac )
```

= (0.6 * 248 * 1.33)
= 198.53 MPa

AISC Unity Check [Sc](must be < or = to 1.00) :
= (Sma/Sa)+(0.85*S)/((1-Sma/Spex)*Sb)
= (2/183)+(0.85 *49.869)/((1 -2/1446) *199)
= 0.2224

WRC 107 Stress Analysis for Leg to Shell Junction, Ope Condition

Rectangular Attachment Parameter	C11	125.999	mm
Rectangular Attachment Parameter	C22	280.950	mm

Input Echo, WRC107/537 Item 1, Description: LEGS

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	3.0000	mm
Vessel Diameter	Dv	600.000	mm
Vessel Thickness	Tv	7.000	mm
Design Temperature		85.00	癈
Attachment Type	Type	Rectangular	
Parameter C11	C11	126.00	mm
Parameter C22	C22	280.95	mm
Thickness of Reinforcing Pad	Tpad	8.000	mm
Pad Parameter C11P	C11p	225.000	mm
Pad Parameter C22P	C22p	300.000	mm
Design Internal Pressure	Dp	1.000	MPa
Include Pressure Thrust		No	
Vessel Centerline Direction Cosine	Vx	0.000	
Vessel Centerline Direction Cosine	Vy	1.000	
Vessel Centerline Direction Cosine	Vz	0.000	
Nozzle Centerline Direction Cosine	Nx	1.000	
Nozzle Centerline Direction Cosine	Ny	0.000	
Nozzle Centerline Direction Cosine	Nz	0.000	
Global Force (SUS)	Fx	0.0	N
Global Force (SUS)	Fy	1157.2	N
Global Force (SUS)	Fz	0.0	N
Global Moment (SUS)	Mx	0.0	N-mm
Global Moment (SUS)	My	0.0	N-mm
Global Moment (SUS)	Mz	44531.9	N-mm
Internal Pressure (SUS)	P	1.00	MPa
Include Pressure Thrust		No	
Global Force (OCC)	Fx	1263.3	N
Global Force (OCC)	Fy	1689.8	N
Global Force (OCC)	Fz	0.0	N
Global Moment (OCC)	Mx	0.0	N-mm
Global Moment (OCC)	My	0.0	N-mm
Global Moment (OCC)	Mz	380975.8	N-mm
Occasional Internal Pressure (OCC)	Pvar	0.00	MPa
Use Interactive Control		No	
WRC107 Version	Version	March 1979	
Include Pressure Stress Indices per Div. 2		No	

Compute Pressure Stress per WRC-368 No

Note:
WRC Bulletin 537 provides equations for the dimensionless curves found in bulletin 107. As noted in the foreword to bulletin 537, "537 is equivalent to WRC 107". Where 107 is printed in the results below, "537" can be interchanged with "107".

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	0.0	N
Circumferential Shear	VC	0.0	N
Longitudinal Shear	VL	1157.2	N
Circumferential Moment	MC	0.0	N-mm
Longitudinal Moment	ML	-44531.9	N-mm
Torsional Moment	MT	0.0	N-mm

Dimensionless Parameters used : Gamma = 25.75

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.412	4C	2.578	(A,B)
N(PHI) / (P/Rm)	0.412	3C	1.234	(C,D)
M(PHI) / (P)	0.278	2C1	0.027	(A,B)
M(PHI) / (P)	0.278	1C !	0.059	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.266	3A	1.106	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.301	1A	0.075	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.348	3B	2.010	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.323	1B	0.017	(A,B,C,D)
N(x) / (P/Rm)	0.349	3C	1.528	(A,B)
N(x) / (P/Rm)	0.349	4C	2.915	(C,D)
M(x) / (P)	0.360	1C1	0.037	(A,B)
M(x) / (P)	0.360	2C !	0.030	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.266	4A	2.051	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.382	2A	0.029	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.348	4B	0.976	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.392	2B	0.021	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (MPa)

Type of Stress	Load	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
		Stress Intensity Values at							
Circ. Memb.	P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Bend.	P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb.	MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb.	MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb.	ML	0.2	0.2	-0.2	-0.2	0.0	0.0	0.0	0.0
Circ. Bend.	ML	0.3	-0.3	-0.3	0.3	0.0	0.0	0.0	0.0
Tot. Circ. Str.		0.5	-0.1	-0.5	0.1	0.0	0.0	0.0	0.0
Long. Memb.	P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend.	P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb.	MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend.	MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb.	ML	0.1	0.1	-0.1	-0.1	0.0	0.0	0.0	0.0
Long. Bend.	ML	0.3	-0.3	-0.3	0.3	0.0	0.0	0.0	0.0

Tot. Long. Str.	0.5	-0.2	-0.5	0.2	0.0	0.0	0.0	0.0
Shear VC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.2	-0.2	0.2	0.2
Shear MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Shear	0.0	0.0	0.0	0.0	-0.2	-0.2	0.2	0.2
Str. Int.	0.5	0.2	0.5	0.2	0.3	0.3	0.3	0.3

Dimensionless Parameters used : Gamma = 76.25

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.494	4C	3.617	(A,B)
N(PHI) / (P/Rm)	0.494	3C	1.109	(C,D)
M(PHI) / (P)	0.409	2C1	0.005	(A,B)
M(PHI) / (P)	0.409	1C !	0.068	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.406	3A	1.379	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.435	1A	0.055	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.447	3B	2.210	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.438	1B	0.003	(A,B,C,D)
N(x) / (P/Rm)	0.454	3C	1.269	(A,B)
N(x) / (P/Rm)	0.454	4C	4.084	(C,D)
M(x) / (P)	0.461	1C1	0.009	(A,B)
M(x) / (P)	0.461	2C !	0.036	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.406	4A	6.472	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.499	2A	0.021	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.447	4B	1.229	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.473	2B	0.004	(A,B,C,D)

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

Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (MPa)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Bend. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. ML	0.5	0.5	-0.5	-0.5	0.0	0.0	0.0	0.0
Circ. Bend. ML	0.4	-0.4	-0.4	0.4	0.0	0.0	0.0	0.0
Tot. Circ. Str.	0.9	0.1	-0.9	-0.1	0.0	0.0	0.0	0.0
Long. Memb. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. ML	0.3	0.3	-0.3	-0.3	0.0	0.0	0.0	0.0
Long. Bend. ML	0.5	-0.5	-0.5	0.5	0.0	0.0	0.0	0.0
Tot. Long. Str.	0.8	-0.1	-0.8	0.1	0.0	0.0	0.0	0.0
Shear VC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.5	-0.5	0.5	0.5
Shear MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Tot. Shear	0.0	0.0	0.0	0.0	-0.5	-0.5	0.5	0.5
Str. Int.	0.9	0.3	0.9	0.3	1.0	1.0	1.0	1.0

WRC 107 Stress Calculation for OCCasional loads:

Radial Load	P	1263.3	N
Circumferential Shear	VC	0.0	N
Longitudinal Shear	VL	1689.8	N
Circumferential Moment	MC	0.0	N-mm
Longitudinal Moment	ML	-380975.8	N-mm
Torsional Moment	MT	0.0	N-mm

Dimensionless Parameters used : Gamma = 25.75
Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Attachment Junction (MPa)

Type of Stress Load	Stress Intensity Values at							
	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-0.9	-0.9	-0.9	-0.9	-0.4	-0.4	-0.4	-0.4
Circ. Bend. P	-1.4	1.4	-1.4	1.4	-3.1	3.1	-3.1	3.1
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. ML	1.6	1.6	-1.6	-1.6	0.0	0.0	0.0	0.0
Circ. Bend. ML	2.8	-2.8	-2.8	2.8	0.0	0.0	0.0	0.0
Tot. Circ. Str.	2.1	-0.6	-6.6	1.7	-3.6	2.7	-3.6	2.7
Long. Memb. P	-0.5	-0.5	-0.5	-0.5	-1.0	-1.0	-1.0	-1.0
Long. Bend. P	-1.9	1.9	-1.9	1.9	-1.6	1.6	-1.6	1.6
Long. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. ML	1.2	1.2	-1.2	-1.2	0.0	0.0	0.0	0.0
Long. Bend. ML	2.8	-2.8	-2.8	2.8	0.0	0.0	0.0	0.0
Tot. Long. Str.	1.5	-0.2	-6.4	3.0	-2.6	0.6	-2.6	0.6
Shear VC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.3	-0.3	0.3	0.3
Shear MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Shear	0.0	0.0	0.0	0.0	-0.3	-0.3	0.3	0.3
Str. Int.	2.1	0.6	6.6	3.0	3.6	2.7	3.6	2.7

Dimensionless Parameters used : Gamma = 76.25
Stress Concentration Factors: Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad (MPa)

Type of Stress Load	Stress Intensity Values at							
	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	-3.7	-3.7	-3.7	-3.7	-1.1	-1.1	-1.1	-1.1
Circ. Bend. P	-2.2	2.2	-2.2	2.2	-32.2	32.2	-32.2	32.2
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Memb. ML	4.5	4.5	-4.5	-4.5	0.0	0.0	0.0	0.0
Circ. Bend. ML	3.4	-3.4	-3.4	3.4	0.0	0.0	0.0	0.0
Tot. Circ. Str.	1.9	-0.5	-13.7	-2.7	-33.4	31.1	-33.4	31.1
Long. Memb. P	-1.3	-1.3	-1.3	-1.3	-4.2	-4.2	-4.2	-4.2

Long. Bend. P	-4.1	4.1	-4.1	4.1	-17.0	17.0	-17.0	17.0
Long. Memb. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Bend. MC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Memb. ML	2.7	2.7	-2.7	-2.7	0.0	0.0	0.0	0.0
Long. Bend. ML	4.0	-4.0	-4.0	4.0	0.0	0.0	0.0	0.0
Tot. Long. Str.	1.4	1.5	-12.2	4.0	-21.2	12.7	-21.2	12.7
Shear VC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear VL	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Shear MT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tot. Shear	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Str. Int.	1.9	2.0	13.7	6.7	33.4	31.1	33.4	31.1

WRC 107 / 537 Stress Summations:

Vessel Stress Summation at Attachment Junction (MPa)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	24.8	25.8	24.8	25.8	24.8	25.8	24.8	25.8
Circ. Pm (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Pm(TOTAL)	24.8	25.8	24.8	25.8	24.8	25.8	24.8	25.8
Circ. Pl (SUS)	0.2	0.2	-0.2	-0.2	0.0	0.0	0.0	0.0
Circ. Pl (OCC)	0.7	0.7	-2.5	-2.5	-0.4	-0.4	-0.4	-0.4
Circ. Pl(TOTAL)	0.9	0.9	-2.7	-2.7	-0.4	-0.4	-0.4	-0.4
Circ. Q (SUS)	0.3	-0.3	-0.3	0.3	0.0	0.0	0.0	0.0
Circ. Q (OCC)	1.4	-1.4	-4.2	4.2	-3.1	3.1	-3.1	3.1
Circ. Q (TOTAL)	1.7	-1.7	-4.5	4.5	-3.1	3.1	-3.1	3.1
Long. Pm (SUS)	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4
Long. Pm (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Pm(TOTAL)	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4
Long. Pl (SUS)	0.1	0.1	-0.1	-0.1	0.0	0.0	0.0	0.0
Long. Pl (OCC)	0.7	0.7	-1.7	-1.7	-1.0	-1.0	-1.0	-1.0
Long. Pl(TOTAL)	0.8	0.8	-1.8	-1.8	-1.0	-1.0	-1.0	-1.0
Long. Q (SUS)	0.3	-0.3	-0.3	0.3	0.0	0.0	0.0	0.0
Long. Q (OCC)	0.8	-0.8	-4.7	4.7	-1.6	1.6	-1.6	1.6
Long. Q (TOTAL)	1.2	-1.2	-5.1	5.1	-1.6	1.6	-1.6	1.6
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pm (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pm(TOTAL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.0	0.0	0.0	0.0	-0.2	-0.2	0.2	0.2
Shear Pl (OCC)	0.0	0.0	0.0	0.0	-0.3	-0.3	0.3	0.3
Shear Pl(TOTAL)	0.0	0.0	0.0	0.0	-0.4	-0.4	0.4	0.4
Shear Q (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Q (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Q (TOTAL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm (SUS)	24.8	25.8	24.8	25.8	24.8	25.8	24.8	25.8
Pm (SUS+OCC)	24.8	25.8	24.8	25.8	24.8	25.8	24.8	25.8
Pm+Pl (SUS)	24.9	25.9	24.6	25.6	24.8	25.8	24.8	25.8
Pm+Pl (SUS+OCC)	25.7	26.7	22.1	23.1	24.4	25.4	24.4	25.4
Pm+Pl+Q (Total)	27.4	25.0	17.6	27.6	21.2	28.5	21.2	28.5

Stress Summation Comparison (MPa):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	25.76	137.90	Passed
Pm (SUS+OCC)	25.76	165.48	Passed
Pm+Pl (SUS)	25.95	206.85	Passed
Pm+Pl (SUS+OCC)	26.68	248.22	Passed
Pm+Pl+Q (TOTAL)	28.48	413.70	Passed

WRC 107 / 537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge (MPa)

Type of Stress Load	Stress Intensity Values at Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	75.3	76.3	75.3	76.3	75.3	76.3	75.3	76.3
Circ. Pm (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Circ. Pm(TOTAL)	75.3	76.3	75.3	76.3	75.3	76.3	75.3	76.3
Circ. Pl (SUS)	0.5	0.5	-0.5	-0.5	0.0	0.0	0.0	0.0
Circ. Pl (OCC)	0.7	0.7	-8.2	-8.2	-1.1	-1.1	-1.1	-1.1
Circ. Pl(TOTAL)	1.2	1.2	-8.7	-8.7	-1.1	-1.1	-1.1	-1.1
Circ. Q (SUS)	0.4	-0.4	-0.4	0.4	0.0	0.0	0.0	0.0
Circ. Q (OCC)	1.2	-1.2	-5.5	5.5	-32.2	32.2	-32.2	32.2
Circ. Q (TOTAL)	1.6	-1.6	-5.9	5.9	-32.2	32.2	-32.2	32.2
Long. Pm (SUS)	37.6	37.6	37.6	37.6	37.6	37.6	37.6	37.6
Long. Pm (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long. Pm(TOTAL)	37.6	37.6	37.6	37.6	37.6	37.6	37.6	37.6
Long. Pl (SUS)	0.3	0.3	-0.3	-0.3	0.0	0.0	0.0	0.0
Long. Pl (OCC)	1.4	1.4	-4.1	-4.1	-4.2	-4.2	-4.2	-4.2
Long. Pl(TOTAL)	1.8	1.8	-4.4	-4.4	-4.2	-4.2	-4.2	-4.2
Long. Q (SUS)	0.5	-0.5	-0.5	0.5	0.0	0.0	0.0	0.0
Long. Q (OCC)	-0.1	0.1	-8.1	8.1	-17.0	17.0	-17.0	17.0
Long. Q (TOTAL)	0.4	-0.4	-8.6	8.6	-17.0	17.0	-17.0	17.0
Shear Pm (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pm (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pm(TOTAL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Pl (SUS)	0.0	0.0	0.0	0.0	-0.5	-0.5	0.5	0.5
Shear Pl (OCC)	0.0	0.0	0.0	0.0	-0.7	-0.7	0.7	0.7
Shear Pl(TOTAL)	0.0	0.0	0.0	0.0	-1.2	-1.2	1.2	1.2
Shear Q (SUS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Q (OCC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shear Q (TOTAL)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pm (SUS)	75.3	76.3	75.3	76.3	75.3	76.3	75.3	76.3
Pm (SUS+OCC)	75.3	76.3	75.3	76.3	75.3	76.3	75.3	76.3
Pm+Pl (SUS)	75.8	76.8	74.7	75.7	75.3	76.3	75.3	76.3
Pm+Pl (SUS+OCC)	76.5	77.5	66.5	67.5	74.1	75.1	74.1	75.1
Pm+Pl+Q (Total)	78.1	75.9	60.6	73.4	41.9	107.3	41.9	107.3

Stress Summation Comparison (MPa):

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
Pm (SUS)	76.25	137.90	Passed
Pm (SUS+OCC)	76.25	165.48	Passed

Pm+Pl (SUS)	76.78	206.85	Passed
Pm+Pl (SUS+OCC)	77.50	248.22	Passed
Pm+Pl+Q (TOTAL)	107.34	413.70	Passed

Bolting Size Requirement for Leg Baseplates :

Baseplate Material		SA-516 70	
Baseplate Allowable Stress	SBA	137.90	MPa
Baseplate Length	B	240.0000	mm
Baseplate Width	D	240.0000	mm
Baseplate Thickness	BTHK	20.0000	mm
Leg Dimension Along Baseplate Length	d	125.9992	mm
Leg Dimension Along Baseplate Width	b	74.0004	mm
Dist. from the Leg Edge to Bolt Hole Center	z	55.0000	mm
Bolt Material		SA-36	
Bolt Allowable Stress	STBA	114.46	MPa
Anchor Bolt Nominal Diameter	BOD	24.0000	mm
Number of Anchor Bolts in Tension per Leg	NB	1	
Total Number of Anchors Bolt per Leg	NBT	2	
Ultimate 28-day Concrete Strength	FCPRIME	20.685	MPa

LEG BASEPLATE and BOLTING Analysis, including Moments

I-Beam Leg

Base Plate Available Area (AA):

```
    = B * D
    = 240.0 * 240.0
    = 57600.00  mm?
```

Clearance Between The Bolt And The Leg Edge (BCL):

```
    = z - BOD / 2
    = 55.0 - 24.0/2
    = 43.00  mm
```

Moment at Baseplate (MOMENT):

```
    = Vleg * Lleg
    = 1263.28 * 880.0
    = 1112138.50  N-mm
```

Axial Load on the baseplate (P):

```
    = Operating Weight per leg  (as Seismic + Operating case is controlling)
    = 1157.21  N
```

Eccentricity (e):

```
    = MOMENT * Conv_Factor / P
    = 1112139 *1.00/1157.21
    = 960.66 mm > D/6 [Plate Uplift Condition]

 a  = (D - d) / 2
    = (240.0 - 126.0)/2
    = 57.00  mm
```

Modular Ratio Of Steel/Concrete (n):

```
    = ES / EC
    = 203402.5/21526.32
    = 9.45

 F  = 0.5 * d + z
    = 0.5 * 126.0 + 55.0
    = 118.00  mm

 K1 = 3.0 (e - 0.5*D)
    = 3.0 (960.66 - 0.5*240.0)
    = 2521.98
```

```
K2 = 6 * n * Ast / B * (F + e)
   = 6 * 9.45 * 152.95/240.0 * (118.0 + 960.66)
   = 38972.93

K3 = -K2 * (0.5 * D + F)
   = -38972.93 * (0.5 * 240.0 + 118.0)
   = -9275542.42
```

Solving For The Effective Bearing Length Using Iteration:

```
Y³ + K1 * Y² + K2 * Y + K3 = 0
Y³ + 99.29 * Y² + 60.41 * Y - 566.03 = 0
Y  = 52.93  mm

NUM = (D / 2 - Y / 3 - e)
    = (240.0/2 - 52.93/3 - 960.66)
    = -858.30

DENOM = (D / 2 - Y / 3 + F)
      = (240.0/2 - 52.93/3 + 118.0)
      = 220.36
```

Total Bolt Tension Force (T):

```
= - P * NUM / DENOM
= - 1157.21 * -858.3/220.36
= 4507.40  N
```

Overturning Moment Due To Bolt In Tension (Mt):

```
= T * (0.5 * D + F - Y)
= 4507.4 * (0.5 * 240.0 + 118.0 - 52.93)
= 834536.38  N-mm
```

Bearing Pressure (FC):

```
= 2 * (P + T) / (Y * B)
= 2 * (1157.21 + 4507.4)/(52.93 * 240.0)
= 0.89 MPa [ <= FCPRIME ( 20.68)]
```

Equivalent Bearing Pressure (f1):

```
= FC * (Y - a) / Y
= 0.89 * (52.93 - 57.0)/52.93
= -0.07  MPa
```

Overturning Moment Due To Bearing Pressure (Mc):

```
= (a² * B / 6) * (f1 + 2 * FC)
= (57.0² * 240.0/6) * (-0.07 + 2 * 0.89)
= 222993.78  N-mm
```

The Baseplate Required Thickness (TREQ):

```
= (6 * MAX(Mt,Mc) / (B * 1.5 * SBA))^.5
= (6 * 834536/(240.0 * 206.85))^.5
= 10.04  mm
```

Required bolt area (ABREQM): per D. Moss

```
= T / STBA
= 4507.4/114.46
= 39.3840 mm? [ < Ast ( 152.95) --> PASSED]
```

Distance from Top of Legs to Vessel CG (CD_DIST):

```
= 150.19 mm
```

Total Overturning Moment at Baseplate (Mbb):

```
= ( Mleg / max([CD_DIST], minDist) )* ( CD_DIST + Lleg )
= ( 584009/max( 150.19, 38.1 ) ) * ( 150.19 + 880.0 )
= 4005805.75  N-mm
```

Required Total Bolt Area per Leg (ABREQB): per H. Bednar

```
= (1 / (Nleg * STBA)) * ((4 * Mbb / (Rn * 2) ) - W )
= (1/(3 * 114.46)) * ((4 * 4005806/(690.93)) - 3471.63 )
```

= 57.4054 mm?

Available Total Bolt Corr. Area per Leg (ABAVL):
= As * NBT
= 152.95 * 2.0
= 305.9014 mm? [> ABREQB (57.41) --> PASSED]

Summary of Results:

		Actual	Required	Pass/Fail
Baseplate Thickness	(mm):	20.000	10.041	Pass
Bolt Root Area (Bednar)	(mm?):	305.90	57.41	Pass
Bolt Root Area (D. Moss)	(mm?):	152.95	39.38	Pass

Note: The required thickness calculation is performed based on:
Strong axis orientation of the beam leg
Even number of bolts installed only on the B dimension sides

Nozzle Calculation Summary:

Description	MAWP MPa	Ext	MAPNC MPa	UG-45	[tr] mm	Weld Path	Areas or Stresses
Noz N3 Fr10	1.0000	...	...	OK	5.17	OK	No Calc[*]
Noz N1 Fr20	1.0000	...	...	OK	5.21	OK	Passed
Noz H Fr20	1.0000	...	...	OK	5.21	OK	Passed
Noz P Fr20	1.0000	...	...	OK	5.21	OK	No Calc[*]
Noz T Fr20	1.0000	...	...	OK	5.21	OK	No Calc[*]
Noz N2 Fr30	1.0000	...	...	OK	5.17	OK	No Calc[*]
Noz S Fr30	1.0000	...	...	OK	5.17	OK	No Calc[*]
Noz S Fr30	1.0000	...	...	OK	5.17	OK	No Calc[*]

MAWP Summary:

```
Minimum MAWP Nozzles          :          1.000 Nozzle  : Noz S Fr30
Minimum MAWP Shells/Flanges   :          1.000 Element :
Minimum MAPnc Shells/Flanges  :          1.960 Element :
--------------------------------------------------------
Computed Vessel M.A.W.P.      :          1.000 MPa
```

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

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

Check the Spatial Relationship between the Nozzles

From Node	Nozzle Description	Y Coordinate mm	Layout Angle deg	Dia. Limit mm
10	Noz N3 Fr10	0.000	0.000	110.440
20	Noz N1 Fr20	400.000	90.000	216.520
20	Noz H Fr20	400.000	180.000	320.160
20	Noz P Fr20	1040.000	180.000	80.040
20	Noz T Fr20	800.000	180.000	110.440
30	Noz N2 Fr30	0.000	0.000	167.840
30	Noz S Fr30	0.000	45.000	53.400

The nozzle spacing is computed by the following:

= Sqrt($ll^2 + lc^2$) where
ll - Arc length along the inside vessel surface in the long. direction.
lc - Arc length along the inside vessel surface in the circ. direction

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

INPUT VALUES, Nozzle Description: Noz N3 Fr10 From : 10

```
Pressure for Reinforcement Calculations        P       1.0000  MPa
Temperature for Internal Pressure           Temp           85   C

Shell Material                                     SA-516 70
Shell Allowable Stress at Temperature         Sv      137.90  MPa
Shell Allowable Stress At Ambient            Sva      137.90  MPa

Inside Diameter of Elliptical Head             D      600.00  mm
Aspect Ratio of Elliptical Head               Ar        2.00
Head Finished (Minimum) Thickness              t      7.0000  mm
Head Internal Corrosion Allowance              c      3.0000  mm
Head External Corrosion Allowance             co      0.0000  mm

Distance from Head Centerline                 L1      0.0000  mm

User Entered Minimum Design Metal Temperature         -10.00   C
```

Type of Element Connected to the Shell : Nozzle

```
Material                                            SA-106 B
Material UNS Number                                   K03006
Material Specification/Type                       Smls. pipe
Allowable Stress at Temperature               Sn      117.90  MPa
Allowable Stress At Ambient                  Sna      117.90  MPa

Diameter Basis (for tr calc only)                         OD
Layout Angle                                            0.00  deg
Diameter                                             60.3000   mm

Size and Thickness Basis                              Actual
Actual Thickness                              tn      5.5400  mm

Flange Material                                       SA-105
Flange Type                                 Weld Neck Flange

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

Outside Projection                            ho    150.0000  mm
Weld leg size between Nozzle and Pad/Shell    Wo      8.0000  mm
Groove weld depth between Nozzle and Vessel Wgnv      7.0000  mm
Inside Projection                              h      0.0000  mm
Weld leg size, Inside Element to Shell        Wi      0.0000  mm
ASME Code Weld Type per UW-16                           None

Class of attached Flange                           150
Grade of attached Flange                           GR 1.1
```

The Pressure Design option was Design Pressure + static head.

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

```
               |  |
               |  |
               |  |
               |  |
  ____________/|  |
 |          \  |  |
 |           \ |  |
 |____________\|__|
```

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

Reinforcement CALCULATION, Description: Noz N3 Fr10

ASME Code, Section VIII, Div. 1, 2015, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation          60.300  mm.
Actual Thickness Used in Calculation                  5.540  mm
```

Nozzle input data check completed without errors.

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

```
 = (P*K1*D))/(2*Sv*E-0.2*P) per UG-37(a)(3)
 = (1.*0.892*606.0)/(2 *137.9*1.0-0.2*1.)
 = 1.9604 mm
```

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

```
 = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
 = (1.*30.15)/(118*1.0+0.4*1.)
 = 0.2549 mm
```

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

```
Parallel to Vessel Wall (Diameter Limit)            Dl   110.4400  mm
Parallel to Vessel Wall, opening length              d    55.2200  mm
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     6.3500  mm
```

Note:

Taking a UG-36(c)(3)(a) exemption for nozzle: Noz N3 Fr10.
This calculation is valid for nozzles that meet all the requirements of paragraph UG-36. Please check the Code carefully, especially for nozzles that are not isolated or do not meet Code spacing requirements. To force the computation of areas for small nozzles go to Tools->Configuration and check the box to force the UG-37 small nozzle area calculation or force the Appendix 1-10 computation in Nozzle Design Options.

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

```
Wall Thickness for Internal/External pressures        ta = 3.2549 mm
Wall Thickness per UG16(b),                        tr16b = 4.5000 mm
Wall Thickness, shell/head, internal pressure       trb1 = 5.1702 mm
Wall Thickness               tb1 = max(trb1, tr16b) = 5.1702 mm
Wall Thickness               tb2 = max(trb2, tr16b) = 4.5000 mm
Wall Thickness per table UG-45                       tb3 = 6.4200 mm
```

Determine Nozzle Thickness candidate [tb]:

```
 = min[ tb3, max( tb1,tb2) ]
 = min[ 6.42, max( 5.1702, 4.5 ) ]
 = 5.1702 mm
```

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

```
 = max( ta, tb )
 = max( 3.2549, 5.1702 )
 = 5.1702 mm
```

Available Nozzle Neck Thickness = 5.5400 mm --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):

```
Sustained  :    20.0,  Allowable :    117.9 MPa  Passed
Expansion  :     0.0,  Allowable :    274.7 MPa  Passed
Occasional :     5.2,  Allowable :    156.8 MPa  Passed
Shear      :    35.3,  Allowable :     82.5 MPa  Passed
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

MDMT of the Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 5.54, tr = 0.255, c = 3.0 mm, E* = 1.0
Stress Ratio = tr * (E*)/(tg - c) = 0.1, Temp. Reduction = 78 C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29	C
Min Metal Temp. at Required thickness (UCS 66.1)	-104	C

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

Govrn. thk, tg = 5.54, tr = 0.255, c = 3.0 mm, E* = 1.0
Stress Ratio = tr * (E*)/(tg - c) = 0.1, Temp. Reduction = 78 C

Min Metal Temp. w/o impact per UCS-66, Curve B	-29	C
Min Metal Temp. at Required thickness (UCS 66.1)	-104	C
Governing MDMT of all the sub-joints of this Junction :	-104	C

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

Where the Stress Reduction Ratio per UCS-66(b)(1)(b) is :
Design Pressure/Ambient Rating = 1.00/1.96 = 0.510

Note: Using the minimum value from (b)(1)(b) and (b)(1)(c) above as the calculated nozzle flange MDMT.

Weld Size Calculations, Description: Noz N3 Fr10

Intermediate Calc. for nozzle/shell Welds Tmin 2.5400 mm

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	1.7780 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm

Skipping the nozzle attachment weld strength calculations.
Per UW-15(b)(2) the nozzles exempted by UG-36(c)(3)(a)
(small nozzles) do not require a weld strength check.

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 1.0000 MPa

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

The Drop for this Nozzle is : 0.8337 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 157.8337 mm

Input Echo, PD:5500 Annex G Local Stress Analysis

Radial Load (positive outward)	Fr	2400.00	N
Circumferential Shear	Fc	2400.00	N
Longitudinal Shear	Fl	1800.00	N
Torsional Moment	Mt	263999.8	N-mm
Circumferential Moment	Mc	36000.0	N-mm
Longitudinal Moment	Ml	50000.0	N-mm

Allowable Stress Intensity Factor (Mem + Bend) 2.25
Print Membrane Stress at the Attachment junction No

PD-5500 Annex G Nozzle to Sphere Junction Stress Analysis

Stress Calculations at the Edge of the Nozzle Neck :

Resultant Shear Force	Srss(Fc^2+ Fl^2)	S	3000.	N
Resultant Moment	Srss(Mc^2+ Ml^2)	M	61612.	N-mm
Shell Mean Radius		R	545.000	mm
Nozzle Mean Radius		r	28.880	mm
Thickness Ratio		t/T'	0.6350	
Ratio of Shell Mean Radius to Shell Thk.		R/T'	136.2494	
Value of Rho		r/R*(R/T')^1/2	0.6185	
Value of u (=s)		u	1.1257	

Stress Concentration Factor for Pressure	2.4062	
Stress Concentration Factor for Radial Force	1.7154	
Stress Concentration Factor for Bending Moment	0.9898	
Stress Concentration Factor for Shear	0.6034	
Total Stress due to Pressure	163.92	MPa
Total Stress due to Radial Loads	66.21	MPa
Total Stress due to Shear Forces	2.49	MPa
Total Stress due to Bending Moments	67.89	MPa
Total Stress due to Torsional Moment	9.09	MPa
Maximum Stress at Sphere/Attachment Junction	309.61	MPa

Check the Maximum Stresses versus defined Allowables :
Max. Str. Int. (Mem + Bend): 309.61 Allowable: 310.27 MPa

Maximum Loads: PD:5500 Annex G.2.8 (Alternative Rules - Information Only):

Flush Nozzle located in a sphere:

Note: Pmax is determined per PD:5500 Section 3.5.4:

Shell Effective Mean Diameter [D]:
= Di + es + Min(fp/fs, 1)*tp + cas - caext
= 1080.0 + 7.0 + Min(0.0/137.9, 1)*0.0 + 3.0 - 0.0
= 1090.0 mm

Nozzle Mean Diameter [d]:
= do - eb + can - caext
= 60.3 - 5.54 + 3.0 - 0.0 = 57.76 mm

Adjusted value of [Ratio erb/ers]:
= min(fn/fs, 1) * erb / ers
= min(117.905/137.9, 1) * 2.54/4.0 = 0.5429

Compute the Maximum Pressure [Pmax]
The value of Pmax is 1.683 MPa and is derived as follows:

Required Shell Thickness [esp]
= Pmax * D / (4 * fs)
= 1.683 * 1090.0/(4 * 137.9) = 3.327 mm

Compute Ratio [C.ers/eps]
= C * ers / eps
= 1.0 * 4.0/3.327 = 1.2025

Compute the Value of [Rho] :
= d/D * sqrt(D / (2 * as))
= 57.76/1090.0 * sqrt(1090.0/(2 * 4.0)) = 0.6185

From Graph: Figure 3.5-10 we obtain a value of erb/ers of: .5429

Linear Interpolation Points from: Figure 3.5-10

Rho1	Rho	Rho2
0.7000	0.6185	0.6000

Cers/eps1	1.2000	0.660		0.520
Cers/eps	1.2025 <- Interpolated		0.5429	
Cers/eps2	1.1000	0.860		0.690

As Calculated Nozzle Thickness equals Actual Thickness: Pmax is correct.

Maxium Allowable Radial Force Fzmax and Moment [MBmax]:

Determine the value of [k]:
= min(2 * fn * eab / (fs * eac) * (eab / d)$^{.5}$, 1)
= min(2*117.905*2.54/(137.9*4.0) * (2.54/57.76)$^{.5}$ 1)
= 0.228

Determine the value of [LamdaS]:
= d/(R * eac)$^{.5}$= 57.76/(545.0 * 4.0)$^{.5}$
= 1.237

Determine the Maximum Allowable Radial Force: [FZmax]:
= fs *eac^2 (1.82 + 2.4 ((1 + k)$^{.5}$* LamdaS + 0.91 * k * LamdaS^2)
= 137.9*4.0^2 (1.82+2.4((1+ 0.228)$^{.5}$1.237+0.91* 0.228*1.237^2)
= 36666.457 N

From Figure 2.1, FZmax must not exceed: 17883.045 N

Determine the Maximum Allowable Moment: [MBmax]:
= fs * eac^2 * d/4 * (4.9 + 2 ((1 + k)$^{.5}$* LamdaS + 0.91 * k * LamdaS^2)
= 137.9 * 4.0^2 * 57.76/4 *
(4.9 + 2*(1 + 0.228)$^{.5}$* 1.237 + 0.91 * 0.228 * 1.237^2))
= 253645.25 N-mm

From Figure 2.2, Mbmax must not exceed: 1241233 N-mm

Unity Checks per PD:5500 2.4 for Simultaneous Loads:
P/Pmax = 0.594 Fz/Fzmax = 0.134 Mb/Mbmax = .243
P/Pmax + Fz/Fzmax + Mb/Mbmax = .971

Summary of results:

	P MPa	Fz N	Mb N-mm
Actual:	1.000	2399.998	61611.691
Allowable:	1.683	17883.045	253645.250
Ratio:	0.594	0.134	0.243

Ratio of combined values: .971 (must be <= 1.0)

The Given Force and Moments Comply with the Code

INPUT VALUES, Nozzle Description: Noz N1 Fr20 From : 20

Pressure for Reinforcement Calculations	P	1.0000	MPa
Temperature for Internal Pressure	Temp	85	C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	MPa
Shell Allowable Stress At Ambient	Sva	137.90	MPa
Inside Diameter of Cylindrical Shell	D	600.00	mm
Shell Finished (Minimum) Thickness	t	8.0000	mm
Shell Internal Corrosion Allowance	c	3.0000	mm
Shell External Corrosion Allowance	co	0.0000	mm
Distance from Bottom/Left Tangent		400.00	mm
User Entered Minimum Design Metal Temperature		-10.00	C

Type of Element Connected to the Shell : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	MPa
Allowable Stress At Ambient	Sna	117.90	MPa
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		114.3000	mm
Size and Thickness Basis		Actual	
Actual Thickness	tn	6.0200	mm
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm
Weld leg size between Nozzle and Pad/Shell	Wo	6.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	6.0000	mm
Inside Projection	h	0.0000	mm
Weld leg size, Inside Element to Shell	Wi	0.0000	mm
ASME Code Weld Type per UW-16		None	
Class of attached Flange		150	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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

```
                |   |
                |   |
                |   |
                |   |
 ____________/|   |
|           \ |   |
|            \|   |
|____________\|__|
```

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

Reinforcement CALCULATION, Description: Noz N1 Fr20

ASME Code, Section VIII, Div. 1, 2015, UG-37 to UG-45

```
 Actual Outside Diameter Used in Calculation          114.300  mm.
 Actual Thickness Used in Calculation                   6.020  mm
```

Nozzle input data check completed without errors.

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

```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (1.*303.0)/(138*1.0-0.6*1.)
  = 2.2068 mm
```

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

```
  = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = (1.*57.15)/(118*1.0+0.4*1.)
  = 0.4831 mm
```

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

```
 Wall Thickness for Internal/External pressures      ta = 3.4831 mm
 Wall Thickness per UG16(b),                      tr16b = 4.5000 mm
 Wall Thickness, shell/head, internal pressure     trb1 = 5.2068 mm
 Wall Thickness                  tb1 = max(trb1, tr16b) = 5.2068 mm
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm
 Wall Thickness per table UG-45                     tb3 = 8.2578 mm
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 8.258, max( 5.2068, 4.5 ) ]
  = 5.2068 mm
```

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

```
  = max( ta, tb )
  = max( 3.4831, 5.2068 )
  = 5.2068 mm
```

Available Nozzle Neck Thickness = 6.0200 mm --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):

```
 Sustained  :     23.4,  Allowable :    117.9 MPa  Passed
 Expansion  :      0.0,  Allowable :    271.3 MPa  Passed
 Occasional :      8.7,  Allowable :    156.8 MPa  Passed
 Shear      :     25.0,  Allowable :     82.5 MPa  Passed
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

MDMT of the Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 6.02, tr = 0.483, c = 3.0 mm, E* = 1.0
Stress Ratio = tr * (E*)/(tg - c) = 0.16, Temp. Reduction = 78 C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B          -29  C
 Min Metal Temp. at Required thickness (UCS 66.1)       -104  C
```

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

Govrn. thk, tg = 6.02, tr = 0.483, c = 3.0 mm, E* = 1.0
Stress Ratio = tr * (E*)/(tg - c) = 0.16, Temp. Reduction = 78 C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B          -29  C
 Min Metal Temp. at Required thickness (UCS 66.1)       -104  C
```

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

Where the Stress Reduction Ratio per UCS-66(b)(1)(b) is :
```
 Design Pressure/Ambient Rating = 1.00/1.96 = 0.510
```

Note: Using the minimum value from (b)(1)(b) and (b)(1)(c) above as the calculated nozzle flange MDMT.

Nozzle Calculations per App. 1-10: Internal Pressure Case:

Thickness of Nozzle [tn]:
```
  = thickness - corrosion allowance
  = 6.02 - 3.0
  = 3.020 mm
```

Effective Pressure Radius [Reff]:
```
  = Di/2 + corrosion allowance
  = 600.0/2 + 3.0
  = 303.000 mm
```

Effective Length of Vessel Wall [LR]:
```
  = 8 * t
  = 8 * 5.0
  = 40.000 mm
```

Thickness Limit Candidate [LH1]:
```
  = t + 0.78 * sqrt( Rn * tn )
  = 5.0 + 0.78 * sqrt( 54.13 * 3.02 )
  = 14.973 mm
```

Thickness Limit Candidate [LH2]:
```
  = Lpr1 + T
  = 150.0 + 5.0
  = 155.000 mm
```

Thickness Limit Candidate [LH3]:
```
  = 8( t + te )
  = 8( 5.0 + 0.0 )
  = 40.000 mm
```

Effective Nozzle Wall Length Outside the Vessel [LH]:
```
  = min[ LH1, LH2, LH3 ]
  = min[ 14.973, 155.0, 40.0 )
  = 14.973 mm
```

Effective Vessel Thickness [teff]:
```
  = t
  = 5.000 mm
```

Determine Parameter [Lamda]:
```
  = min( 10, ( Dn + Tn )/( sqrt( ( Di + teff ) * teff )) )
  = min( 10, (108.26 + 3.02)/( sqrt((606.0 + 5.0) * 5.0)) )
  = 2.013
```

Compute Areas A1-A43 (No Pad) or A1-A5 (With Pad) :

Area Contributed by the Vessel Wall [A1]:
```
  = t * LR * max( Lamda/4, 1 )
  = 5.0 * 40.0 * max( 2.013/4, 1 )
  = 200.001 mm?
```

Area Contributed by the Nozzle Outside the Vessel Wall [A2]:
```
  = tn * LH
  = 3.02 * 14.973
  = 45.218 mm?
```

Area Contributed by the Outside Fillet Weld [A41]:
```
  = 0.5 * Leg41²
  = 0.5 * 6.0²
  = 18.000 mm?
```

The total area contributed by A1 through A43 [AT]:
```
  = A1 + frn( A2 + A3 ) + A41 + A42 + A43
  = 200.001+1.0(45.218+0.0)+18.0+0.0+0.0
  = 263.219 mm?
```

Allowable Local Primary Membrane Stress [Sallow]:
```
  = 1.5 * S * E
  = 1.5 * 137.9 * 1.0
  = 206.9 MPa
```

Determine Force acting on the Nozzle [fN]:
```
  = P * Rn( LH - t )
  = 1. * 54.13( 14.973 - 5.0 )
  = 539.8 N
```

Determine Force acting on the Shell [fS]:
```
  = P * Reff( LR + tn )
  = 1. * 303.0( 40.0 + 3.02 )
  = 13034.0 N
```

Discontinuity Force from Internal Pressure [fY]:
```
  = P * Reff * Rnc
  = 1. * 303.0 * 54.13
  = 16400.0 N
```

Area Resisting Internal Pressure [Ap]:
```
  = Rn( LH - t ) + Reff( LR + tn + Rnc )
  = 54.13( 14.973 - 5.0 ) + 303.0( 40.0 + 3.02 + 54.13 )
  = 29976.3 mm?
```

Maximum Allowable Working Pressure Candidate [Pmax1]:
```
  = Sallow /( 2 * Ap/AT - Rxs/teff )
  = 206.85/( 2 * 29976.312/263.219 - 303.0/5.0 )
  = 1.2 MPa
```

Maximum Allowable Working Pressure Candidate [Pmax2]:
```
  = S[t/Reff]
  = 137.9[5.0/303.0]
  = 2.3 MPa
```

Maximum Allowable Working Pressure [Pmax]:
```
  = min( Pmax1, Pmax2 )
  = min( 1.237, 2.276 )
  = 1.237 MPa
```

Average Primary Membrane Stress [SigmaAvg]:
```
  = ( fN + fS + fY ) / AT
  = ( 539.782 + 13033.987 + 16399.994 )/263.219
  = 113.884 MPa
```

General Primary Membrane Stress [SigmaCirc]:
```
  = P * Reff / teff
  = 1. * 303.0/5.0
  = 60.6 MPa
```

Maximum Local Primary Membrane Stress [PL]:
```
  = max( 2 * SigmaAvg - SigmaCirc, SigmaCirc )
```

```
  = max( 2 * 113.884 - 60.6, 60.6 )
  = 167.2 MPa
```

Summary of Nozzle Pressure/Stress Results:

Allowed Local Primary Membrane Stress	Sallow	206.85	MPa
Local Primary Membrane Stress	PL	167.17	MPa
Maximum Allowable Working Pressure	Pmax	1.24	MPa

Strength of Nozzle Attachment Welds per 1-10 and U-2(g)

Discontinuity Force Factor [ky]:

```
  = ( Rnc + tn ) / Rnc
  = ( 54.13 + 3.02 )/54.13
  = 1.056 For set-in Nozzles
```

Weld Length of Nozzle to Shell Weld [Ltau]:

```
  = pi/2 * ( Rn + tn )
  = pi/2 * ( 54.13 + 3.02 )
  = 89.771 mm
```

Weld Throat Dimensions, (0.7071*Leg Dimensions) [L41T, L42T, L43T]:

```
  = 4.243,   0.000,   0.000, mm
```

Weld Load Value [fwelds]:

```
  = min( fy * ky, 1.5 * Sn( A2 + A3 ), pi/4*P*Rn^2*ky^2 )
  = min(16400*1.06,1.5*117.9(45.218+0.0),pi/4*1.0*54.13^2*1.06^2)
  = 2564.988 N
```

Weld Stress Value [tau]:

```
  = fwelds/(Ltau(0.49*L41T + 0.6*tw1 + 0.49*L43T ) )
  = 2564.988/(89.771(0.49*4.243 + 0.6*5.0 + 0.49*0.0 ) )
  = 5.626 < or = to 137.900 Weld Stress Passed
```

Weld Size Calculations, Description: Noz N1 Fr20

Intermediate Calc. for nozzle/shell Welds	Tmin	3.0200	mm

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	2.1140 = 0.7 * tmin.	4.2420 = 0.7 * Wo mm

Maximum Allowable Pressure for this Nozzle at this Location:

Converged Max. Allow. Pressure in Operating case	1.0000	MPa

The Drop for this Nozzle is : 5.4939 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 163.4939 mm

Input Echo, WRC297 Item 1, Description: Noz N1 Fr20 :

Diameter Basis for Cylindrical Shell	ID	
Shell Corrosion Allowance	3.0000	mm
Shell Diameter	600.000	mm
Shell Thickness	8.0000	mm
Shell Stress Concentration Factor	1.000	
Diameter Basis for Nozzle	OD	
Nozzle Corrosion Allowance	3.0000	mm
Nozzle Diameter	114.300	mm
Nozzle Thickness	6.0200	mm
Nozzle Stress Concentration Factor	1.000	

Note: External Forces and Moments in WRC 107 Convention:
This loads are assumed to be SUStained loads.

Design Internal Pressure	Dp	1.00	MPa
Radial Load	P	4800.01	N
Circumferential Shear	Vc	3600.00	N

Longitudinal Shear	Vl	4800.01	N
Circumferential Moment	Mc	130000.00	N-mm
Longitudinal Moment	Ml	260000.00	N-mm
Torsional Moment	Mt	740000.00	N-mm

Include Axial Pressure Thrust	No
Include Pressure Stress Indices per Div. 2	No

Stress Computations at the Edge of the Nozzle:

WRC 297 Curve Access Parameters:

Vessel Mean Diameter	(D)	=	611.000	mm
Nozzle Outside Diameter	(d)	=	114.300	mm
Vessel Thickness used	(T)	=	5.000	mm
Nozzle Thickness used	(t)	=	3.020	mm
T / t		=	1.656	
d / t		=	37.848	

Lambda = $[(d/D)*(D/T)^{1/2}]$ = 2.068

Nr/P	=	0.063
Mr/P	=	0.099
M0/P	=	0.045
N0/P	=	0.140
MrD/Mc	=	0.207
NrDL/Mc	=	0.093
M0d/Mc	=	0.109
N0DL/Mc	=	0.171
MrD/Ml	=	0.107
NrDL/Ml	=	0.056
M0D/Ml	=	0.050
N0DL/Ml	=	0.248

Vessel Stresses

LONGITUDINAL PLANE (Stresses Normal to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
	(MPa)			
Outplane Membrane (P)	-26	-26	-26	-26
Outplane Bending (P)	-52	52	-52	52
Outplane Membrane (Mc)	0	0	0	0
Outplane Bending (Mc)	0	0	0	0
Outplane Membrane (ML)	-22	-22	22	22
Outplane Bending (ML)	-27	27	27	-27
Normal Pressure Stress	60	61	60	61
Outplane Stress Summary	-68	91	30	82

Vessel Stresses

LONGITUDINAL PLANE (Stresses parallel to longitudinal plane)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
	(MPa)			
Inplane Membrane (P)	-12	-12	-12	-12
Inplane Bending (P)	-113	113	-113	113
Inplane Membrane (Mc)	0	0	0	0
Inplane Bending (Mc)	0	0	0	0
Inplane Membrane (ML)	-5	-5	5	5
Inplane Bending (ML)	-58	58	58	-58
Inplane Pressure Stress	30	30	30	30
Inplane Stress Summary	-159	184	-32	78

Vessel Stresses

LONGITUDINAL PLANE (Shear stress normal to	Au Top	Al Top	Bu Bottom	Bl Bottom

longitudinal plane)	Outside	Inside	Outside	Inside
	(MPa		)	
Outplane Shear (Vc)	4	4	-4	-4
Outplane Shear (Vl)	0	0	0	0
Outplane Shear (Mt)	7	7	7	7
Shear Stress Summary	11	11	3	3

Vessel Stresses

LONGITUDINAL PLANE	Au	Al	Bu	Bl
(Stress Intensities	Top	Top	Bottom	Bottom
	Outside	Inside	Outside	Inside
	(MPa		)	
Two * Max Shear Stress	160	186	62	83

Vessel Stresses

CIRCUMFERENTIAL PLANE	Cu	Cl	Du	Dl
(Stresses Normal to	Left	Left	Right	Right
circumferential plane)	Outside	Inside	Outside	Inside
	(MPa		)	
Outplane Membrane (P)	-26	-26	-26	-26
Outplane Bending (P)	-52	52	-52	52
Outplane Membrane (Mc)	-7	-7	7	7
Outplane Bending (Mc)	-29	29	29	-29
Outplane Membrane (ML)	0	0	0	0
Outplane Bending (ML)	0	0	0	0
Normal Pressure Stress	30	30	30	30
Outplane Stress Summary	-86	77	-11	33

Vessel Stresses

CIRCUMFERENTIAL PLANE	Cu	Cl	Du	Dl
(Stresses parallel to	Left	Left	Right	Right
circumferential plane)	Outside	Inside	Outside	Inside
	(MPa		)	
Inplane Membrane (P)	-12	-12	-12	-12
Inplane Bending (P)	-113	113	-113	113
Inplane Membrane (Mc)	-4	-4	4	4
Inplane Bending (Mc)	-56	56	56	-56
Inplane Membrane (ML)	0	0	0	0
Inplane Bending (ML)	0	0	0	0
Inplane Pressure Stress	60	61	60	61
Inplane Stress Summary	-126	214	-4	110

Vessel Stresses

CIRCUMFERENTIAL PLANE	Cu	Cl	Du	Dl
(Shear stress normal to	Left	Left	Right	Right
circumferential plane)	Outside	Inside	Outside	Inside
	(MPa		)	
Outplane Shear (Vc)	0	0	0	0
Outplane Shear (Vl)	-5	-5	5	5
Torsional Shear (Mt)	7	7	7	7
Shear Stress Summary	1	1	12	12

Vessel Stresses

CIRCUMFERENTIAL PLANE	Cu	Cl	Du	Dl
(Stress Intensities	Left	Left	Right	Right
	Outside	Inside	Outside	Inside
	(MPa		)	
Two * Max Shear Stress	126	214	25	112

Nozzle Stresses

LONGITUDINAL PLANE	Au	Al	Bu	Bl
(Stresses in the	Top	Top	Bottom	Bottom
hoop direction)	Outside	Inside	Outside	Inside

	(MPa		)
Hoop Membrane (P)	-26	-26	-26	-26
Hoop Bending (P)	0	0	0	0
Hoop Membrane (Mc)	0	0	0	0
Hoop Bending (Mc)	0	0	0	0
Hoop Membrane (ML)	-22	-22	22	22
Hoop Bending (ML)	0	0	0	0
Hoop Pressure Stress	20	22	20	22
Hoop Stress Summary	-28	-27	16	17

Nozzle Stresses

LONGITUDINAL PLANE (Stresses Normal to pipe cross-section)	Au Top Outside	Al Top Inside	Bu Bottom Outside	Bl Bottom Inside
	(MPa		)	
Axial Membrane (P)	-4	-4	-4	-4
Axial Bending (P)	-211	211	-211	211
Axial Membrane (Mc)	0	0	0	0
Axial Bending (Mc)	0	0	0	0
Axial Membrane (ML)	-9	-9	9	9
Axial Bending (ML)	-118	118	118	-118
Axial Pressure Stress	10	10	10	10
Axial Stress Summary	-333	326	-78	108

Nozzle Stresses

LONGITUDINAL PLANE (Shear stress)	Au Outside	Al Inside	Bu Outside	Bl Inside
	(MPa		)	
Shear due to (Vc)	6	6	-6	-6
Shear due to (Vl)	0	0	0	0
Shear due to Torsion	11	11	11	11
Shear Stress Summary	18	18	5	5

Nozzle Stresses

LONGITUDINAL PLANE (Stress Intensities	Au Outside	Al Inside	Bu Outside	Bl Inside
	(MPa		)	
Two * Max Shear Stress	334	355	95	109

Nozzle Stresses

CIRCUMFERENTIAL PLANE (Stresses in the hoop direction)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
	(MPa		)	
Hoop Membrane (P)	-26	-26	-26	-26
Hoop Bending (P)	0	0	0	0
Hoop Membrane (Mc)	-7	-7	7	7
Hoop Bending (Mc)	0	0	0	0
Hoop Membrane (ML)	0	0	0	0
Hoop Bending (ML)	0	0	0	0
Hoop Pressure Stress	20	22	20	22
Hoop Stress Summary	-13	-12	1	2

Nozzle Stresses

CIRCUMFERENTIAL PLANE (Stresses Normal to pipe cross-section)	Cu Left Outside	Cl Left Inside	Du Right Outside	Dl Right Inside
	(MPa		)	
Axial Membrane (P)	-4	-4	-4	-4
Axial Bending (P)	-211	211	-211	211
Axial Membrane (Mc)	-4	-4	4	4
Axial Bending (Mc)	-120	120	120	-120
Axial Membrane (ML)	0	0	0	0

Axial Bending (ML)	0	0	0	0
Axial Pressure Stress	10	10	10	10
Axial Stress Summary	-330	333	-81	102

Nozzle Stresses

CIRCUMFERENTIAL PLANE (Shear stress)	Cu Outside	Cl Inside (MPa)	Du Outside	Dl Inside
Shear due to (Vc)	0	0	0	0
Shear due to (Vl)	-8	-8	8	8
Shear due to Torsion	11	11	11	11
Shear Stress Summary	3	3	20	20

Nozzle Stresses

CIRCUMFERENTIAL PLANE (Stress Intensities	Cu Outside	Cl Inside (MPa)	Du Outside	Dl Inside
Two * Max Shear Stress	330	346	92	107

WRC 297 Stress Summations per ASME Sec. VIII Div. 2:

Vessel Stress Summation at Vessel-Nozzle Junction

Type of Stress Int. Location	Stress Values at (MPa) Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	60	61	60	61	60	61	60	61
Circ. Pl (SUS)	-48	-48	-4	-4	-16	-16	-8	-8
Circ. Q (SUS)	-79	79	-25	25	-169	169	-57	57
Long. Pm (SUS)	30	30	30	30	30	30	30	30
Long. Pl (SUS)	-17	-17	-7	-7	-33	-33	-19	-19
Long. Q (SUS)	-171	171	-55	55	-81	81	-23	23
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	4	4	-4	-4	-5	-5	5	5
Shear Q (SUS)	7	7	7	7	7	7	7	7
Pm (SUS)	60.0	61.0	60.0	61.0	60.0	61.0	60.0	61.0
Pm+Pl (SUS)	16.5	17.0	56.5	57.5	48.1	49.0	52.6	53.6
Pm+Pl+Q (Total)	159.3	185.3	63.3	83.6	125.1	214.0	25.0	111.8

Stress Summation Comparison

Type of Stress Int.	Max. S.I. (MPa)	S.I. Allowable	Result
Pm (SUS)	61.00	137.90	Passed
Pm+Pl (SUS)	57.46	206.85	Passed
Pm+Pl+Q (TOTAL)	214.03	413.70	Passed

WRC 297 Stress Summations per ASME Sec. VIII Div. 2:

Nozzle Stress Summation at Vessel-Nozzle Junction

Type of Stress Int. Location	Stress Values at (MPa) Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	20	22	20	22	20	22	20	22
Circ. Pl (SUS)	-48	-48	-4	-4	-33	-33	-19	-19

Circ. Q (SUS)	0	0	0	0	0	0	0	0
Long. Pm (SUS)	10	10	10	10	10	10	10	10
Long. Pl (SUS)	-13	-13	5	5	-8	-8	0	0
Long. Q (SUS)	-329	329	-93	93	-331	331	-91	91
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	6	6	-6	-6	-8	-8	8	8
Shear Q (SUS)	11	11	11	11	11	11	11	11
Pm (SUS)	20.0	22.0	20.0	22.0	20.0	22.0	20.0	22.0
Pm+Pl (SUS)	29.4	27.5	21.5	22.7	21.9	20.6	18.4	17.5
Pm+Pl+Q (Total)	332.9	353.6	94.5	108.3	329.0	344.1	90.4	105.1

Stress Summation Comparison

Type of Stress Int.	Max. S.I. (MPa)	S.I. Allowable (MPa)	Result
Pm (SUS)	22.00	117.90	Passed
Pm+Pl (SUS)	29.37	176.86	Passed
Pm+Pl+Q (TOTAL)	353.64	353.71	Passed

INPUT VALUES, Nozzle Description: Noz H Fr20 From : 20

Pressure for Reinforcement Calculations	P	1.0000	MPa
Temperature for Internal Pressure	Temp	85	C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	MPa
Shell Allowable Stress At Ambient	Sva	137.90	MPa
Inside Diameter of Cylindrical Shell	D	600.00	mm
Shell Finished (Minimum) Thickness	t	8.0000	mm
Shell Internal Corrosion Allowance	c	3.0000	mm
Shell External Corrosion Allowance	co	0.0000	mm
Distance from Bottom/Left Tangent		400.00	mm
User Entered Minimum Design Metal Temperature		-10.00	C

Type of Element Connected to the Shell : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	MPa
Allowable Stress At Ambient	Sna	117.90	MPa
Diameter Basis (for tr calc only)		OD	
Layout Angle		180.00	deg
Diameter		168.3000	mm
Size and Thickness Basis		Actual	
Actual Thickness	tn	7.1100	mm
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	200.0000	mm
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	8.0000	mm
Inside Projection	h	0.0000	mm
Weld leg size, Inside Element to Shell	Wi	0.0000	mm
ASME Code Weld Type per UW-16		None	
Class of attached Flange		150	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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

```
               |   |
               |   |
               |   |
               |   |
  ____________/|   |
 |          \  |   |
 |           \ |   |
 |____________\|___|
```

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

Reinforcement CALCULATION, Description: Noz H Fr20

ASME Code, Section VIII, Div. 1, 2015, UG-37 to UG-45

```
 Actual Outside Diameter Used in Calculation           168.300  mm.
 Actual Thickness Used in Calculation                    7.110  mm
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Cylindrical Shell, Tr [Int. Press]
```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (1.*303.0)/(138*1.0-0.6*1.)
  = 2.2068 mm
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
```
  = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = (1.*84.15)/(118*1.0+0.4*1.)
  = 0.7113 mm
```

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
 Wall Thickness for Internal/External pressures      ta = 3.7113 mm
 Wall Thickness per UG16(b),                       tr16b = 4.5000 mm
 Wall Thickness, shell/head, internal pressure      trb1 = 5.2068 mm
 Wall Thickness                  tb1 = max(trb1, tr16b) = 5.2068 mm
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm
 Wall Thickness per table UG-45                      tb3 = 10.1600 mm
```

Determine Nozzle Thickness candidate [tb]:
```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 10.16, max( 5.2068, 4.5 ) ]
  = 5.2068 mm
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
  = max( ta, tb )
  = max( 3.7113, 5.2068 )
  = 5.2068 mm
```

Available Nozzle Neck Thickness = 7.1100 mm --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

MDMT of the Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 7.11, tr = 0.711, c = 3.0 mm, E* = 1.0
Stress Ratio = tr * (E*)/(tg - c) = 0.173, Temp. Reduction = 78 C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B            -29  C
 Min Metal Temp. at Required thickness (UCS 66.1)         -104  C
```

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

Govrn. thk, tg = 7.11, tr = 0.711, c = 3.0 mm, E* = 1.0
Stress Ratio = tr * (E*)/(tg - c) = 0.173, Temp. Reduction = 78 C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B            -29  C
 Min Metal Temp. at Required thickness (UCS 66.1)         -104  C

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

Where the Stress Reduction Ratio per UCS-66(b)(1)(b) is :
```
 Design Pressure/Ambient Rating = 1.00/1.96 = 0.510
```

Note: Using the minimum value from (b)(1)(b) and (b)(1)(c) above as the calculated nozzle flange MDMT.

Nozzle Calculations per App. 1-10: Internal Pressure Case:

Thickness of Nozzle [tn]:
```
= thickness - corrosion allowance
= 7.11 - 3.0
= 4.110 mm
```

Effective Pressure Radius [Reff]:
```
= Di/2 + corrosion allowance
= 600.0/2 + 3.0
= 303.000 mm
```

Effective Length of Vessel Wall [LR]:
```
= 8 * t
= 8 * 5.0
= 40.000 mm
```

Thickness Limit Candidate [LH1]:
```
= t + 0.78 * sqrt( Rn * tn )
= 5.0 + 0.78 * sqrt( 80.04 * 4.11 )
= 19.147 mm
```

Thickness Limit Candidate [LH2]:
```
= Lpr1 + T
= 200.0 + 5.0
= 205.000 mm
```

Thickness Limit Candidate [LH3]:
```
= 8( t + te )
= 8( 5.0 + 0.0 )
= 40.000 mm
```

Effective Nozzle Wall Length Outside the Vessel [LH]:
```
= min[ LH1, LH2, LH3 ]
= min[ 19.147, 205.0, 40.0 )
= 19.147 mm
```

Effective Vessel Thickness [teff]:
```
= t
= 5.000 mm
```

Determine Parameter [Lamda]:
```
= min( 10, ( Dn + Tn )/( sqrt( ( Di + teff ) * teff )) )
= min( 10, (160.08 + 4.11)/( sqrt((606.0 + 5.0) * 5.0)) )
= 2.971
```

Compute Areas A1-A43 (No Pad) or A1-A5 (With Pad) :

Area Contributed by the Vessel Wall [A1]:
```
= t * LR * max( Lamda/4, 1 )
= 5.0 * 40.0 * max( 2.971/4, 1 )
= 200.001 mm?
```

Area Contributed by the Nozzle Outside the Vessel Wall [A2]:
```
= tn * LH
= 4.11 * 19.147
= 78.695 mm?
```

Area Contributed by the Outside Fillet Weld [A41]:
```
= 0.5 * Leg41²
= 0.5 * 8.0²
= 32.000 mm?
```

The total area contributed by A1 through A43 [AT]:
```
  = A1 + frn( A2 + A3 ) + A41 + A42 + A43
  = 200.001+1.0(78.695+0.0)+32.0+0.0+0.0
  = 310.696 mm?
```

Allowable Local Primary Membrane Stress [Sallow]:
```
  = 1.5 * S * E
  = 1.5 * 137.9 * 1.0
  = 206.9 MPa
```

Determine Force acting on the Nozzle [fN]:
```
  = P * Rn( LH - t )
  = 1. * 80.04( 19.147 - 5.0 )
  = 1132.2 N
```

Determine Force acting on the Shell [fS]:
```
  = P * Reff( LR + tn )
  = 1. * 303.0( 40.0 + 4.11 )
  = 13364.2 N
```

Discontinuity Force from Internal Pressure [fY]:
```
  = P * Reff * Rnc
  = 1. * 303.0 * 80.04
  = 24250.1 N
```

Area Resisting Internal Pressure [Ap]:
```
  = Rn( LH - t ) + Reff( LR + tn + Rnc )
  = 80.04( 19.147 - 5.0 ) + 303.0( 40.0 + 4.11 + 80.04 )
  = 38749.8 mm?
```

Maximum Allowable Working Pressure Candidate [Pmax1]:
```
  = Sallow /( 2 * Ap/AT - Rxs/teff )
  = 206.85/( 2 * 38749.824/310.696 - 303.0/5.0 )
  = 1.1 MPa
```

Maximum Allowable Working Pressure Candidate [Pmax2]:
```
  = S[t/Reff]
  = 137.9[5.0/303.0]
  = 2.3 MPa
```

Maximum Allowable Working Pressure [Pmax]:
```
  = min( Pmax1, Pmax2 )
  = min( 1.095, 2.276 )
  = 1.095 MPa
```

Average Primary Membrane Stress [SigmaAvg]:
```
  = ( fN + fS + fY ) / AT
  = ( 1132.24 + 13364.226 + 24250.059 )/310.696
  = 124.719 MPa
```

General Primary Membrane Stress [SigmaCirc]:
```
  = P * Reff / teff
  = 1. * 303.0/5.0
  = 60.6 MPa
```

Maximum Local Primary Membrane Stress [PL]:
```
  = max( 2 * SigmaAvg - SigmaCirc, SigmaCirc )
  = max( 2 * 124.719 - 60.6, 60.6 )
  = 188.8 MPa
```

Summary of Nozzle Pressure/Stress Results:

Allowed Local Primary Membrane Stress	Sallow	206.85	MPa
Local Primary Membrane Stress	PL	188.84	MPa
Maximum Allowable Working Pressure	Pmax	1.10	MPa

Strength of Nozzle Attachment Welds per 1-10 and U-2(g)

Discontinuity Force Factor [ky]:

```
  = ( Rnc + tn ) / Rnc
  = ( 80.04 + 4.11 )/80.04
  = 1.051 For set-in Nozzles
```

Weld Length of Nozzle to Shell Weld [Ltau]:

```
  = pi/2 * ( Rn + tn )
  = pi/2 * ( 80.04 + 4.11 )
  = 132.183 mm
```

Weld Throat Dimensions, (0.7071*Leg Dimensions) [L41T, L42T, L43T]:

```
  = 5.657,    0.000,    0.000, mm
```

Weld Load Value [fwelds]:

```
  = min( fy * ky, 1.5 * Sn( A2 + A3 ), pi/4*P*Rn^2*ky^2 )
  = min(24250*1.05,1.5*117.9(78.695+0.0),pi/4*1.0*80.04^2*1.05^2)
  = 5561.106 N
```

Weld Stress Value [tau]:

```
  = fwelds/(Ltau(0.49*L41T + 0.6*tw1 + 0.49*L43T ) )
  = 5561.106/(132.183(0.49*5.657 + 0.6*5.0 + 0.49*0.0 ) )
  = 7.290 < or = to 137.900 Weld Stress Passed
```

<u>Weld Size Calculations, Description: Noz H Fr20</u>

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      4.1100  mm
```

Results Per UW-16.1:

```
                      Required Thickness    Actual Thickness
 Nozzle Weld         2.8770 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm
```

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case       1.0000  MPa
```

The Drop for this Nozzle is : 12.0438 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 220.0438 mm

INPUT VALUES, Nozzle Description: Noz P Fr20 From : 20

Pressure for Reinforcement Calculations	P	1.0000	MPa
Temperature for Internal Pressure	Temp	85	C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	MPa
Shell Allowable Stress At Ambient	Sva	137.90	MPa
Inside Diameter of Cylindrical Shell	D	600.00	mm
Shell Finished (Minimum) Thickness	t	8.0000	mm
Shell Internal Corrosion Allowance	c	3.0000	mm
Shell External Corrosion Allowance	co	0.0000	mm
Distance from Bottom/Left Tangent		1040.00	mm
User Entered Minimum Design Metal Temperature		-10.00	C

Type of Element Connected to the Shell : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	MPa
Allowable Stress At Ambient	Sna	117.90	MPa
Diameter Basis (for tr calc only)		OD	
Layout Angle		180.00	deg
Diameter		48.3000	mm
Size and Thickness Basis		Actual	
Actual Thickness	tn	7.1400	mm
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	8.0000	mm
Inside Projection	h	0.0000	mm
Weld leg size, Inside Element to Shell	Wi	0.0000	mm
ASME Code Weld Type per UW-16		None	
Class of attached Flange		150	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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

```
                      |   |
                      |   |
                      |   |
                      |   |
   ____________/|   |
  |            \  |   |
  |             \ |   |
  |______________\|__|
```

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

Reinforcement CALCULATION, Description: Noz P Fr20

ASME Code, Section VIII, Div. 1, 2015, UG-37 to UG-45

```
 Actual Outside Diameter Used in Calculation          48.300  mm.
 Actual Thickness Used in Calculation                  7.140  mm
```

Nozzle input data check completed without errors.

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

```
  = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
  = (1.*303.0)/(138*1.0-0.6*1.)
  = 2.2068 mm
```

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

```
  = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = (1.*24.15)/(118*1.0+0.4*1.)
  = 0.2041 mm
```

Note:

Taking a UG-36(c)(3)(a) exemption for nozzle: Noz P Fr20.
This calculation is valid for nozzles that meet all the requirements of paragraph UG-36. Please check the Code carefully, especially for nozzles that are not isolated or do not meet Code spacing requirements. To force the computation of areas for small nozzles go to Tools->Configuration and check the box to force the UG-37 small nozzle area calculation or force the Appendix 1-10 computation in Nozzle Design Options.

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

```
 Wall Thickness for Internal/External pressures      ta = 3.2041 mm
 Wall Thickness per UG16(b),                      tr16b = 4.5000 mm
 Wall Thickness, shell/head, internal pressure     trb1 = 5.2068 mm
 Wall Thickness                 tb1 = max(trb1, tr16b) = 5.2068 mm
 Wall Thickness                 tb2 = max(trb2, tr16b) = 4.5000 mm
 Wall Thickness per table UG-45                     tb3 = 6.4200 mm
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 6.42, max( 5.2068, 4.5 ) ]
  = 5.2068 mm
```

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

```
  = max( ta, tb )
  = max( 3.2041, 5.2068 )
  = 5.2068 mm
```

Available Nozzle Neck Thickness = 7.1400 mm --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

MDMT of the Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 7.14, tr = 0.204, c = 3.0 mm, E* = 1.0
Stress Ratio = tr * (E*)/(tg - c) = 0.049, Temp. Reduction = 78 C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B          -29  C
 Min Metal Temp. at Required thickness (UCS 66.1)       -104  C
```

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

Govrn. thk, tg = 7.14, tr = 0.204, c = 3.0 mm, E* = 1.0
Stress Ratio = tr * (E*)/(tg - c) = 0.049, Temp. Reduction = 78 C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B          -29  C
 Min Metal Temp. at Required thickness (UCS 66.1)       -104  C
```

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

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

```
 Design Pressure/Ambient Rating = 1.00/1.96 = 0.510
```

Note: Using the minimum value from (b)(1)(b) and (b)(1)(c) above as the calculated nozzle flange MDMT.

Weld Size Calculations, Description: Noz P Fr20

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      4.1400  mm
```

Results Per UW-16.1:

```
                       Required Thickness    Actual Thickness
 Nozzle Weld          2.8980 = 0.7 * tmin.  5.6560 = 0.7 * Wo mm
```

Skipping the nozzle attachment weld strength calculations.
Per UW-15(b)(2) the nozzles exempted by UG-36(c)(3)(a)
(small nozzles) do not require a weld strength check.

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case       1.0000  MPa
```

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

The Drop for this Nozzle is : 0.9736 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 158.9736 mm

INPUT VALUES, Nozzle Description: Noz T Fr20 From : 20

Pressure for Reinforcement Calculations	P	1.0000	MPa
Temperature for Internal Pressure	Temp	85	C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	MPa
Shell Allowable Stress At Ambient	Sva	137.90	MPa
Inside Diameter of Cylindrical Shell	D	600.00	mm
Shell Finished (Minimum) Thickness	t	8.0000	mm
Shell Internal Corrosion Allowance	c	3.0000	mm
Shell External Corrosion Allowance	co	0.0000	mm
Distance from Bottom/Left Tangent		800.00	mm
User Entered Minimum Design Metal Temperature		-10.00	C

Type of Element Connected to the Shell : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	MPa
Allowable Stress At Ambient	Sna	117.90	MPa
Diameter Basis (for tr calc only)		OD	
Layout Angle		180.00	deg
Diameter		60.3000	mm
Size and Thickness Basis		Actual	
Actual Thickness	tn	5.5400	mm
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	8.0000	mm
Inside Projection	h	0.0000	mm
Weld leg size, Inside Element to Shell	Wi	0.0000	mm
ASME Code Weld Type per UW-16		None	
Class of attached Flange		150	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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

```
               |   |
               |   |
               |   |
               |   |
  ____________/|   |
 |         \   |   |
 |          \  |   |
 |___________\|___|
```

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

Reinforcement CALCULATION, Description: Noz T Fr20

ASME Code, Section VIII, Div. 1, 2015, UG-37 to UG-45

```
 Actual Outside Diameter Used in Calculation          60.300  mm.
 Actual Thickness Used in Calculation                  5.540  mm
```

Nozzle input data check completed without errors.

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

```
   = (P*R)/(Sv*E-0.6*P) per UG-27 (c)(1)
   = (1.*303.0)/(138*1.0-0.6*1.)
   = 2.2068 mm
```

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

```
   = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
   = (1.*30.15)/(118*1.0+0.4*1.)
   = 0.2549 mm
```

Note:

*Taking a UG-36(c)(3)(a) exemption for nozzle: Noz T Fr20.
This calculation is valid for nozzles that meet all the requirements of paragraph UG-36. Please check the Code carefully, especially for nozzles that are not isolated or do not meet Code spacing requirements. To force the computation of areas for small nozzles go to Tools->Configuration and check the box to force the UG-37 small nozzle area calculation or force the Appendix 1-10 computation in Nozzle Design Options.*

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

```
 Wall Thickness for Internal/External pressures      ta = 3.2549 mm
 Wall Thickness per UG16(b),                      tr16b = 4.5000 mm
 Wall Thickness, shell/head, internal pressure     trb1 = 5.2068 mm
 Wall Thickness                tb1 = max(trb1, tr16b) = 5.2068 mm
 Wall Thickness                tb2 = max(trb2, tr16b) = 4.5000 mm
 Wall Thickness per table UG-45                    tb3 = 6.4200 mm
```

Determine Nozzle Thickness candidate [tb]:

```
   = min[ tb3, max( tb1,tb2) ]
   = min[ 6.42, max( 5.2068, 4.5 ) ]
   = 5.2068 mm
```

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

```
   = max( ta, tb )
   = max( 3.2549, 5.2068 )
   = 5.2068 mm
```

Available Nozzle Neck Thickness = 5.5400 mm --> OK

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

MDMT of the Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 5.54, tr = 0.255, c = 3.0 mm, E* = 1.0
Stress Ratio = tr * (E*)/(tg - c) = 0.1, Temp. Reduction = 78 C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B           -29  C
 Min Metal Temp. at Required thickness (UCS 66.1)        -104  C
```

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

Govrn. thk, tg = 5.54, tr = 0.255, c = 3.0 mm, E* = 1.0
Stress Ratio = tr * (E*)/(tg - c) = 0.1, Temp. Reduction = 78 C

```
 Min Metal Temp. w/o impact per UCS-66, Curve B           -29  C
 Min Metal Temp. at Required thickness (UCS 66.1)        -104  C
```

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

Where the Stress Reduction Ratio per UCS-66(b)(1)(b) is :
Design Pressure/Ambient Rating = 1.00/1.96 = 0.510

Note: Using the minimum value from (b)(1)(b) and (b)(1)(c) above as the calculated nozzle flange MDMT.

Weld Size Calculations, Description: Noz T Fr20

Intermediate Calc. for nozzle/shell Welds Tmin 2.5400 mm

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	1.7780 = 0.7 * tmin.	5.6560 = 0.7 * Wo mm

Skipping the nozzle attachment weld strength calculations.
Per UW-15(b)(2) the nozzles exempted by UG-36(c)(3)(a)
(small nozzles) do not require a weld strength check.

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 1.0000 MPa

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

The Drop for this Nozzle is : 1.5189 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 159.5189 mm

INPUT VALUES, Nozzle Description: Noz N2 Fr30 From : 30

Pressure for Reinforcement Calculations	P	1.0000	MPa
Temperature for Internal Pressure	Temp	85	C
Shell Material		SA-516 70	
Shell Allowable Stress at Temperature	Sv	137.90	MPa
Shell Allowable Stress At Ambient	Sva	137.90	MPa
Inside Diameter of Elliptical Head	D	600.00	mm
Aspect Ratio of Elliptical Head	Ar	2.00	
Head Finished (Minimum) Thickness	t	7.0000	mm
Head Internal Corrosion Allowance	c	3.0000	mm
Head External Corrosion Allowance	co	0.0000	mm
Distance from Head Centerline	L1	0.0000	mm
User Entered Minimum Design Metal Temperature		-10.00	C

Type of Element Connected to the Shell : Nozzle

Material		SA-106 B	
Material UNS Number		K03006	
Material Specification/Type		Smls. pipe	
Allowable Stress at Temperature	Sn	117.90	MPa
Allowable Stress At Ambient	Sna	117.90	MPa
Diameter Basis (for tr calc only)		OD	
Layout Angle		0.00	deg
Diameter		88.9000	mm
Size and Thickness Basis		Actual	
Actual Thickness	tn	5.4900	mm
Flange Material		SA-105	
Flange Type		Weld Neck Flange	
Corrosion Allowance	can	3.0000	mm
Joint Efficiency of Shell Seam at Nozzle	E1	1.00	
Joint Efficiency of Nozzle Neck	En	1.00	
Outside Projection	ho	150.0000	mm
Weld leg size between Nozzle and Pad/Shell	Wo	8.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	7.0000	mm
Inside Projection	h	0.0000	mm
Weld leg size, Inside Element to Shell	Wi	0.0000	mm
ASME Code Weld Type per UW-16		None	
Class of attached Flange		150	
Grade of attached Flange		GR 1.1	

The Pressure Design option was Design Pressure + static head.

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

```
               |  |
               |  |
               |  |
               |  |
 ____________/|  |
|           \ |  |
|            \|  |
|____________\|__|
```

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

Reinforcement CALCULATION, Description: Noz N2 Fr30

ASME Code, Section VIII, Div. 1, 2015, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation          88.900  mm.
Actual Thickness Used in Calculation                  5.490  mm
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Elliptical Head, Tr [Int. Press]
```
 = (P*K1*D))/(2*Sv*E-0.2*P) per UG-37(a)(3)
 = (1.*0.892*606.0)/(2 *137.9*1.0-0.2*1.)
 = 1.9604 mm
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
```
 = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
 = (1.*44.45)/(118*1.0+0.4*1.)
 = 0.3757 mm
```

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl    167.8400   mm
Parallel to Vessel Wall, opening length              d     83.9200   mm
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp      6.2250   mm
```

Note:

Taking a UG-36(c)(3)(a) exemption for nozzle: Noz N2 Fr30.
This calculation is valid for nozzles that meet all the requirements of paragraph UG-36. Please check the Code carefully, especially for nozzles that are not isolated or do not meet Code spacing requirements. To force the computation of areas for small nozzles go to Tools->Configuration and check the box to force the UG-37 small nozzle area calculation or force the Appendix 1-10 computation in Nozzle Design Options.

UG-45 Minimum Nozzle Neck Thickness Requirement: [Int. Press.]
```
Wall Thickness for Internal/External pressures       ta = 3.3757 mm
Wall Thickness per UG16(b),                        tr16b = 4.5000 mm
Wall Thickness, shell/head, internal pressure       trb1 = 5.1702 mm
Wall Thickness                tb1 = max(trb1, tr16b) = 5.1702 mm
Wall Thickness                tb2 = max(trb2, tr16b) = 4.5000 mm
Wall Thickness per table UG-45                        tb3 = 7.8000 mm
```

Determine Nozzle Thickness candidate [tb]:
```
 = min[ tb3, max( tb1,tb2) ]
 = min[ 7.8, max( 5.1702, 4.5 ) ]
 = 5.1702 mm
```

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
```
 = max( ta, tb )
 = max( 3.3757, 5.1702 )
 = 5.1702 mm
```

Available Nozzle Neck Thickness = 5.4900 mm --> OK

Stresses on Nozzle due to External and Pressure Loads per the ASME B31.3 Piping Code (see 319.4.4 and 302.3.5):
```
Sustained  :    17.6,  Allowable :    117.9 MPa  Passed
Expansion  :     0.0,  Allowable :    277.2 MPa  Passed
Occasional :     8.2,  Allowable :    156.8 MPa  Passed
Shear      :    18.1,  Allowable :     82.5 MPa  Passed
```

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

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

MDMT of the Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 5.49, tr = 0.376, c = 3.0 mm, E* = 1.0
Stress Ratio = tr * (E*)/(tg - c) = 0.151, Temp. Reduction = 78 C

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -29  C
Min Metal Temp. at Required thickness (UCS 66.1)       -104  C
```

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

Govrn. thk, tg = 5.49, tr = 0.376, c = 3.0 mm, E* = 1.0
Stress Ratio = tr * (E*)/(tg - c) = 0.151, Temp. Reduction = 78 C

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -29  C
Min Metal Temp. at Required thickness (UCS 66.1)       -104  C

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

Where the Stress Reduction Ratio per UCS-66(b)(1)(b) is :
Design Pressure/Ambient Rating = 1.00/1.96 = 0.510

Note: Using the minimum value from (b)(1)(b) and (b)(1)(c) above as the calculated nozzle flange MDMT.

Weld Size Calculations, Description: Noz N2 Fr30

```
Intermediate Calc. for nozzle/shell Welds    Tmin      2.4900   mm
```

Results Per UW-16.1:

```
                        Required Thickness     Actual Thickness
Nozzle Weld           1.7430 = 0.7 * tmin.   5.6560 = 0.7 * Wo mm
```

Skipping the nozzle attachment weld strength calculations.
Per UW-15(b)(2) the nozzles exempted by UG-36(c)(3)(a)
(small nozzles) do not require a weld strength check.

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 1.0000 MPa

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

The Drop for this Nozzle is : 1.8137 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 158.8137 mm

Input Echo, PD:5500 Annex G Local Stress Analysis

```
Radial Load     (positive outward)            Fr      3600.00   N
Circumferential Shear                         Fc      3600.00   N
Longitudinal Shear                            Fl      2700.00   N
Torsional Moment                              Mt    120000.0    N-mm
Circumferential Moment                        Mc     32000.0    N-mm
Longitudinal Moment                           Ml     48000.0    N-mm

Allowable Stress Intensity Factor (Mem + Bend)         2.25
Print Membrane Stress at the Attachment junction         No
```

PD-5500 Annex G Nozzle to Sphere Junction Stress Analysis

Stress Calculations at the Edge of the Nozzle Neck :

```
Resultant Shear Force     Srss( Fc²+ Fl²)   S      4500.  N
Resultant Moment          Srss( Mc²+ Ml²)   M     57689.  N-mm
Shell Mean Radius                                  R     545.000  mm
Nozzle Mean Radius                                 r      43.205  mm
Thickness Ratio                                 t/T'      0.6225
Ratio of Shell Mean Radius to Shell Thk.        R/T'    136.2494
Value of Rho                          r/R*(R/T')^1/2      0.9253
Value of u (=s)                                    u      1.6841

Stress Concentration Factor for Pressure                  2.9729
Stress Concentration Factor for Radial Force              1.7428
Stress Concentration Factor for Bending Moment            1.2837
Stress Concentration Factor for Shear                     0.3167

Total Stress due to Pressure                            202.53  MPa
Total Stress due to Radial Loads                         67.45  MPa
Total Stress due to Shear Forces                          1.31  MPa
Total Stress due to Bending Moments                      36.84  MPa
Total Stress due to Torsional Moment                      1.86  MPa

Maximum Stress at Sphere/Attachment Junction            309.99  MPa
```

Check the Maximum Stresses versus defined Allowables :

Max. Str. Int. (Mem + Bend): 309.99 Allowable: 310.27 MPa

Maximum Loads: PD:5500 Annex G.2.8 (Alternative Rules - Information Only):

Flush Nozzle located in a sphere:

Note: Pmax is determined per PD:5500 Section 3.5.4:

Shell Effective Mean Diameter [D]:
```
= Di + es + Min(fp/fs, 1 )*tp + cas - caext
= 1080.0 + 7.0 + Min(0.0/137.9, 1 )*0.0 + 3.0 - 0.0
= 1090.0 mm
```

Nozzle Mean Diameter [d]:
```
= do - eb + can - caext
= 88.9 - 5.49 + 3.0 - 0.0 = 86.41 mm
```

Adjusted value of [Ratio erb/ers]:
```
= min(fn/fs, 1 ) * erb / ers
= min(117.905/137.9, 1 ) * 2.49/4.0 = 0.5322
```

Compute the Maximum Pressure [Pmax]

The value of Pmax is 1.356 MPa and is derived as follows:

Required Shell Thickness [esp]
```
= Pmax * D / ( 4 * fs )
= 1.356 * 1090.0/( 4 * 137.9 ) = 2.68 mm
```

Compute Ratio [C.ers/eps]
```
= C * ers / eps
= 1.0 * 4.0/2.68 = 1.4927
```

Compute the Value of [Rho] :
```
= d/D * sqrt( D / ( 2 * as ))
= 86.41/1090.0 * sqrt(1090.0/( 2 * 4.0 )) = 0.9253
```

From Graph: Figure 3.5-10 we obtain a value of erb/ers of: .5322

Linear Interpolation Points from: Figure 3.5-10

Rho1	Rho	Rho2
1.0000	0.9253	0.9000

```
  Cers/eps1       1.5000       0.590                                  0.500
 Cers/eps        1.4927 <- Interpolated       0.5322
  Cers/eps2       1.4000       0.730                                  0.610
```

As Calculated Nozzle Thickness equals Actual Thickness: Pmax is correct.

Maxium Allowable Radial Force Fzmax and Moment [MBmax]:

Determine the value of [k]:

```
  = min( 2 * fn * eab / ( fs * eac ) * ( eab / d )^.5, 1 )
  = min(2*117.905*2.49/(137.9*4.0) * (2.49/86.41)^.5 1)
  = 0.181
```

Determine the value of [LamdaS]:

```
  = d/( R * eac )^.5= 86.41/( 545.0 * 4.0 )^.5
  = 1.851
```

Determine the Maximum Allowable Radial Force: [FZmax]:

```
  = fs  *eac^2 ( 1.82 + 2.4 ( ( 1 + k )^.5* LamdaS + 0.91 * k * LamdaS^2 )
  = 137.9*4.0^2 (1.82+2.4((1+ 0.181)^.51.851+0.91* 0.181*1.851^2)
  = 48711.434 N
```

From Figure 2.1, FZmax must not exceed: 27113.225 N

Determine the Maximum Allowable Moment: [MBmax]:

```
  = fs * eac^2 * d/4 * ( 4.9 + 2 ( ( 1 + k )^.5* LamdaS + 0.91 * k * LamdaS^2 )
  = 137.9 * 4.0^2 * 86.41/4 *
   (4.9 + 2*(1 + 0.181)^.5* 1.851 + 0.91 * 0.181 * 1.851^2))
  = 452245.562 N-mm
```

From Figure 2.2, Mbmax must not exceed: 2509924 N-mm

Unity Checks per PD:5500 2.4 for Simultaneous Loads:

```
 P/Pmax =   0.737   Fz/Fzmax =   0.133   Mb/Mbmax = .128
 P/Pmax + Fz/Fzmax + Mb/Mbmax                     = .998
```

Summary of results:

	P MPa	Fz N	Mb N-mm
Actual:	1.000	3600.002	57688.824
Allowable:	1.356	27113.225	452245.562
Ratio:	0.737	0.133	0.128

Ratio of combined values: .998 (must be <= 1.0)

The Given Force and Moments Comply with the Code

INPUT VALUES, Nozzle Description: Noz S Fr30 From : 30

```
Pressure for Reinforcement Calculations         P       1.0000  MPa
Temperature for Internal Pressure            Temp           85    C

Shell Material                                        SA-516 70
Shell Allowable Stress at Temperature          Sv       137.90  MPa
Shell Allowable Stress At Ambient             Sva       137.90  MPa

Inside Diameter of Elliptical Head              D       600.00  mm
Aspect Ratio of Elliptical Head                Ar         2.00
Head Finished (Minimum) Thickness               t       7.0000  mm
Head Internal Corrosion Allowance               c       3.0000  mm
Head External Corrosion Allowance              co       0.0000  mm

Distance from Head Centerline                  L1     200.0000  mm

User Entered Minimum Design Metal Temperature           -10.00    C
```

Type of Element Connected to the Shell : Nozzle

```
Material                                                SA-106 B
Material UNS Number                                       K03006
Material Specification/Type                           Smls. pipe
Allowable Stress at Temperature                Sn       117.90  MPa
Allowable Stress At Ambient                   Sna       117.90  MPa

Diameter Basis (for tr calc only)                          OD
Layout Angle                                             45.00  deg
Diameter                                               33.4000   mm

Size and Thickness Basis                                 Actual
Actual Thickness                               tn       6.3500  mm

Flange Material                                          SA-105
Flange Type                                     Weld Neck Flange

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

Outside Projection                             ho     150.0000  mm
Weld leg size between Nozzle and Pad/Shell     Wo       5.0000  mm
Groove weld depth between Nozzle and Vessel  Wgnv       7.0000  mm
Inside Projection                               h       0.0000  mm
Weld leg size, Inside Element to Shell         Wi       0.0000  mm
ASME Code Weld Type per UW-16                             None

Class of attached Flange                              150
Grade of attached Flange                              GR 1.1
```

The Pressure Design option was Design Pressure + static head.

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

```
               |   |
               |   |
               |   |
               |   |
  ____________/|   |
 |          \  |   |
 |           \ |   |
 |____________\|___|
```

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

Note : Checking Nozzle in the Meridional direction.

Reinforcement CALCULATION, Description: Noz S Fr30

ASME Code, Section VIII, Div. 1, 2015, UG-37 to UG-45

```
Actual Outside Diameter Used in Calculation          33.400  mm.
Actual Thickness Used in Calculation                  6.350  mm
```

Nozzle input data check completed without errors.

Reqd thk per UG-37(a)of Elliptical Head, Tr [Int. Press]
```
= (P*K1*D))/(2*Sv*E-0.2*P) per UG-37(a)(3)
= (1.*0.892*606.0)/(2 *137.9*1.0-0.2*1.)
= 1.9604 mm
```

Reqd thk per UG-37(a)of Nozzle Wall, Trn [Int. Press]
```
= (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
= (1.*16.7)/(118*1.0+0.4*1.)
= 0.1412 mm
```

UG-40, Limits of Reinforcement : [Internal Pressure]
```
Parallel to Vessel Wall (Diameter Limit)            Dl    58.3757  mm
Parallel to Vessel Wall, opening length              d    29.1879  mm
Normal to Vessel Wall (Thickness Limit), no pad   Tlnp     8.3750  mm
```

Note:

Taking a UG-36(c)(3)(a) exemption for nozzle: Noz S Fr30.
This calculation is valid for nozzles that meet all the requirements of paragraph UG-36. Please check the Code carefully, especially for nozzles that are not isolated or do not meet Code spacing requirements. To force the computation of areas for small nozzles go to Tools->Configuration and check the box to force the UG-37 small nozzle area calculation or force the Appendix 1-10 computation in Nozzle Design Options.

Nozzle Junction Minimum Design Metal Temperature (MDMT) Calculations:

MDMT of the Nozzle Neck to Flange Weld, Curve: B

Govrn. thk, tg = 6.35, tr = 0.141, c = 3.0 mm, E* = 1.0
Stress Ratio = tr * (E*)/(tg - c) = 0.042, Temp. Reduction = 78 C

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -29  C
Min Metal Temp. at Required thickness (UCS 66.1)       -104  C
```

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

Govrn. thk, tg = 6.35, tr = 0.141, c = 3.0 mm, E* = 1.0
Stress Ratio = tr * (E*)/(tg - c) = 0.042, Temp. Reduction = 78 C

```
Min Metal Temp. w/o impact per UCS-66, Curve B          -29  C
Min Metal Temp. at Required thickness (UCS 66.1)       -104  C

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

ANSI Flange MDMT including Temperature reduction per UCS-66.1:

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

Where the Stress Reduction Ratio per UCS-66(b)(1)(b) is :
```
Design Pressure/Ambient Rating = 1.00/1.96 = 0.510
```

Note: Using the minimum value from (b)(1)(b) and (b)(1)(c) above *as the calculated nozzle flange MDMT.*

Weld Size Calculations, Description: Noz S Fr30

```
 Intermediate Calc. for nozzle/shell Welds   Tmin      3.3500  mm
```

Results Per UW-16.1:

```
                        Required Thickness    Actual Thickness
 Nozzle Weld           2.3450 = 0.7 * tmin.  3.5350 = 0.7 * Wo mm
```

Skipping the nozzle attachment weld strength calculations.
Per UW-15(b)(2) the nozzles exempted by UG-36(c)(3)(a)
(small nozzles) do not require a weld strength check.

Maximum Allowable Pressure for this Nozzle at this Location:

```
 Converged Max. Allow. Pressure in Operating case       1.0000  MPa
```

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

Note : Checking Nozzle in the Latitudinal direction.

Reinforcement CALCULATION, Description: Noz S Fr30

ASME Code, Section VIII, Div. 1, 2015, UG-37 to UG-45

```
 Actual Outside Diameter Used in Calculation           33.400  mm.
 Actual Thickness Used in Calculation                   6.350  mm
```

Nozzle input data check completed without errors.

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

```
  = (P*K1*D))/(2*Sv*E-0.2*P) per UG-37(a)(3)
  = (1.*0.892*606.0)/(2 *137.9*1.0-0.2*1.)
  = 1.9604 mm
```

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

```
  = (P*Ro)/(Sn*E+0.4*P) per Appendix 1-1 (a)(1)
  = (1.*16.7)/(118*1.0+0.4*1.)
  = 0.1412 mm
```

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

```
 Parallel to Vessel Wall (Diameter Limit)            Dl     53.4000  mm
 Parallel to Vessel Wall, opening length              d     26.7000  mm
 Normal to Vessel Wall (Thickness Limit), no pad    Tlnp     8.3750  mm
```

Note:

*Taking a UG-36(c)(3)(a) exemption for nozzle: Noz S Fr30.
This calculation is valid for nozzles that meet all the requirements of paragraph UG-36. Please check the Code carefully, especially for nozzles that are not isolated or do not meet Code spacing requirements. To force the computation of areas for small nozzles go to Tools->Configuration and check the box to force the UG-37 small nozzle area calculation or force the Appendix 1-10 computation in Nozzle Design Options.*

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

```
 Wall Thickness for Internal/External pressures       ta = 3.1412 mm
 Wall Thickness per UG16(b),                        tr16b = 4.5000 mm
 Wall Thickness, shell/head, internal pressure      trb1 = 5.1702 mm
 Wall Thickness                  tb1 = max(trb1, tr16b) = 5.1702 mm
 Wall Thickness                  tb2 = max(trb2, tr16b) = 4.5000 mm
 Wall Thickness per table UG-45                      tb3 = 5.9464 mm
```

Determine Nozzle Thickness candidate [tb]:

```
  = min[ tb3, max( tb1,tb2) ]
  = min[ 5.946, max( 5.1702, 4.5 ) ]
```

= 5.1702 mm

Minimum Wall Thickness of Nozzle Necks [tUG-45]:
= max(ta, tb)
= max(3.1412, 5.1702)
= 5.1702 mm

Available Nozzle Neck Thickness = 6.3500 mm --> OK

Weld Size Calculations, Description: Noz S Fr30

Intermediate Calc. for nozzle/shell Welds Tmin 3.3500 mm

Results Per UW-16.1:

	Required Thickness	Actual Thickness
Nozzle Weld	2.3450 = 0.7 * tmin.	3.5350 = 0.7 * Wo mm

Skipping the nozzle attachment weld strength calculations.
Per UW-15(b)(2) the nozzles exempted by UG-36(c)(3)(a)
(small nozzles) do not require a weld strength check.

Maximum Allowable Pressure for this Nozzle at this Location:
Converged Max. Allow. Pressure in Operating case 1.0000 MPa

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

The Drop for this Nozzle is : 6.9013 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 164.4177 mm

Nozzle Schedule:

Description	Nominal or Actual Size	Schd or FVC Type	Flg Type	Nozzle O/Dia mm	Wall Thk mm	Reinforcing Pad Diameter mm	Reinforcing Pad Thk mm	Cut Length mm	Flg Class
Noz S Fr30	33 mm	Actual	WNF	33.4	6.3	...	...	164	150
Noz P Fr20	48 mm	Actual	WNF	48.3	7.1	...	...	158	150
Noz N3 Fr10	60 mm	Actual	WNF	60.3	5.5	...	...	157	150
Noz T Fr20	60 mm	Actual	WNF	60.3	5.5	...	...	159	150
Noz N2 Fr30	88 mm	Actual	WNF	88.9	5.5	...	...	158	150
Noz N1 Fr20	114 mm	Actual	WNF	114.3	6.0	...	...	163	150
Noz H Fr20	168 mm	Actual	WNF	168.3	7.1	...	...	220	150

General Notes for the above table:

The Cut Length is the Outside Projection + Inside Projection + Drop +
In Plane Shell Thickness. This value does not include weld gaps,
nor does it account for shrinkage.

In the case of Oblique Nozzles, the Outside Diameter must
be increased. The Re-Pad WIDTH around the nozzle is calculated as follows:
Width of Pad = (Pad Outside Dia. (per above) - Nozzle Outside Dia.)/2

For hub nozzles, the thickness and diameter shown are those of the smaller
and thinner section.

Nozzle Material and Weld Fillet Leg Size Details (mm):

Description	Material	Shl Grve Weld	Noz Shl/Pad Weld	Pad OD Weld	Pad Grve Weld	Inside Weld
Noz S Fr30	SA-106 B	7.000	5.000	...	...	...
Noz P Fr20	SA-106 B	8.000	8.000	...	...	...
Noz N3 Fr10	SA-106 B	7.000	8.000	...	...	...
Noz T Fr20	SA-106 B	8.000	8.000	...	...	...
Noz N2 Fr30	SA-106 B	7.000	8.000	...	...	...
Noz N1 Fr20	SA-106 B	6.000	6.000	...	...	...
Noz H Fr20	SA-106 B	8.000	8.000	...	...	...

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

Nozzle Miscellaneous Data:

Description	Elev/Distance From Datum mm	Layout Angle deg	Proj Outside mm	Proj Inside mm	Installed in Component
Noz S Fr30	...	45.0	150.00	0.00	Node: 30
Noz P Fr20	1000.000	180.0	150.00	0.00	Node: 20
Noz N3 Fr10	...	0.0	150.00	0.00	Node: 10
Noz T Fr20	760.000	180.0	150.00	0.00	Node: 20
Noz N2 Fr30	...	0.0	150.00	0.00	Node: 30
Noz N1 Fr20	360.000	90.0	150.00	0.00	Node: 20
Noz H Fr20	360.000	180.0	200.00	0.00	Node: 20

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*
	[10]	B	-29	-48	-29	0.543	7.000	1.000
	[7]	B	-29	-48	-29	0.441	8.000	1.000
	[8]	B	-29	-48		0.442	8.000	0.850
	[10]	B	-29	-48	-29	0.543	7.000	1.000
	[7]	B	-29	-48	-29	0.441	8.000	1.000
Noz N3 Fr10	[1]	B	-29	-104		0.100	5.540	1.000
Nozzle Flg	[4]		-29	-104		0.100		
Noz N1 Fr20	[1]	B	-29	-104		0.160	6.020	1.000
Nozzle Flg	[4]		-29	-104		0.160		
Noz H Fr20	[1]	B	-29	-104		0.173	7.110	1.000
Nozzle Flg	[4]		-29	-104		0.173		
Noz P Fr20	[1]	B	-29	-104		0.049	7.140	1.000
Nozzle Flg	[4]		-29	-104		0.049		
Noz T Fr20	[1]	B	-29	-104		0.100	5.540	1.000
Nozzle Flg	[4]		-29	-104		0.100		
Noz N2 Fr30	[1]	B	-29	-104		0.151	5.490	1.000
Nozzle Flg	[4]		-29	-104		0.151		
Noz S Fr30	[1]	B	-29	-104		0.042	6.350	1.000
Nozzle Flg	[4]		-29	-104		0.042		
Warmest MDMT:			-29	-48				

Required Minimum Design Metal Temperature -10 C
Warmest Computed Minimum Design Metal Temperature -48 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)

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

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

ASME Code, Section VIII, Division 1, 2015

Diameter Spec : 600.000 mm ID		
Vessel Design Length, Tangent to Tangent	1500.00	mm
Distance of Bottom Tangent above Grade	0.00	mm
Specified Datum Line Distance	40.00	mm
Shell Material	SA-516 70	
Nozzle Material	SA-106 B	
Internal Design Temperature	85	C
Internal Design Pressure	1.000	MPa
External Design Temperature	20	C
Maximum Allowable Working Pressure	1.000	MPa
Hydrostatic Test Pressure	1.300	MPa
Required Minimum Design Metal Temperature	-10	C
Warmest Computed Minimum Design Metal Temperature	-48	C
Wind Design Code	ASCE-2010	
Earthquake Design Code	ASCE 7-2010	

Element Pressures and MAWP (MPa):

Element Description	Design Pres. + Stat. head	External Pressure	M.A.W.P	Corrosion Allowance
Ellipse	1.000	0.000	1.842	3.0000
Cylinder	1.000	0.000	1.915	3.0000
Ellipse	1.000	0.000	1.842	3.0000

Element Types and Properties:

Element Type	"To" Elev mm	Length mm	Element Thk mm	R e q d T h k Int.	Ext.	Joint Eff Long	Circ
Ellipse	0.0	40.0	8.0	5.2	4.5	1.00	0.85
Cylinder	1420.0	1420.0	8.0	5.6	No Calc	0.85	0.85
Ellipse	1460.0	40.0	8.0	5.2	4.5	1.00	0.85

Element thicknesses are shown as Nominal if specified, otherwise are Minimum

Loads for Foundation/Support Design:

Total Wind Shear on top of all Legs	647.	N
Total Earthquake Shear on top of all Legs	1506.	N
Total Wind Moment at top of all Legs	275819.	N-mm
Total Earthquake Moment at top of all Legs	584009.	N-mm
Max. Wind Shear on one Leg (top & bottom)	543.	N
Max. Earthq. Shear on one Leg (top & bottom)	1263.	N
Max. Wind Moment at base of one Leg	477931.	N-mm
Max. Earthquake Moment at base of one Leg	1112138.	N-mm
Max. Vertical Load (Wt. + Wind) on one Leg	1955.	N
Max. Vertical Load (Wt. + Eq.) on one Leg	2847.	N

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

Weights:

Fabricated	- Bare W/O Removable Internals	362.9 kg
Shop Test	- Fabricated + Water (Full)	843.4 kg
Shipping	- Fab. + Rem. Intls.+ Shipping App.	362.9 kg
Erected	- Fab. + Rem. Intls.+ Insul. (etc)	362.9 kg
Empty	- Fab. + Intls. + Details + Wghts.	362.9 kg
Operating	- Empty + Operating Liquid (No CA)	362.9 kg
Field Test	- Empty Weight + Water (Full)	843.4 kg

```
PV Elite 2017 SP1, Licensee: JIANGSU SUNPOWER TECHNOLOGY
FileName : BUNDLE LUG
Leg & Lug Analysis New Leg/Lug           Item:    2  11:02a Sep 22,2017
```

Input Echo, Leg & Lug Item 2, Description: New Leg/Lug

```
Design Internal Pressure                                  1.00  MPa
Design Temperature for Attachment           TEMP         85.00  C
Vessel Outside Diameter                       OD       816.000  mm
Vessel Wall Thickness                         Ts        8.0000  mm
Vessel Corrosion Allowance                   Cas        3.0000  mm
Vessel Material                                     SA-515 70
Vessel Material UNS Number                             K03101
Vessel Allowable Stress at Design              S        137.90  MPa
Analysis Type:                                       Lifting Lug

Empty Weight of Vessel                      Wemp       5000.00  N
Operating Weight of Vessel (vertical load )    W          0.00  N

Lifting Lug Material                                SA-516 70
Lifting Lug Material UNS Number                        K02700
Lifting Lug Yield Stress                   YIELD        241.81  MPa

Lifting Lug Orientation to Vessel             Perpendicular
Total Height of Lifting Lug                    w      160.0000  mm
Thickness of Lifting Lug                       t       12.0000  mm
Diameter of Hole in Lifting Lug               dh       50.0000  mm
Radius of Semi-Circular Arc of Lifting Lug     r       50.0000  mm
Height of Lug from bottom to Center of Hole    h      100.0000  mm
Offset from Vessel OD to Center of Hole      off      100.0000  mm
Minimum thickness of Fillet Weld around Lug   tw        8.0000  mm
Length of weld along side of Lifting Lug      wl      160.0000  mm
Length of Weld along Bottom of Lifting Lug    wb       20.0000  mm
Lift Orientation                                     Vertical
Force Along Vessel Axis                      Fax          0.00  N
Force Normal to Vessel                        Fn          0.00  N
Force Tangential to Vessel                    Ft          0.00  N
Impact Factor                             Impfac          1.50

Occasional Load Factor (AISC A5.2)        Occfac          1.00
```

Results for lifting lugs, Description : New Leg/Lug

```
Weld Group Inertia about the Circumferential Axis   ILC  7720952.000  mm**4
Weld Group Centroid distance in the Long. Direction YLL       88.000  mm
Dist. of Weld Group Centroid from Lug bottom      YLL_B       80.000  mm
Weld Group Inertia about the Longitudinal Axis      ILL   280319.688  mm**4
Weld Group Centroid Distance in the Circ. Direction YLC       14.000  mm
```

Applying the Impact factor to the loads:

Primary Shear Stress in the Welds due to Shear Loads [Ssll]:

```
 = Sqrt( Fax^2+Ft^2+Fn^2 ) / ( (2*wl+wb) * tw )
 = Sqrt(0^2+0^2+0^2) / ( (2*160.0 +20.0 ) * 8.0000 )
 = 0.00 MPa
```

Shear Stress in the Welds due to Bending Loads [Sblf]:

```
 = (Fn*(h-YLL_B)) *YLL/ILC + (Fax*off *YLL/ILC) + (Ft*off *YLC/ILL)
 = (0 *(100.000 -80.000 )) * 88.000 /7720952 +
   (0 *100.000 * 88.000 /7720952 ) +
   (0 *100.000 * 14.000 /280319.688)
 = 0.00 MPa
```

Total Shear Stress for Combined Loads [St]:

```
 = Ssll + Sblf
 = 0.000 + 0.000
 = 0.00 MPa
```

Allowable Shear Stress for Combined Loads [Sta]:

```
  = 0.4 * Yield * Occfac (AISC Shear All.)
  = 0.4 * 241 * 1.00
  = 96.72 MPa
```

Shear Stress in Lug above Hole [Shs]:

```
  = Sqrt( Fax^2 + Fn^2 + Ft^2 ) / Sha
  = Sqrt( 0^2 + 0^2 + 0^2 ) / 600.000
  = 0.00 MPa
```

Allowable Shear Stress in Lug above Hole [Sas]:

```
  = 0.4 * Yield * Occfac
  = 0.4 * 241 * 1.00
  = 96.72 MPa
```

Pin Hole Bearing Stress [Pbs]:

```
  = Sqrt( Fax^2 + Fn^2 ) / ( t * dh )
  = Sqrt( 0^2 + 0^2 ) / ( 12.000 * 50.000 )
  = 0.00 MPa
```

Allowable Bearing Stress [Pba]:

```
  = Min( 0.75 * Yield * Occfac, 0.9*Yield ) AISC Bearing All.
  = Min( 0.75 * 241 * 1.00 , 217.6 )
  = 181.36 MPa
```

Bending stress at the base of the lug [Fbs]:

```
  = Ft*off / (w*t² / 6) + Fax*off / (w²*t / 6)
  = 0 * 100.000 / (160.000 * 12.000² / 6) +
    0 * 100.000 / (160.000² * 12.000 / 6)
  = 0.00  MPa
```

Tensile stress at the base of the lug [Fa]:

```
  = Fn / (w * t) = 0 / (160.000 * 12.000 )
  = 0.00  MPa
```

Total Combined Stress at the base of the lug:
= Fbs + Fa = 0.0 MPa

Lug Allowable Stress for Bending and Tension:

```
  = Min( 0.66 * Yield * Occfac, 0.75*Yield )
  = Min( 0.66 * 241 * 1.00 , 181.4 ) = 159.6 MPa
```

Note: Check the Shell Stresses using method such as WRC-107.

Summary of Results

Stress (MPa)	Actual	Allowable	P/F
Primary Shear Stress of Weld :	0.00	96.72	Ok
Shear Stress above Hole :	0.00	96.72	Ok
Pin Hole Bearing Stress :	0.00	181.36	Ok
Total Combined Stress at the lug base :	0.00	159.59	Ok

PV Elite 2017 SP1, Licensee: JIANGSU SUNPOWER TECHNOLOGY
FileName : D8502
Vessel Design Summary: Step: 28 8:36pm Sep 21,2017

Leg Lug Results Summary for Item 2 : New Leg/Lug

The Vessel outside diameter is 816.000 mm

Summary of Results

Stress (MPa)	Actual	Allowable	P/F
Primary Shear Stress of Weld :	0.00	96.72	Ok
Shear Stress above Hole :	0.00	96.72	Ok
Pin Hole Bearing Stress :	0.00	181.36	Ok
Total Combined Stress at the lug base :	0.00	159.59	Ok