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Report No.: DC_FDX30446_Rev3

Oxygen Vessel Design Calculations

Analysis as per PD5500: 2018 CAT 2

SimuMech
DESIGN • ANALYSE • VERIFY
APPROVED
M.A. BUYS
Pr.Eng. 20140281

DWG No.: FX-M-A-115

REVISION TABLE

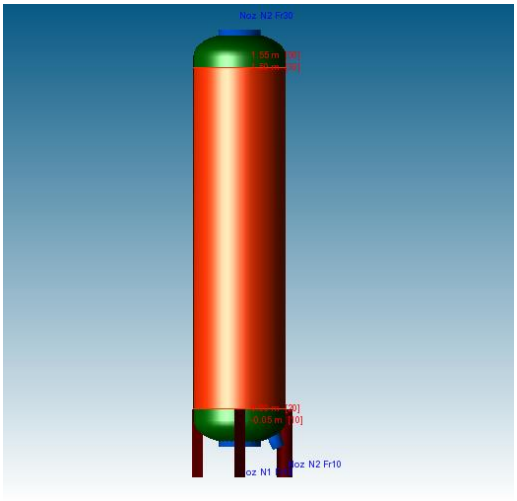
ITEM	DESCRIPTION	REV
1	FLANGE MATERIAL CHANGE TO A516 - 70	1
2	WORKING PRESSURE CORRECTED	2

20 May, 2021

This document comprises the following:

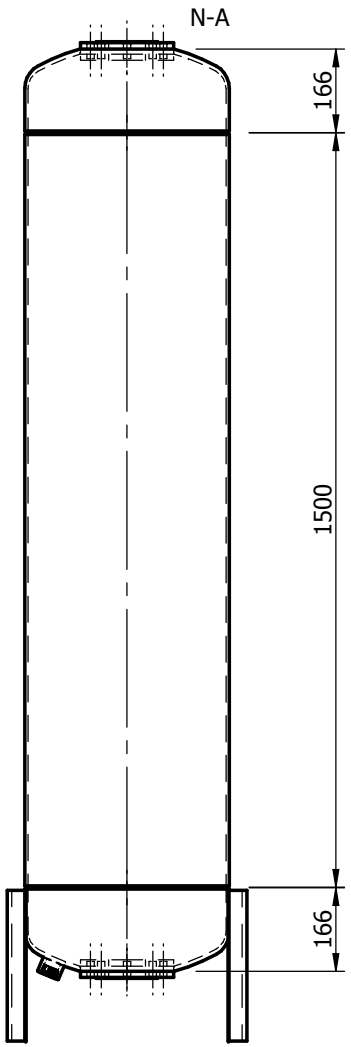
Sections

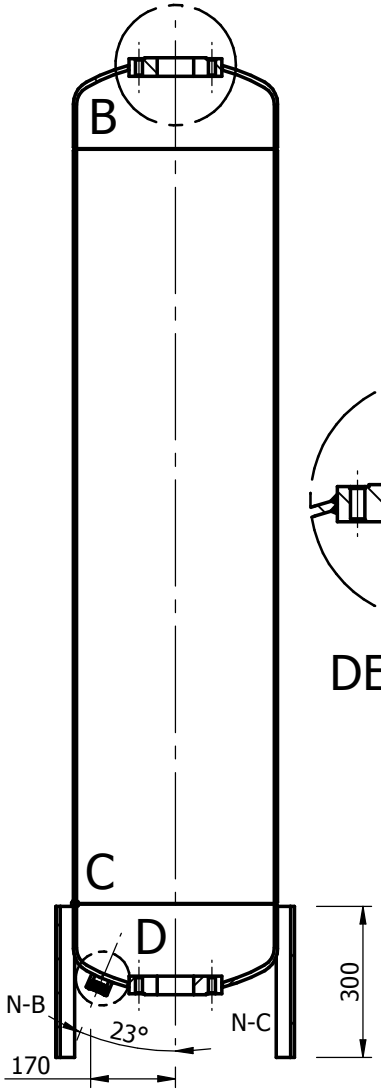
DESIGN DATA	
DESIGN CODE	PD5500 (2018)
DESIGN PRESSURE (kPa)	650
DESIGN TEMPERATURE min / max (Deg C)	5-50
HYDRAULIC TEST PRESSURE	845
RADIOGRAPHY	SPOT
STRESS RELIEVE	NO
INSPECTION AUTHORITY	RITC
DATE OF TEST	2021
CORROSION ALLOWANCE (mm)	3.175mm
WORKING PRESSURE (kPa)	650
WORKING TEMPERATURE (Deg C)	25
VOLUME (m3)	0.243
SANS 347 HAZARD CATEGORY	IV

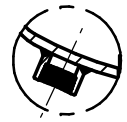


REPORT PREPARED FOR: VACUUM AND FLUID TECHNOLOGY

COMPILED BY: LE GREEN (PrTechEng) 201470150

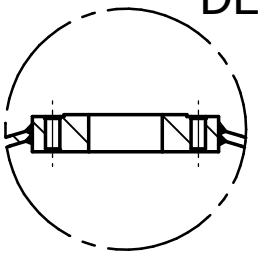




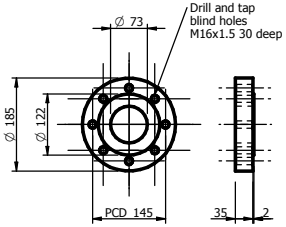


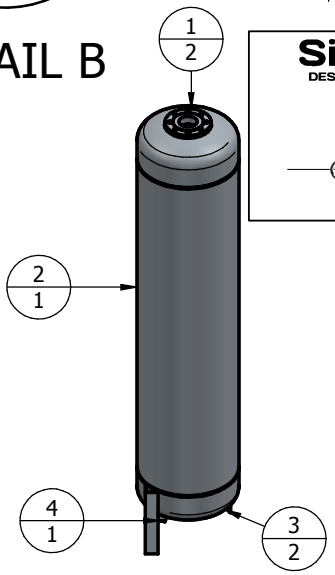
DETAIL D

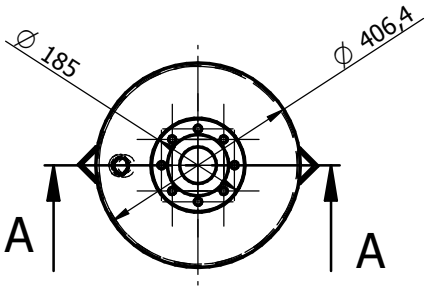
DETAIL C



DETAIL B







SECTION A-A

Item Number	Title	Quantity
1	Flange D185_A516-70	2
2	Pipe_400NB_SCH10_1500mm_ASTM A106	1
3	Welding Cap_400NB_wt9.5mm_ANSI B16.9_A 234 WPB	2
4	Half Coupling_1" NPTF_3000#_A-105	1
5*	EA_50 x 50 x 5mm_100mm_P235GH	2

DESIGN DATA	
DESIGN CODE	PD5500 (2018)
DESIGN PRESSURE (kPa)	650
DESIGN TEMPERATURE (Deg C)	50
HYDRAULIC TEST PRESSURE	845
RADIOGRAPHY	SPOT
STRESS RELIEVE	NO
INSPECTION AUTHORITY	RITC
DATE OF TEST	2021
CORROSION ALLOWANCE (mm)	3.175mm
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NOZZLE SCHEDULE

MARK	QTY	SIZE	RATING (NB)	SERVICE
A	1	D185	35mm	INLET
B	1	1" NPT	3000 lbs	INSTRUMENT
C	1	D185	35mm	OUTLET

EXISTING VESSEL DESIGN CODE:
PD5500 2018 CAT 2
CONFORMITY ASSESMENT
MODULE:G

LESLIE GREEN (PrTechEng)
201470145

	DESCRIPTION	DATE	REV
	WORKING PRESSURE CORRECTION	25-05-21	2
LG	FLANGE MATERIAL CHANGE TO A516-70	20-05-21	1
LG	ADDED WALL THICKNESSES TO END CAPS	20-05-21	1
APPROVED	REVISION HISTORY		

XGM Consulting Engineers
UNIT E9 CENTURY SQUARE CENCURY CITY
leslie@xgmconsult.co.za
Tel: 065 144 9562

TITLE: OXYGEN VESSEL
A3 FDX 30446

Client: VFT	Order No.	Scale:
Drawn: LG	Date: 25-05-21	Client Dwg No.
Drawing No. FX-M-A-115		Revision 2

CALCULATIONS

Table of Contents

PV Elite Vessel Analysis Program: Input Data

Design Internal Pressure (for Hydrotest)	0.65	N/mm²
Design Internal Temperature	50.0	°C
Hydrotest Position	Horizontal	
Projection of Nozzle from Vessel Top	0	mm
Projection of Nozzle from Vessel Bottom	0	mm
Minimum Design Metal Temperature	-28.9	°C
Construction Category	Category 2	
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	
Consider Vortex Shedding	N	
Perform a Corroded Hydrotest	N	

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

Wind Design Code		SANS 10160-3:2010	
Basic Wind Speed	[V]	28	m/sec
Terrain Category		A	
Base Elevation		0	m
Topography Factor		1.0	
Site Elevation		0	m.
Force Coefficient [Cf]		0.69999999	

Seismic Design Code		SANS 10160-4:2010	
Ref. horizontal peak ground accel.	[ag]	0.1000	
Ground type		1	
Behavior factor	[q]	1.0000	

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

Complete Listing of Vessel Elements and Details:

Element From Node	10	
Element To Node	20	
Element Type	Elliptical	
Description		
Distance "FROM" to "TO"	0.0508	m
Element Outside Diameter	406.4	mm
Element Thickness	8.335	mm

Internal Corrosion Allowance	3.175	mm
Nominal Thickness	9.525	mm
External Corrosion Allowance	0	mm
Design Internal Pressure	0.65	N/mm²
Design Temperature Internal Pressure	50	°C
Design External Pressure	0	N/mm²
Design Temperature External Pressure	50	°C
Effective Diameter Multiplier	1.2	
Material Name	A-234 WPB	
Allowable Stress, Ambient	160996	kPa
Allowable Stress, Operating	160996	kPa
Material Density	7750	kg/m³
Elliptical Head Factor	2.0	
Weld is pre-Heated	N/A	
Element From Node	10	
Detail Type	Nozzle	
Detail ID	Noz N1 Fr10	
Dist. from "FROM" Node / Offset dist	0	mm
Nozzle Diameter	185	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	None	
Nozzle Matl	A-516 70	
Element From Node	10	
Detail Type	Nozzle	
Detail ID	Noz N2 Fr10	
Dist. from "FROM" Node / Offset dist	135	mm
Nozzle Diameter	57.15	mm
Nozzle Schedule	None	
Nozzle Class	None	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	5.9382	N
Grade of Attached Flange	None	
Nozzle Matl	A-105	

Element From Node	20	
Element To Node	30	
Element Type	Cylinder	
Description		
Distance "FROM" to "TO"	1.5	m
Element Outside Diameter	406.4	mm
Element Thickness	5.556	mm
Internal Corrosion Allowance	3.175	mm
Nominal Thickness	6.35	mm
External Corrosion Allowance	0	mm
Design Internal Pressure	0.65	N/mm²
Design Temperature Internal Pressure	50	°C
Design External Pressure	0	N/mm²
Design Temperature External Pressure	50	°C
Effective Diameter Multiplier	1.2	
Material Name	A-106 B	
Allowable Stress, Ambient	160996	kPa
Allowable Stress, Operating	160996	kPa
Material Density	7750	kg/m³
Weld is pre-Heated	N/A	
Element From Node	20	
Detail Type	Leg	

Detail ID	LEGS	
Dist. from "FROM" Node / Offset dist	0	m
Diameter at Leg Centerline	434.27	mm
Leg Orientation	1	
Number of Legs	2	
Section Identifier	AE50X50X5	
Length of Legs	0.3	m

Element From Node	30	
Element To Node	50	
Element Type	Elliptical	
Description		
Distance "FROM" to "TO"	0.0508	m
Element Outside Diameter	406.4	mm
Element Thickness	8.335	mm
Internal Corrosion Allowance	3.175	mm
Nominal Thickness	9.525	mm
External Corrosion Allowance	0	mm
Design Internal Pressure	0.65	N/mm^2
Design Temperature Internal Pressure	50	°C
Design External Pressure	0	N/mm^2
Design Temperature External Pressure	50	°C
Effective Diameter Multiplier	1.2	
Material Name	A-234 WPB	
Allowable Stress, Ambient	160996	kPa
Allowable Stress, Operating	160996	kPa
Material Density	7750	kg/m^3
Elliptical Head Factor	2.0	
Weld is pre-Heated	N/A	

Element From Node	30	
Detail Type	Nozzle	
Detail ID	Noz N2 Fr30	
Dist. from "FROM" Node / Offset dist	0	mm
Nozzle Diameter	185	mm
Nozzle Schedule	None	
Nozzle Class	None	
Layout Angle	0.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0	N
Grade of Attached Flange	None	
Nozzle Matl	A-516 70	

XY Coordinate Calculations:

From	To	X (Horiz.) m	Y (Vert.) m	DX (Horiz.) m	DY (Vert.) m
10	20	...	0.0508	...	0.0508
20	30	...	1.5508	...	1.5
30	50	...	1.6016	...	0.0508

Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd N/mm²	Nominal Thickness mm	Total Corr Allowance mm	Element Diameter mm	Allowable Stress(SE) kPa
10	20	0.65	9.525	3.175	406.4	160996
20	30	0.65	6.35	3.175	406.4	160996
30	50	0.65	9.525	3.175	406.4	160996

Element Required Thickness and MAWP :

From	To	Design Pressure N/mm²	M.A.W.P. Corroded N/mm²	M.A.P. New & Cold N/mm²	Minimum Thickness mm	Required Thickness mm
10	20	0.65	4.31086	6.96337	8.335	4.15611
20	30	0.65	1.89764	4.46316	5.556	3.99372
30	50	0.65	4.31086	6.96337	8.335	4.15611
Minimum			1.898	4.463		

MAWP: 1.898 N/mm², limited by: Cylinder.

Internal Pressure Calculation Results :

British Standard PD 5500:2018+A1:2018

Elliptical Head From 10 To 20 A-234 WPB at 50 °C

Thickness Due to Internal Pressure (er):
= Values_Used_Min(HT, HE1, HE2), P/f, he/D, D Per 3.5.2 Domed Ends
= Values_Used_Min(105.77,2539975,2539975),0.00404,0.2603,406.4
= 0.9811 + 3.1750 = 4.1561 mm

Max. All. Working Pressure at Given Thickness (MAWP):
= 4.31 N/mm²

Maximum Allowable Pressure, New and Cold (MAPNC):
= 6.96 N/mm²

Actual Stress at Given Thickness:
= (P * Rica) / ecor
= (0.65*198.04)/5.16
= 24946.32 kPa

Required Thickness of Straight Flange = 4.010 mm

Minimum Design Metal Temperature per PD 5500: Annex D:

Note: Membrane stress computed in the corroded condition.
When considering the reference thickness the new thickness is used.

Minimum Design Metal Temperature ThetaD: -29 °C

Reference material thickness: 9.525 mm

Required Charpy Impact Test Temperature per D.6.1 for the As-Welded Case [RITT]:
= (ThetaR - (-49.83 + 0.4408e + 0.1792e^2 - 0.006218e^3 + 5.992E-5e^4)) /
(1.868 - 0.1324e + 0.00512e^2 - 0.000101e^3 + 7.939E-7e^4)
= (-15.0 - (-49.83 + 0.4408*9.5 + 0.1792*9.5^2 - 0.006218*9.5^3 + 5.992E-5*9.5^4))/
(1.868 - 0.1324*9.5 + 0.00512*9.5^2 - 0.000101*9.5^3 + 7.939E-7*9.5^4)
= 19.4 °C

Design Stress kPa	Actual Stress kPa	Category	PWHT	ThetaS °C	ThetaC °C	ThetaH °C
160996.3	24946.3	2	As Welded	50	-10	0

Design Reference Temperature ThetaR: 11 °C, (Modified Below)

Because Thickness <= 10 mm Table D.3 is Applied, thus:
Table D.3 give limiting ThetaR = -15 °C for 9.525 mm
ThetaR = 11 °C, but from Table D.3 Exempt Temp. = -15.0 °C

Because Actual ThetaR > Table D.3 ThetaR - IMPACT TESTING IS EXEMPT

Caution: Please review the above results to ensure compliance with the specific project requirements.

Cylindrical Shell From 20 To 30 A-106 B at 50 °C

Thickness Due to Internal Pressure (er):
= (P * Do) / (2 * f + p) per 3.5.1.2 Eqn. 3.5.1-2
= (0.65*406.4)/(2*160996.33+0.65)
= 0.8187 + 3.1750 = 3.9937 mm

Max. All. Working Pressure at Given Thickness (MAWP):
= (2 * f * ecor) / (Doca - ecor)
= (2*160996.33*2.38)/(406.4-2.38)
= 1.90 N/mm²

Maximum Allowable Pressure, New and Cold (MAPNC):
= (2 * fa * e) / (D - e)
= (2*160996.33*5.56)/(406.4-5.56)
= 4.46 N/mm²

Actual Stress at Given Thickness:
= (P * Ri) / ecor
= (0.65*200.82)/2.381
= 54821.21 kPa

Minimum Design Metal Temperature per PD 5500: Annex D:

Note: Membrane stress computed in the corroded condition.
When considering the reference thickness the new thickness is used.

Minimum Design Metal Temperature ThetaD: -29 °C

Reference material thickness: 6.350 mm

Required Charpy Impact Test Temperature per D.6.1 for the As-Welded Case [RITT]:
= (ThetaR - (-49.83 + 0.4408e + 0.1792e^2 - 0.006218e^3 + 5.992E-5e^4)) /
(1.868 - 0.1324e + 0.00512e^2 - 0.000101e^3 + 7.939E-7e^4)
= (-20.0 - (-49.83 + 0.4408*6.3 + 0.1792*6.3^2 - 0.006218*6.3^3 + 5.992E-5*6.3^4))/
(1.868 - 0.1324*6.3 + 0.00512*6.3^2 - 0.000101*6.3^3 + 7.939E-7*6.3^4)
= 17.6 °C

Design Stress kPa	Actual Stress kPa	Category	PWHT	ThetaS °C	ThetaC °C	ThetaH °C
160996.3	54821.2	2	As Welded	10	-10	0

Design Reference Temperature ThetaR: -29 °C, (Modified Below)

Because Thickness <= 10 mm Table D.3 is Applied, thus:
Table D.3 give limiting ThetaR = -20 °C for 6.35 mm

ThetaR = -29 °C, but from Table D.3 Exempt Temp. = -20.0 °C

Because Actual ThetaR < Table D.3 ThetaR - IMPACT TESTING IS MANDATORY

Caution: Please review the above results to ensure compliance with the specific project requirements.

Elliptical Head From 30 To 50 A-234 WPB at 50 °C

Thickness Due to Internal Pressure (er):
= Values_Used_Min(HT, HE1, HE2), P/f, he/D, D Per 3.5.2 Domed Ends
= Values_Used_Min(105.77,2539975,2539975),0.00404,0.2603,406.4
= 0.9811 + 3.1750 = 4.1561 mm

Max. All. Working Pressure at Given Thickness (MAWP):
= 4.31 N/mm²

Maximum Allowable Pressure, New and Cold (MAPNC):
= 6.96 N/mm²

Actual Stress at Given Thickness:
= (P * Rica) / ecor
= (0.65*198.04)/5.16
= 24946.32 kPa

Required Thickness of Straight Flange = 4.010 mm

Minimum Design Metal Temperature per PD 5500: Annex D:

Note: Membrane stress computed in the corroded condition.
When considering the reference thickness the new thickness is used.

Minimum Design Metal Temperature ThetaD: -29 °C

Reference material thickness: 9.525 mm

Required Charpy Impact Test Temperature per D.6.1 for the As-Welded Case [RITT]:
= (ThetaR - (-49.83 + 0.4408e + 0.1792e^2 - 0.006218e^3 + 5.992E-5e^4)) /
(1.868 - 0.1324e + 0.00512e^2 - 0.000101e^3 + 7.939E-7e^4)
= (-15.0 - (-49.83 + 0.4408*9.5 + 0.1792*9.5^2 - 0.006218*9.5^3 + 5.992E-5*9.5^4))/
(1.868 - 0.1324*9.5 + 0.00512*9.5^2 - 0.000101*9.5^3 + 7.939E-7*9.5^4)
= 19.4 °C

Design Stress kPa	Actual Stress kPa	Category	PWHT	ThetaS °C	ThetaC °C	ThetaH °C
160996.3	24946.3	2	As Welded	50	-10	0

Design Reference Temperature ThetaR: 11 °C, (Modified Below)

Because Thickness <= 10 mm Table D.3 is Applied, thus:
Table D.3 give limiting ThetaR = -15 °C for 9.525 mm
ThetaR = 11 °C, but from Table D.3 Exempt Temp. = -15.0 °C

Because Actual ThetaR > Table D.3 ThetaR - IMPACT TESTING IS EXEMPT

Caution: Please review the above results to ensure compliance with the specific project requirements.

Hydrostatic Test Pressure Results:

PD:5500 5.8.5-1, Standard Test Pressure
= 1.25 * P * fa/ft * (t / (t - c)) (per 5.8.5-1)
= 1.25 * 0.65 * 1.0 * (8.335/(8.335 - 3.175))

= 1.3124 N/mm²

PD:5500 5.8.5-1, Field Test Pressure
= 1.25 * P * fa/ft (per 5.8.5-1)
= 1.25 * 0.65 * 160996.328/160996.328
= 0.8125 N/mm²

Lower Bound Test Pressure	ptL	1.312	N/mm²
Upper Bound Test Pressure	ptH	1.896	N/mm²
1.35 times the Specified Design P	1.35*Dsgprs	0.877	N/mm²

Standard Test Pressure, 1.3124 N/mm², used in table below.

Stresses on Elements due to Test Pressure (kPa):

From	To	Pressure	Stress	Allowable	Ratio
10	20	1.316	30436.3	216897.2	0.140
20	30	1.316	46828.1	216897.2	0.216
30	50	1.316	30436.3	216897.2	0.140

Elements Suitable for Internal Pressure.

Element and Detail Weights:

From	To	Element Metal Wgt. kgm	Element ID Volume m³	Corroded Metal Wgt. kgm	Corroded ID Volume m³	Extra due Misc % kgm
10	20	18.7873	0.013811	12.5249	0.014395	...
20	30	93.1446	0.18411	46.9403	0.19008	...
30	50	18.7873	0.013811	12.5249	0.014395	...
Total		130	0.21	71	0.22	0

Weight of Details:

From	Type	Weight of Detail kgm	X Offset, Dtl. Cent. m	Y Offset, Dtl. Cent. m	Description
10	Nozl	24.9356	...	-0.14823	Noz N1 Fr10
10	Nozl	0.60557	0.135	-0.14646	Noz N2 Fr10
20	Legs	2.23203	...	-0.15	LEGS
30	Nozl	34.4093	...	0.21684	Noz N2 Fr30

Total Weight of Each Detail Type:

Nozzles	60.0
Legs	2.2
Sum of the Detail Weights	62.2 kgm

Weight Summation Results: (kgm)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	130.7	130.7	130.7	130.7	130.7	130.7
Nozzles	60.0	60.0	60.0	60.0	60.0	60.0
Legs	2.2	2.2	2.2	2.2	2.2	2.2
Test Liquid	...	211.6	...	...	...	...
Totals	192.9	404.5	192.9	192.9	192.9	192.9

Weight Summary:

Fabricated Wt.	- Bare Weight without Removable Internals	192.9 kgm
Shop Test Wt.	- Fabricated Weight + Water (Full)	404.5 kgm
Shipping Wt.	- Fab. Weight + removable Intls.+ Shipping App.	192.9 kgm
Erected Wt.	- Fab. Wt + or - loose items (trays,platforms etc.)	192.9 kgm
Ope. Wt. no Liq	- Fab. Weight + Internals. + Details + Weights	192.9 kgm
Operating Wt.	- Empty Weight + Operating Liq. Uncorroded	192.9 kgm
Field Test Wt.	- Empty Weight + Water (Full)	404.5 kgm
Mass of the Upper 1/3 of the Vertical Vessel		62.7 kgm

Outside Surface Areas of Elements:

From	To	Surface Area m²
10	20	0.24631
20	30	1.92212
30	50	0.24631
Total		2.415 m²

Element and Detail Weights:

From	To	Total Ele. Empty Wgt. kgm	Total. Ele. Oper. Wgt. kgm	Total. Ele. Hydro. Wgt. kgm	Total Dtl. Offset Mom. N-m	Oper. Wgt. No Liquid kgm
10	20	44.3285	44.3285	58.1314	0.80198	44.3285
20	Legs	...	...	...	...	...
Legs	30	93.1446	93.1446	277.146	...	93.1446
30	50	53.1966	53.1966	66.9995	...	53.1966

Cumulative Vessel Weight

From	To	Cumulative Ope Wgt. No Liquid kgm	Cumulative Oper. Wgt. kgm	Cumulative Hydro. Wgt. kgm
10	20	...	...	...
20	Legs	-44.3285	-44.3285	-58.1314
Legs	30	146.341	146.341	344.146
30	50	53.1966	53.1966	66.9995

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-m	Cumulative Oper. Mom. N-m	Cumulative Hydro. Mom. N-m
10	20	0.80198	0.80198	0.80198
20	Legs	0.80198	0.80198	0.80198
Legs	30	...	...	...
30	50	...	...	...

Nozzle Flange MAWP Results:

There does not appear to be any valid core flange data to process. Please see the nozzle summary for MAWP information on Jacket side nozzles if there are any.

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 3.67097 Hz.

The Natural Frequency for the Vessel (Ope...) is 3.67097 Hz.

Input Values:

Wind Design Code		SANS 10160-3:2010	
Basic Wind Speed	[V]	28	m/sec
Terrain Category		A	
Base Elevation		0	m
Topography Factor		1.0	
Site Elevation		0	m.
Force Coefficient [Cf]		0.69999999	

Calculated Values:

Probability factor (cprob)	1.000
Table lookup value air density from Table 4	0.120E+01 kg/m³

Sample Calculation for the First Element:

Probability factor [cprob] per 7.2.3:
= [(1 - K * ln(-ln(1- p))/(1 - K * ln(-ln(0.98)))]^n
= [(1 - 0.2 * ln(-ln(1- 0.02))/(1 - 0.2 * ln(-ln(0.98)))]^ 0.5
= 1.000

Basic wind speed [vb] per 7.2.2:
= Probability factor * Fundemental value of basic wind speed
= 1.0 * 12.517
= 28.001 m/sec

Peak basic wind speed [vbpeak] per 7.3.1.1:
= 1.4 * vb
= 1.4 * 28.001
= 39.201 m/sec

Height of interest for first element [z]:
= Centroid Height + Base Height
= 0.088 + 0.0
= 0.088 m. [.088 m]

Roughness factor at height of the first element [Cr(z)]:
= Interpolated value from the table 3 at 0.088 m.
= 0.922

Peak wind speed at height of the first element [vp(z)] per 7.3.1.1:
= Cr(z) * Co(z) * vbpeak
= 0.922 * 1.0 * 39.201
= 36.151 m/sec

Peak wind speed pressure at height of the first element [qp(z)] per 7.4:
= 1/2 * RO * vb(z)^2
= 1/2 * 0.120E+01 * 36.151^2
= 0.7841E+03 N./m² [0.7841E+00 kPa]

Wind force on the first element [Fw] per 7.5.3.2:
= Cs * Cd * Cf * qp(z) * Aref
= 1.0 * 1.0 * 0.7 * 784.116 * 0.065
= 35.8 N.

Element	z m	Area m²	Pressure kPa	Force N
Node 10 to 20	0.088	0.065	0.784	35.833
Node 20 to 30	0.898	0.731	0.819	419.344
Node 30 to 50	1.717	0.065	0.855	39.069

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 m
 Df  - Damping Factor < 0.75 Unstable,  > 0.95 Stable
 Dr  - Average internal diameter of top half of vessel m
  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 m
 Lc  - Total length of conical section(s) of vessel m
 tb  - Uncorroded plate thickness at bottom of vessel mm
 V30 - Design Wind Speed provided by user m/sec
 Vc  - Critical wind velocity m/sec
 Vw  - Maximum wind speed at top of structure m/sec
 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, <= 0.314E+04 (High); 0.314E+04 < 0.393E+04 (Probable)
 P30 - wind pressure 30 feet above the base
```

Check other Conditions and Basic Assumptions:

```
 #1 - Total Cone Length / Total Length < 0.5
      0.0/1.602 = 0.0

 #2 - ( D / L² ) * 10⁴ < 8.0 (English Units)
    - ( 1.33/5.25² ) * 10⁴ = 482.904 [Geometry Violation]
```

Compute the vibration possibility. If Vp > 0.393E+04 no chance. [Vp]:

```
  = W / ( L * Dr² )
  = 1316/( 1.6 * 0.401² )
  = 0.51015E+04
```

Since Vp is > 0.393E+04 no further vibration analysis is required !

The Natural Frequency for the Vessel (Ope...) is 3.67097 Hz.

Wind Load Calculation:

From	To	Wind Height m	Wind Diameter m	Wind Area m²	Wind Pressure kPa	Element Wind Load N
10	20	0.087551	0.48768	0.065269	0.78409	35.8326
20	30	0.89823	0.48768	0.73134	0.81894	419.344
30	50	1.71725	0.48768	0.065269	0.85491	39.0688

Input Values:

```
Seismic Design Code                        SANS 10160-4:2010
Ref. horizontal peak ground accel.  [ag]              0.1000
Ground type                                              1
Behavior factor                      [q]              1.0000
```

Calculated Values:

```
Soil factor based on ground type from Table 2       1.000
Value of TB based on ground type from Table 2      0.150
Value of TC based on ground type from Table 2      0.400
Value of TD based on ground type from Table 2       2.000
```

Sample Calculation for the Force on the First Element [F1n]:

Fundamental period of vibration [T]:
```
  = 1 / Natural Frequency
  = 1/3.671
  = 0.272 sec
```

Design spectrum for elastic analysis [Sd(T)] per 5.3:
```
  = ag * S( 2.5/q )
  = 0.1 * 1.0( 2.5/1.0 )
  = 0.250
```

Sustained vertical load [Wn] per 8.3:
```
  = Summation of self weight loads of all elements
  = 1.870 KN  [1869.7 N]
```

Design Base Shear Load per 8.5.1 [Vn] :
```
  = Sd(T) * Wn
  = 0.25 * 1.87
  = 0.467 KN  [467.4 N]
```

Factor to determine lateral seismic force on element 1 [Cv1] per 8.5.3:
```
  = W1 * h1 / SUM[ Wi * hi ]
  = 434.685 * 0.025/1564.691
  = 0.00706
```

Vertical distribution of seismic forces for element 1 [F1n] per 8.5.3:
```
  = Cv1 * Vn
  = 0.00706 * 0.467
  = 0.003 KN  [3.3 N]
```

The Natural Frequency for the Vessel (Ope...) is 3.67097 Hz.

Earthquake Load Calculation:

From	To	Earthquake Height m	Earthquake Weight N	Element Ope Load N	Element Emp Load N
10	20	0.0254	434.685	3.29831	3.29831
20	Legs	0.0508	...	...	...
Legs	30	0.8008	913.376	218.502	218.502
30	50	1.5762	521.646	245.624	245.624

The following table is for the Operating Case.

Wind/Earthquake Shear, Bending:

From	To	Distance to Support m	Cumulative Wind Shear N	Earthquake Shear N	Wind Bending N-m	Earthquake Bending N-m
10	20	0.069016	...	...	...	...
20	Legs	...	35.8326	3.29831	2.47404	0.22773
Legs	30	0.75	494.245	467.424	373.486	549.259
30	50	1.56902	39.0688	245.624	2.69747	16.9589

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

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	20	...	0.099404	0.099404	0.00049702
20	Legs	35.8326	0.099404	0.099404	0.00049702
Legs	30	494.245	0.10585	0.11809	0.00051411
30	50	39.0688	0.11853	0.11896	0.00051411

Critical Wind Velocity for Tower Vibration:

From	To	1st Crit. Wind Speed m/sec	2nd Crit. Wind Speed m/sec
10	20	8.92723	55.7952
20	30	8.92723	55.7952
30	50	8.92723	55.7952

Allowable deflection at the Tower Top (Ope)(6.000"/100ft. Criteria)
Allowable deflection : 8.008 Actual deflection : 0.119 mm

Longitudinal Stress Constants:

From	To	Metal Area New m²	Metal Area Corroded m²	Section Modulus New mm³	Section Modulus Corroded mm³
10	20	0.010421	0.0065027	1037297	652451
20	30	0.0069949	0.0030214	701137	305248
30	50	0.010421	0.0065027	1037297	652451

Longitudinal Allowable Stresses:

From	To	Tensile kPa	Hydrotest Tensile kPa	Compressive kPa	Hydrotest Compressive kPa
10	20	193196	260277	-121931	-134513
20	Legs	193196	260277	-109579	-123329
Legs	30	193196	260277	-109579	-123329
30	50	193196	260277	-121931	-134513

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 kPa	Longitudinal Stress External Pressure kPa	Longitudinal Stress Hydrotest Pressure kPa
10	20	12312.8	...	15020.3
20	30	27249.1	...	23019.7
30	50	12312.8	...	15020.3

Longitudinal Stresses due to Weight Loads for these Conditions:

From	To	Wght. Str. Empty kPa	Wght. Str. Operating kPa	Wght. Str. Hydrotest kPa	Wght. Str. Emp. Mom. kPa	Wght. Str. Opr. Mom. kPa
10	20	...	...	...	1.22872	1.22872
20	Legs	143.839	143.839	...	2.62631	2.62631
Legs	30	-474.854	-474.854	...	...	...
30	50	-80.2017	-80.2017	...	...	...

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

From	To	Wght. Str. Hyd. Mom. kPa	Bend. Str. Oper. Wind kPa	Bend. Str. Oper. Equ. kPa	Bend. Str. Hyd. Wind kPa	Bend. Str. Hyd. Equ. kPa
10	20	...	...	...	...	...
20	Legs	...	8.10194	0.74576	...	...
Legs	30	...	1223.09	1798.71	...	...
30	50	...	4.1328	25.9827	...	...

Longitudinal Stresses due to these Conditions:

From	To	Vortex Shedding Operating Case kPa	Vortex Shedding Empty Case kPa	Vortex Shedding Test Case kPa	Earthquake Empty Case kPa
10	20	...	...	...	...
20	Legs	...	...	...	0.74576
Legs	30	...	...	...	1798.71
30	50	...	...	...	25.9827

Longitudinal Stresses due to Applied Axial Forces:

From	To	Longitudinal Stress Y Forces Wind kPa	Longitudinal Stress Y Forces Seismic kPa
10	20	...	...
20	Legs	...	...
Legs	30	...	...
30	50	...	...

Longitudinal Stresses due to User Forces and Moments:

From	To	Wind For/Mom Corroded kPa	Earthquake For/Mom Corroded kPa	Wind For/Mom No Corrosion kPa	Earthquake For/Mom No Corrosion kPa
10	20	...	...	...	...
20	Legs	...	...	...	...
Legs	30	...	...	...	...
30	50	...	...	...	...

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.

For PD:5500 the computed stress intensities are compared to the design stress f and the compressive stress is compared to the allowable compressive as Rat 4.

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

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

From Node	f1-f2	f2+0.5p Hoop+.5p		Rat 1	Rat 2	Rat 3	Rat 4
	Stress Intensities			Stress Ratios			
10	1.229	1.229	0.000	0.000	0.000	0.000	0.000
20	133.111	154.567	0.000	0.001	0.001	0.000	0.000
20	1697.940	1697.940	0.000	0.009	0.009	0.000	0.015
30	84.335	84.335	0.000	0.000	0.000	0.000	0.001

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

From Node	f1-f2	f2+0.5p Hoop+.5p		Rat 1	Rat 2	Rat 3	Rat 4
	Stress Intensities			Stress Ratios			
10	1.229	1.229	0.000	0.000	0.000	0.000	0.000
20	140.467	147.211	0.000	0.001	0.001	0.000	0.000
20	2273.560	2273.560	0.000	0.012	0.012	0.000	0.021
30	106.184	106.184	0.000	0.001	0.001	0.000	0.001

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

From Node	f1-f2 Stress Intensities	f2+0.5p Stress Intensities	Hoop+.5p Stress Intensities	Rat 1 Stress Ratios	Rat 2 Stress Ratios	Rat 3 Stress Ratios	Rat 4 Stress Ratios
10	1.229	1.229	0.000	0.000	0.000	0.000	0.000
20	133.111	154.567	0.000	0.001	0.001	0.000	0.000
20	1697.940	1697.940	0.000	0.009	0.009	0.000	0.015
30	84.335	84.335	0.000	0.000	0.000	0.000	0.001

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

From Node	f1-f2 Stress Intensities	f2+0.5p Stress Intensities	Hoop+.5p Stress Intensities	Rat 1 Stress Ratios	Rat 2 Stress Ratios	Rat 3 Stress Ratios	Rat 4 Stress Ratios
10	1.229	1.229	0.000	0.000	0.000	0.000	0.000
20	140.467	147.211	0.000	0.001	0.001	0.000	0.000
20	2273.560	2273.560	0.000	0.012	0.012	0.000	0.021
30	106.184	106.184	0.000	0.001	0.001	0.000	0.001

Analysis of Load Case 5 : NP+HW+HI

From Node	f1-f2 Stress Intensities	f2+0.5p Stress Intensities	Hoop+.5p Stress Intensities	Rat 1 Stress Ratios	Rat 2 Stress Ratios	Rat 3 Stress Ratios	Rat 4 Stress Ratios
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Analysis of Load Case 6 : NP+HW+HE

From Node	f1-f2 Stress Intensities	f2+0.5p Stress Intensities	Hoop+.5p Stress Intensities	Rat 1 Stress Ratios	Rat 2 Stress Ratios	Rat 3 Stress Ratios	Rat 4 Stress Ratios
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30	0.000	0.000	0.000	0.000	0.000	0.000	0.000

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

From Node	f1-f2 Stress Intensities	f2+0.5p Stress Intensities	Hoop+.5p Stress Intensities	Rat 1 Stress Ratios	Rat 2 Stress Ratios	Rat 3 Stress Ratios	Rat 4 Stress Ratios
10	12634.795	12638.973	25271.309	0.065	0.065	0.131	0.000
20	27439.035	27728.625	55146.203	0.142	0.144	0.285	0.000
20	29270.088	28322.293	55146.203	0.152	0.147	0.285	0.000
30	12717.900	12236.682	24946.316	0.066	0.063	0.129	0.000

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

From Node	f1-f2 Stress Intensities	f2+0.5p Stress Intensities	Hoop+.5p Stress Intensities	Rat 1 Stress Ratios	Rat 2 Stress Ratios	Rat 3 Stress Ratios	Rat 4 Stress Ratios
10	12634.795	12638.973	25271.309	0.065	0.065	0.131	0.000
20	27431.680	27721.270	55146.203	0.142	0.143	0.285	0.000
20	29845.707	28897.910	55146.203	0.154	0.150	0.285	0.000
30	12739.750	12258.532	24946.316	0.066	0.063	0.129	0.000

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

From Node	f1-f2 Stress Intensities	f2+0.5p Stress Intensities	Hoop+.5p Stress Intensities	Rat 1 Stress Ratios	Rat 2 Stress Ratios	Rat 3 Stress Ratios	Rat 4 Stress Ratios
10	1.229	1.229	0.000	0.000	0.000	0.000	0.000
20	133.111	154.567	0.000	0.001	0.001	0.000	0.000
20	1697.940	1697.940	0.000	0.009	0.009	0.000	0.015
30	84.335	84.335	0.000	0.000	0.000	0.000	0.001

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

From Node	f1-f2 Stress Intensities	f2+0.5p Stress Intensities	Hoop+.5p Stress Intensities	Rat 1 Stress Ratios	Rat 2 Stress Ratios	Rat 3 Stress Ratios	Rat 4 Stress Ratios

10	1.229	1.229	0.000	0.000	0.000	0.000	0.000
20	140.467	147.211	0.000	0.001	0.001	0.000	0.000
20	2273.560	2273.560	0.000	0.012	0.012	0.000	0.021
30	106.184	106.184	0.000	0.001	0.001	0.000	0.001

Analysis of Load Case 11 : HP+HW+HI

From Node	f1-f2 Stress Intensities	f2+0.5p Hoop+.5p		Rat 1	Rat 2	Rat 3	Rat 4 Stress Ratios
10	15416.066	15678.450	31094.514	0.059	0.060	0.119	0.000
20	23808.469	23677.850	47486.316	0.091	0.091	0.182	0.000
20	23808.469	23677.850	47486.316	0.091	0.091	0.182	0.000
30	15416.066	15020.253	30436.318	0.059	0.058	0.117	0.000

Analysis of Load Case 12 : HP+HW+HE

From Node	f1-f2 Stress Intensities	f2+0.5p Hoop+.5p		Rat 1	Rat 2	Rat 3	Rat 4 Stress Ratios
10	15416.066	15678.450	31094.514	0.059	0.060	0.119	0.000
20	23808.469	23677.850	47486.316	0.091	0.091	0.182	0.000
20	23808.469	23677.850	47486.316	0.091	0.091	0.182	0.000
30	15416.066	15020.253	30436.318	0.059	0.058	0.117	0.000

Analysis of Load Case 13 : IP+WE+EW

From Node	f1-f2 Stress Intensities	f2+0.5p Hoop+.5p		Rat 1	Rat 2	Rat 3	Rat 4 Stress Ratios
10	12634.795	12638.973	25271.309	0.065	0.065	0.131	0.000
20	27430.934	27720.523	55146.203	0.142	0.143	0.285	0.000
20	28047.000	27099.205	55146.203	0.145	0.140	0.285	0.000
30	12713.768	12232.550	24946.316	0.066	0.063	0.129	0.000

Analysis of Load Case 14 : IP+WF+CW

From Node	f1-f2 Stress Intensities	f2+0.5p Hoop+.5p		Rat 1	Rat 2	Rat 3	Rat 4 Stress Ratios
10	12633.565	12637.743	25271.309	0.065	0.065	0.131	0.000
20	27510.016	27636.189	55146.203	0.142	0.143	0.285	0.000
20	27777.254	27368.951	55146.203	0.144	0.142	0.285	0.000
30	12683.613	12262.704	24946.316	0.066	0.063	0.129	0.000

Analysis of Load Case 15 : IP+VO+OW

From Node	f1-f2 Stress Intensities	f2+0.5p Hoop+.5p		Rat 1	Rat 2	Rat 3	Rat 4 Stress Ratios
10	12634.795	12638.973	25271.309	0.065	0.065	0.131	0.000
20	27430.934	27720.523	55146.203	0.142	0.143	0.285	0.000
20	28047.000	27099.205	55146.203	0.145	0.140	0.285	0.000
30	12713.768	12232.550	24946.316	0.066	0.063	0.129	0.000

Analysis of Load Case 16 : IP+VE+EW

From Node	f1-f2 Stress Intensities	f2+0.5p Hoop+.5p		Rat 1	Rat 2	Rat 3	Rat 4 Stress Ratios
10	12634.795	12638.973	25271.309	0.065	0.065	0.131	0.000
20	27430.934	27720.523	55146.203	0.142	0.143	0.285	0.000
20	28047.000	27099.205	55146.203	0.145	0.140	0.285	0.000
30	12713.768	12232.550	24946.316	0.066	0.063	0.129	0.000

Analysis of Load Case 17 : NP+VO+OW

From Node	f1-f2 Stress Intensities	f2+0.5p Hoop+.5p		Rat 1	Rat 2	Rat 3	Rat 4 Stress Ratios
10	1.229	1.229	0.000	0.000	0.000	0.000	0.000

20	141.213	146.465	0.000	0.001	0.001	0.000	0.000
20	474.854	474.854	0.000	0.002	0.002	0.000	0.004
30	80.202	80.202	0.000	0.000	0.000	0.000	0.001

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

From Node	f1-f2	f2+0.5p	Hoop+.5p	Rat 1	Rat 2	Rat 3	Rat 4
	Stress Intensities			Stress Ratios			
10	12634.795	12638.973	25271.309	0.065	0.065	0.131	0.000
20	27430.934	27720.523	55146.203	0.142	0.143	0.285	0.000
20	28047.000	27099.205	55146.203	0.145	0.140	0.285	0.000
30	12713.768	12232.550	24946.316	0.066	0.063	0.129	0.000

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

From Node	f1-f2	f2+0.5p	Hoop+.5p	Rat 1	Rat 2	Rat 3	Rat 4
	Stress Intensities			Stress Ratios			
10	1.229	1.229	0.000	0.000	0.000	0.000	0.000
20	141.213	146.465	0.000	0.001	0.001	0.000	0.000
20	474.854	474.854	0.000	0.002	0.002	0.000	0.004
30	80.202	80.202	0.000	0.000	0.000	0.000	0.001

Absolute Maximum of the all of the Stress Ratio's 0.2854

Element From : 20 to : 30
Governing Load Case 7 : IP+OW+WI+FW+BW

Shop/Field Installation Options :

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

Center of Gravity of Nozzles	0.951 m
Center of Gravity of Legs	-0.099 m
Center of Gravity of Bare Shell New and Cold	0.801 m
Center of Gravity of Bare Shell Corroded	0.801 m
Vessel CG in the Operating Condition	0.853 m
Vessel CG in the Fabricated (Shop/Empty) Condition	0.837 m
Vessel CG in the Test Condition	0.818 m

Rigging Analysis Results:

Lifting Weight based the calculated Empty Weight.

Total Effective Length of Vessel for this analysis		1.60 m
Total vessel weight (No Liquid)	Twt	1913.48 N
Impact weight multiplication factor	Imp	1.50
Design lifting weight, DWT = Imp * Twt		2870.22 N
Elevation of the Tailing Lug (bottom)		0.00 m
Elevation of the Lifting Lug (top)		1.60 m
Design Reaction force at the tailing lug		1369.88 N
Design Reaction force at the lifting lug		1500.34 N
CG Distance from Tailing Lug		0.84 m
CG Distance from the Nearer Lifting Lug		0.76 m

Critical Values:

	Max Stress	Elevation	Allowables	
	kPa	m	kPa	
Bending	372.04	0.95	123328.98	
Shear	114.93	1.25	112697.43	(0.7*S)

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

Distance m	Bending Moment N-m	Bending Stress kPa	Shear Force N	Shear Stress kPa
0.00	0.0	0.0	439.6	42.2
0.35	165.8	239.7	56.9	8.1
0.95	257.4	372.0	517.1	73.9
1.55	4.5	4.4	1091.1	104.7

Unity Check (Actual Stress / Allowable Stress):

Maximum Unity Check is 0.003 at elevation 0.9508 m - Must be <=1

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

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

RESULTS FOR LEGS : Operating Case Description: LEGS

Legs attached to: node 20

Section Properties : Single Angle AE50X50X5

South African Steel Construction Handbook 1992 Steel Table

Overall Leg Length		0.300	m
Effective Leg Length	Leglen	0.300	m
Distance Leg Up Side of Vessel		0.000	m
Number of Legs	Nleg	2	
Cross Sectional Area for AE50X50X5	Aleg	0.000	m^2
Section Inertia (strong axis)		110009.852	mm**4
Section Inertia (weak axis)		110009.852	mm**4
Section Modulus (strong axis)		3049.632	mm^3
Section Modulus (weak axis)		3049.632	mm^3
Radius of Gyration (strong axis)		15.100	mm
Radius of Gyration (weak axis)		15.100	mm

Leg Orientation - Strong Axis

Overturning Moment at top of Legs		549.3	N-m
Total Weight Load at top of Legs	W	1869.7	N
Total Shear force at top of Legs		494.2	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

Maximum Shear at top of one Leg [Vleg]:
= (max(Wind, Seismic) + applied forces)(Imax / Itot)
= (494.2)(109448.8/218897.64)
= 247.12 N

Axial Compression, Leg furthest from the Neutral Axis [Sma]:
= W/Nleg + (Mleg/(Nlegm*Rn))/Aleg
= 1870/2 + (549041/(1 * 217.135))/480.0
= 7215.64 kPa

Axial Compression, Leg closest to the Neutral Axis [Sva]:
= (W / Nleg) / Aleg
= (1870/2)/0.
= 1947.67 kPa

Computing Principal Axis and Inertias for Angle.			
Leg lengths and thickness:	50.000	50.000	5.0013
Distance to geometric centroid:	13.934	13.934	
Arm about YY:	11.434	13.566	
Arm about ZZ:	11.066	11.434	
Leg areas:	0.25000E-03	0.22499E-03	
Geometric inertia components YY:	33212.	79393.	
Geometric inertia components ZZ:	82715.	29890.	
Geometric inertias Iy & Iz:	0.11261E+06	0.11261E+06	
Product of inertia:	66546.		
Mohrs Radius:	4.0609		
Average Inertia:	0.11261E+06		

QFACT = 1.0000	FBZ =	163.82	
Principal Axis Inertias (Z&W)	=	45994.	0.17398E+06
Angle to Principal Axis	=	45.000	
Distances to extreme fibers CW & CZ	=	35.355	15.649

```
 FOB from Eq 5-5                    =   3247.0
 Bending allowables Fby & Fbz       =   163.82      163.82

 Shear Center Coordinates Wo & Zo:   15.802      0.0000
 Values for Elastic Flexural-Torsional Buckling Stress:
 E,    G,      J,   R0²:    29500.      11346.     0.96149E-02  1.0974
 AREA, LENGTH, Kw,  Kz:    0.74400      11.811      1.0000      1.0000
 H,    Few,    Fez, Fej:   0.64732      1172.6      309.98      133.62
 Fe computed from C4-1:     128.08

 Initial (Kl/r)max, & (Kl/r)equiv   =   30.647      47.678
 Final (Kl/r)max, & Cc              =   47.678      127.18
 Fa based on Eq 4-1                 =   128.16

                             Actual   Allowable
 Weak Axis Bending    :      17836.92   218366.67   kPa
 Strong Axis Bending  :      10653.04   218366.67   kPa
 Axial Compression    :       7215.64   170831.30   kPa

 UNITY CHECKS ARE: H1-1     0.000
                   H1-2     0.000
                   H1-3     0.173

 AISC Unity Check :   0.173 Should be <= to 1
```

Nozzle Calculation Summary:

Per Section 3.5.4 Based on Graphs 3.5-9 to 3.5-11:

Description	Act Thk mm	Calc Thk mm	Table 3.5-4	Rho Result	Pr. Area Result
Noz N1 Fr10	35.00	...	6.2	Passed	N/A
Noz N2 Fr10	10.39	...	6.8	Passed	N/A
Noz N2 Fr30	35.00	...	6.2	Passed	N/A

Check the Spatial Relationship between the Nozzles

From Node	Nozzle Description	Y Coordinate mm	Layout Angle deg	Mean Radius mm
10	Noz N1 Fr10	0.000	0.000	75.000
10	Noz N2 Fr10	0.000	90.000	24.967
30	Noz N2 Fr30	0.000	0.000	75.000

If any interferences/violations are found, they will be noted below.
Note: One or more Nozzles are closely spaced. Check the Code
paragraph 3.5.4.4 including paragraph 3.5.4.4.1 and
sub paragraphs (a) through (e) for each ligament.

Nozzles : Noz N2 Fr10 and Noz N1 Fr10 are in close proximity.

As + An - At >= K2 * g * P * eps (equation 3.5.4-7)
0.0001 + 0.0013 - 0. >= 1.0 * 1.0 * 138.750 * 0.7056
0.0014 should be greater than or equal to 0.0001 [Passed]

Dim P is: 138.75 mm Dim S is: 38.78 mm Dim Smin is: 66.26 mm
Nozzle: Noz N1 Fr10 was too thick and failed 3.5.4.3.4 d) requirements.

Corroded Thickness of the Nozzle 35.0 shall be less than:
= (2 - d/D) * eas
= (2 - 150.0/691.4083) * 0.2031
= 9.2005 mm

No interference violations have been detected !

Input, Nozzle Desc: Noz N1 Fr10 From: 10

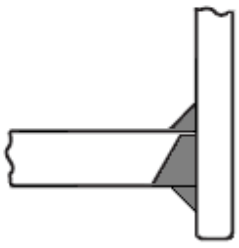
Pressure for Reinforcement Calculations	P	0.6500	N/mm²
Temperature for Internal Pressure	Temp	50	°C
Shell Material		A-234 WPB	
Shell Allowable Stress at Temperature	f	160996.33	kPa
Shell Allowable Stress At Ambient	fa	160996.33	kPa
Inside Diameter of Elliptical Head	Di	389.73	mm
Aspect Ratio of Elliptical Head	Ar	1.92	
Head Finished (Minimum) Thickness	ea	8.3350	mm
Head Internal Corrosion Allowance	c	3.1750	mm
Head External Corrosion Allowance	co	0.0000	mm
Distance from Head Centerline	L1	0.0000	mm

Type of Element Connected to the Shell : Nozzle

Material		A-516 70	
Allowable Stress at Temperature	fn	174996.00	kPa
Allowable Stress At Ambient	fna	174996.00	kPa
Diameter Basis (for tr calc only)		OD	
Layout Angle		0.00	deg
Diameter		185.0000	mm
Size and Thickness Basis		Actual	
Actual Thickness	tn	35.0000	mm
Corrosion Allowance	can	0.0000	mm
Loading Factor applied to ers/eps	C	1.00	
Outside Projection	ho	12.0000	mm
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	6.3500	mm
Inside Projection	h	12.0000	mm
Weld leg size, Inside Element to Shell	Wi	0.0000	mm
User Defined Nozzle/Shell Centerline Angle		90.0000	deg.

The Pressure Design option was Design Pressure + static head.

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



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

Isolated Nozzle Calculation per PD 5500 3.5.4, Description: Noz N1 Fr10

Actual Outside Diameter Used in Calculation	185.000	mm.
Actual Thickness Used in Calculation	35.000	mm

```
 Outside Diameter of Ellipsoidal Head                 :   408.78 mm
 Spherical Mean Diameter of Ellipsoidal Head          :   698.97 mm

 Mean Diameter of Head Skirt / 10                     :    40.04 mm
 Distance from edge of head to edge of Nozzle or pad L :   111.89 mm
```

Note: Nozzle is not too close to the edge of the head.

Nozzle input data check completed without errors.

Shell/Head required thickness due to Internal Pressure (eps)

```
  = P * D / ( 4 * fs - 0.2 * P ) + Cas  [Spherical Section]
  = 0.65 * 698.9687/( 4 * 0.2E+06 - 0.2 * 0.65 ) + 3.175 + 0.0
  = 3.8806 mm
```

Nozzle required thickness due to Internal Pressure (epb)

```
  = ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1
  = (0.65*115.0)/(2*174996.0-0.65)
  = 0.2140 + 0.0000 = 0.2140 mm
```

Per PD 5500 paragraph: 3.5.4.3.3(i) - Analysis Thickness [erb]:
Because erb > (2 - d / D) * (ers + epad)(New)
d = 150.0 and D = 695.7937 and ers = 8.335 and epad = 0.0

```
  erb(max)  =(2-d/D)*(eas+epad)=(2-150.0/695.794)*(8.335+0.0)
            = 14.8731 mm

  Actual Nozzle Thicknes (New) erb = 35.0 mm
  Calulation continued with erb(max) = 14.8731 mm
```

Mean noz dia / Mean Shl Dia d/D: 150.000 / 698.969 = 0.2146

Compute the value of Rho (use eas in place of ers) [rho]:

```
  = d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))
  = 150.0/698.97 * (698.97/( 2*( 8.34 - 3.17 + 0.0 )))½
  = 1.7661
```

Compute the ratio of C eas/eps (use eas in place of ers) [CeRatio]:

```
  = Max( C * ( eas - Cas + Tp ) /  eps, 1 )
  = Max( 1.0 * ( 8.34 - 3.17 + 0.0 )/0.71, 1 )
  = Min( 7.3127, 3.1 )
```

Note: The value of the CeRatio has been set to the maximum graph value.
Which is: 3.1

The following are the curves of rho selected for the analysis:
Values of Rho: 1.6 (Curve1), 1.766 (Computed rho), 1.8 (Curve2)

Values of erb/ers for values of rho: 1.6, 0.0, 1.8, 0.0

Note: Since the graph line for rho cuts the erb/ers = 0 line below the calculated value of Cers/eps, this nozzle is adequately compensated.

Minimum Inside Projection per 3.5.4.3.4 [Lbmin]:

```
  = sqrt( d * erb )
  = sqrt( 150.0 * 0.21 )
  = 5.7 mm
```

Minimum Nozzle Neck thickness per Table 3.5-4, mm

```
 Branch Nominal Size: 185.0000.  Min. thickness for this size: 6.2000   mm
```

Note: The minimum neck thickness chosen was to the closest table value.

3.5.4.3.4, PD 5500 Limits of Reinforcement : Case 1

```
 Effective material Diameter limit                    305.1113  mm
```

Effective material Thickness limit	Lb	5.6653	mm
Minimum Reqd Effective width adjacent to Nozzle	Ls	60.0556	mm
Thickness Limit for Nozzle Group Calculation	Tlc	12.0000	mm

The Drop for this Nozzle is : 12.6801 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 45.0151 mm

Input, Nozzle Desc: Noz N2 Fr10 From: 10

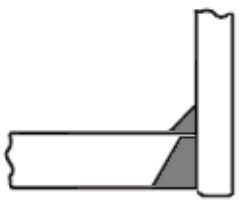
Pressure for Reinforcement Calculations	P	0.6500	N/mm²
Temperature for Internal Pressure	Temp	50	°C
Shell Material		A-234 WPB	
Shell Allowable Stress at Temperature	f	160996.33	kPa
Shell Allowable Stress At Ambient	fa	160996.33	kPa
Inside Diameter of Elliptical Head	Di	389.73	mm
Aspect Ratio of Elliptical Head	Ar	1.92	
Head Finished (Minimum) Thickness	ea	8.3350	mm
Head Internal Corrosion Allowance	c	3.1750	mm
Head External Corrosion Allowance	co	0.0000	mm
Distance from Head Centerline	L1	135.0000	mm

Type of Element Connected to the Shell : Nozzle

Material		A-105	
Allowable Stress at Temperature	fn	164996.23	kPa
Allowable Stress At Ambient	fna	164996.23	kPa
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		57.1500	mm
Size and Thickness Basis		Actual	
Actual Thickness	tn	10.3900	mm
Corrosion Allowance	can	3.1750	mm
Loading Factor applied to ers/eps	C	1.00	
Outside Projection	ho	50.8000	mm
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	6.3500	mm
Inside Projection	h	0.0000	mm
Weld leg size, Inside Element to Shell	Wi	0.0000	mm
User Defined Nozzle/Shell Centerline Angle		90.0000	deg.

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

Isolated Nozzle Calculation per PD 5500 3.5.4, Description: Noz N2 Fr10

Actual Outside Diameter Used in Calculation	57.150	mm.
Actual Thickness Used in Calculation	10.390	mm

```
 Outside Diameter of Ellipsoidal Head                 :   408.78 mm
 Spherical Mean Diameter of Ellipsoidal Head          :   698.97 mm

 Mean Diameter of Head Skirt / 10                     :    40.04 mm
 Distance from edge of head to edge of Nozzle or pad L :    43.24 mm
```

Note: Nozzle is not too close to the edge of the head.

Nozzle input data check completed without errors.

Shell/Head required thickness due to Internal Pressure (eps)

```
  = P * D / ( 4 * fs - 0.2 * P ) + Cas  [Spherical Section]
  = 0.65 * 698.9687/( 4 * 0.2E+06 - 0.2 * 0.65 ) + 3.175 + 0.0
  = 3.8806 mm
```

Nozzle required thickness due to Internal Pressure (epb)

```
  = ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1
  = (0.65*42.72)/(2*164996.23-0.65)
  = 0.0843 + 3.1750 = 3.2593 mm
```

Mean noz dia / Mean Shl Dia d/D: 49.935 / 698.969 = 0.0714

Compute the value of Rho (use eas in place of ers) [rho]:

```
  = d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))
  = 49.93/698.97 * (698.97/( 2*( 8.34 - 3.17 + 0.0 )))½
  =  0.5879
```

Compute the ratio of C eas/eps (use eas in place of ers) [CeRatio]:

```
  = Max( C * ( eas - Cas + Tp ) /  eps, 1 )
  = Max( 1.0 * ( 8.34 - 3.17 + 0.0 )/0.71, 1 )
  = Min( 7.3127, 4.0 )
```

Note: The value of the CeRatio has been set to the maximum graph value.

```
 Which is: 4.0
```

The following are the curves of rho selected for the analysis:
Values of Rho: 0.5 (Curve1), 0.588 (Computed rho), 0.6 (Curve2)

Values of erb/ers for values of rho: 0.5, 0.0, 0.6, 0.0

Note: Since the graph line for rho cuts the erb/ers = 0 line below the calculated value of Cers/eps, this nozzle is adequately compensated.

Minimum Nozzle Neck thickness per Table 3.5-4, mm

```
 Branch Nominal Size: 57.1500.  Min. thickness for this size: 6.7750   mm
```

Note: The minimum neck thickness chosen was to the closest table value.

3.5.4.3.4, PD 5500 Limits of Reinforcement : Case 1

```
 Effective material Diameter limit                    107.0850  mm
 Effective material Thickness limit             Lb      2.0519  mm
 Minimum Reqd Effective width adjacent to Nozzle Ls     24.9675  mm
 Thickness Limit for Nozzle Group Calculation   Tlc     18.9811  mm
```

The Drop for this Nozzle is : 1.1898 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 60.3248 mm

Input, Nozzle Desc: Noz N2 Fr30 From: 30

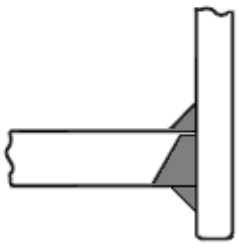
Pressure for Reinforcement Calculations	P	0.6500	N/mm²
Temperature for Internal Pressure	Temp	50	°C
Shell Material		A-234 WPB	
Shell Allowable Stress at Temperature	f	160996.33	kPa
Shell Allowable Stress At Ambient	fa	160996.33	kPa
Inside Diameter of Elliptical Head	Di	389.73	mm
Aspect Ratio of Elliptical Head	Ar	1.92	
Head Finished (Minimum) Thickness	ea	8.3350	mm
Head Internal Corrosion Allowance	c	3.1750	mm
Head External Corrosion Allowance	co	0.0000	mm
Distance from Head Centerline	L1	0.0000	mm

Type of Element Connected to the Shell : Nozzle

Material		A-516 70	
Allowable Stress at Temperature	fn	174996.00	kPa
Allowable Stress At Ambient	fna	174996.00	kPa
Diameter Basis (for tr calc only)		OD	
Layout Angle		0.00	deg
Diameter		185.0000	mm
Size and Thickness Basis		Actual	
Actual Thickness	tn	35.0000	mm
Corrosion Allowance	can	0.0000	mm
Loading Factor applied to ers/eps	C	1.00	
Outside Projection	ho	0.0000	mm
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	mm
Groove weld depth between Nozzle and Vessel	Wgnv	6.3500	mm
Inside Projection	h	66.0000	mm
Weld leg size, Inside Element to Shell	Wi	0.0000	mm
User Defined Nozzle/Shell Centerline Angle		90.0000	deg.

The Pressure Design option was Design Pressure + static head.

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



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

Isolated Nozzle Calculation per PD 5500 3.5.4, Description: Noz N2 Fr30

Actual Outside Diameter Used in Calculation	185.000	mm.
Actual Thickness Used in Calculation	35.000	mm

```
 Outside Diameter of Ellipsoidal Head                 :   408.78 mm
 Spherical Mean Diameter of Ellipsoidal Head          :   698.97 mm

 Mean Diameter of Head Skirt / 10                     :    40.04 mm
 Distance from edge of head to edge of Nozzle or pad L :   111.89 mm
```

Note: Nozzle is not too close to the edge of the head.

Nozzle input data check completed without errors.

Shell/Head required thickness due to Internal Pressure (eps)

```
  = P * D / ( 4 * fs - 0.2 * P ) + Cas  [Spherical Section]
  = 0.65 * 698.9687/( 4 * 0.2E+06 - 0.2 * 0.65 ) + 3.175 + 0.0
  = 3.8806 mm
```

Nozzle required thickness due to Internal Pressure (epb)

```
  = ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1
  = (0.65*115.0)/(2*174996.0-0.65)
  = 0.2140 + 0.0000 = 0.2140 mm
```

Per PD 5500 paragraph: 3.5.4.3.3(i) - Analysis Thickness [erb]:
Because erb > (2 - d / D) * (ers + epad)(New)
d = 150.0 and D = 695.7937 and ers = 8.335 and epad = 0.0

```
  erb(max)  =(2-d/D)*(eas+epad)=(2-150.0/695.794)*(8.335+0.0)
            = 14.8731 mm

  Actual Nozzle Thicknes (New) erb = 35.0 mm
  Calulation continued with erb(max) = 14.8731 mm
```

Mean noz dia / Mean Shl Dia d/D: 150.000 / 698.969 = 0.2146

Compute the value of Rho (use eas in place of ers) [rho]:

```
  = d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))
  = 150.0/698.97 * (698.97/( 2*( 8.34 - 3.17 + 0.0 )))½
  = 1.7661
```

Compute the ratio of C eas/eps (use eas in place of ers) [CeRatio]:

```
  = Max( C * ( eas - Cas + Tp ) /  eps, 1 )
  = Max( 1.0 * ( 8.34 - 3.17 + 0.0 )/0.71, 1 )
  = Min( 7.3127, 3.1 )
```

Note: The value of the CeRatio has been set to the maximum graph value.
Which is: 3.1

The following are the curves of rho selected for the analysis:
Values of Rho: 1.6 (Curve1), 1.766 (Computed rho), 1.8 (Curve2)

Values of erb/ers for values of rho: 1.6, 0.0, 1.8, 0.0

Note: Since the graph line for rho cuts the erb/ers = 0 line below the calculated value of Cers/eps, this nozzle is adequately compensated.

Minimum Inside Projection per 3.5.4.3.4 [Lbmin]:

```
  = sqrt( d * erb )
  = sqrt( 150.0 * 0.21 )
  = 5.7 mm
```

Minimum Nozzle Neck thickness per Table 3.5-4, mm

```
 Branch Nominal Size: 185.0000.  Min. thickness for this size: 6.2000   mm
```

Note: The minimum neck thickness chosen was to the closest table value.

3.5.4.3.4, PD 5500 Limits of Reinforcement : Case 1

```
 Effective material Diameter limit                    305.1113  mm
```

Effective material Thickness limit	Lb	0.0000	mm
Minimum Reqd Effective width adjacent to Nozzle	Ls	60.0556	mm
Thickness Limit for Nozzle Group Calculation	Tlc	0.0000	mm

The Drop for this Nozzle is : 12.6801 mm
The Cut Length for this Nozzle is, Drop + Ho + H + T : 87.0151 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 N2 Fr10	57 mm	Actual	None	57.1	10.4	...	...	60	...
Noz N1 Fr10	185 mm	Actual	None	185.0	35.0	...	...	45	...
Noz N2 Fr30	185 mm	Actual	None	185.0	35.0	...	...	87	...

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 N2 Fr10	A-105	6.350	10.000	...	...	...
Noz N1 Fr10	A-516 70	6.350	10.000	...	...	...
Noz N2 Fr30	A-516 70	6.350	10.000	...	...	...

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

Nozzle Miscellaneous Data:

Description	Elev/Distance From Datum m	Layout Angle deg	Proj Outside mm	Proj Inside mm	Installed in Component
Noz N2 Fr10	...	90.0	50.80	0.00	Node: 10
Noz N1 Fr10	...	0.0	12.00	12.00	Node: 10
Noz N2 Fr30	...	0.0	0.00	66.00	Node: 30

British Standard PD 5500:2018+A1:2018

Diameter Spec : 406.400 mm OD		
Vessel Design Length, Tangent to Tangent	1.60	m
Distance of Bottom Tangent above Grade	0.00	m
Specified Datum Line Distance	0.05	m
Shell Material	A-106 B	
Head Material	A-234 WPB	
Nozzle Material	A-516 70	
Nozzle Material	A-105	
Internal Design Temperature	50	°C
Internal Design Pressure	0.650	N/mm²
External Design Temperature	50	°C
Maximum Allowable Working Pressure	1.898	N/mm²
Hydrostatic Test Pressure	1.312	N/mm²
Wind Design Code	SANS 10160-3:2010	
Earthquake Design Code	SANS 10160-4:2010	

Element Pressures and MAWP (N/mm² & mm):

Element Description or Type	Design Pressure + Stat. head	Ext. Press.	Element M.A.W.P	Corrosion Allowance	Str. Flg. Gov.	In Creep Range
Ellipse	0.650	0.00	4.311	3.1750	No	...
Cylinder	0.650	0.00	1.898	3.1750	N/A	...
Ellipse	0.650	0.00	4.311	3.1750	No	...

Element Types and Properties:

Element Type	"To" Elev m	Element Length m	Nominal Thickness mm	Finished Thickness mm	Reqd Thk Internal mm	Reqd Thk External mm	Long Eff	Circ Eff
Ellipse	0.0	0.1	9.5	8.3	4.2	...	0.85	0.85
Cylinder	1.5	1.5	6.3	5.6	4.0	...	0.85	0.85
Ellipse	1.6	0.1	9.5	8.3	4.2	...	0.85	0.85

Loads for Foundation/Support Design:

Total Wind Shear on top of all Legs	494.	N
Total Earthquake Shear on top of all Legs	467.	N
Total Wind Moment at top of all Legs	373.	N-m
Total Earthquake Moment at top of all Legs	549.	N-m
Max. Wind Shear on one Leg (top & bottom)	247.	N
Max. Earthq. Shear on one Leg (top & bottom)	234.	N
Max. Wind Moment at base of one Leg	74.	N-m
Max. Earthquake Moment at base of one Leg	70.	N-m
Max. Vertical Load (Wt. + Wind) on one Leg	2654.	N
Max. Vertical Load (Wt. + Eq.) on one Leg	3463.	N

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

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	192.9	kgm
Shop Test	- Fabricated + Water (Full)	404.5	kgm
Shipping	- Fab. + Rem. Intls.+ Shipping App.	192.9	kgm
Erected	- Fab. + Rem. Intls.+ Insul. (etc)	192.9	kgm
Empty	- Fab. + Intls. + Details + Wghts.	192.9	kgm
Operating	- Empty + Operating Liquid (No CA)	192.9	kgm
Field Test	- Empty Weight + Water (Full)	404.5	kgm

Table of Contents

PV Elite Vessel Analysis Program: Input Data

Design Internal Pressure (for Hydrotest)		0.65	N/mm²
Design Internal Temperature		50.0	°C
Hydrotest Position		Horizontal	
Projection of Nozzle from Vessel Top		0	mm
Projection of Nozzle from Vessel Bottom		0	mm
Minimum Design Metal Temperature		-28.9	°C
Construction Category		Category 2	
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	
Consider Vortex Shedding		N	
Perform a Corroded Hydrotest		N	
Load Case 1		NP+EW+WI+FW+BW	
Load Case 2		NP+EW+EE+FS+BS	
Load Case 3		NP+OW+WI+FW+BW	
Load Case 4		NP+OW+EQ+FS+BS	
Load Case 5		NP+HW+HI	
Load Case 6		NP+HW+HE	
Load Case 7		IP+OW+WI+FW+BW	
Load Case 8		IP+OW+EQ+FS+BS	
Load Case 9		EP+OW+WI+FW+BW	
Load Case 10		EP+OW+EQ+FS+BS	
Load Case 11		HP+HW+HI	
Load Case 12		HP+HW+HE	
Load Case 13		IP+WE+EW	
Load Case 14		IP+WF+CW	
Load Case 15		IP+VO+OW	
Load Case 16		IP+VE+EW	
Load Case 17		NP+VO+OW	
Load Case 18		FS+BS+IP+OW	
Load Case 19		FS+BS+EP+OW	
Wind Design Code		ASCE-7 93	
Basic Wind Speed	[V]	31.292	m/sec
Surface Roughness Category		C: Open Terrain	
Importance Factor		1.0	
Type of Surface		Moderately Smooth	
Base Elevation		0	m
Percent Wind for Hydrotest		33.0	
Using User defined Wind Press. Vs Elev.		N	
Damping Factor (Beta) for Wind (Ope)		0.0100	
Damping Factor (Beta) for Wind (Empty)		0.0000	
Damping Factor (Beta) for Wind (Filled)		0.0000	
Seismic Design Code		UBC 94	
UBC Seismic Zone (1=1,2=2a,3=2b,4=3,5=4)		0.000	
UBC Importance Factor		1.000	
UBC Soil Type		S1	
UBC Horizontal Force Factor		3.000	
UBC Percent Seismic for Hydrotest		0.000	
Design Pressure + Static Head		Y	
Consider MAP New and Cold in Noz. Design		N	
Consider External Loads for Nozzle Des.		Y	
Use ASME VIII-1 Appendix 1-9		N	

Complete Listing of Vessel Elements and Details:

Element From Node	10	
Element To Node	20	
Element Type	Flange	
Description		
Distance "FROM" to "TO"	0.035	m
Flange Inside Diameter	73	mm
Element Thickness	35	mm
Internal Corrosion Allowance	3.175	mm
Nominal Thickness	0	mm
External Corrosion Allowance	0	mm
Design Internal Pressure	0.65	N/mm^2
Design Temperature Internal Pressure	50	°C
Design External Pressure	0	N/mm^2
Design Temperature External Pressure	50	°C
Effective Diameter Multiplier	1.2	
Material Name	A-516 70	
Allowable Stress, Ambient	174996	kPa
Allowable Stress, Operating	174996	kPa
Material Density	7750	kg/m^3
Perform Flange Stress Calculation (Y/N)	Y	
Weight of ANSI B16.5/B16.47 Flange	0	N
Class of ANSI B16.5/B16.47 Flange		
Grade of ANSI B16.5/B16.47 Flange		
Weld is pre-Heated	N/A	

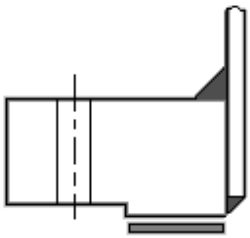
XY Coordinate Calculations:

From	To	X (Horiz.) m	Y (Vert.) m	DX (Horiz.) m	DY (Vert.) m
10	20	...	0.04135	...	0.035

Flange Input Data Values Description: FLANGE :

Item: Node 10 to 20

Description of Flange Geometry (Type)		Loose Ring	
Design Pressure	P	0.65	N/mm²
Design Temperature		50	°C
Internal Corrosion Allowance	ci	3.1750	mm
External Corrosion Allowance	ce	0.0000	mm
Use Corrosion Allowance in Thickness Calcs.		Yes	
Flange Inside Diameter	B	73.000	mm
Flange Outside Diameter	A	185.000	mm
Flange Thickness	t	35.0000	mm
Flange Material		A-516 70	
Flange Allowable Stress At Temperature	Sfo	174996.00	kPa
Flange Allowable Stress At Ambient	Sfa	174996.00	kPa
Bolt Material		42CrMo5-6	
Bolt Allowable Stress At Temperature	Sb	226994.81	kPa
Bolt Allowable Stress At Ambient	Sa	226994.81	kPa
Length of Weld Leg at Back of Ring	tw	0.0000	mm
Number of Splits in Ring Flange	n	0	
Diameter of Bolt Circle	C	145.000	mm
Nominal Bolt Diameter	db	15.8750	mm
Diameter of Bolt Hole	dh	18.8750	mm
Type of Threads		TEMA Thread Series	
Number of Bolts		8	
Flange Face Outside Diameter	Fod	122.000	mm
Flange Face Inside Diameter	Fid	73.000	mm
Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	122.000	mm
Gasket Inside Diameter	Gi	73.000	mm
Gasket Factor	m	0.0000	
Gasket Design Seating Stress	y	0.00	kPa
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	3.1750	mm



PD 5500:2018+A1:2018, Section 3.8

Corroded Flange Thickness,	tc = T-ci	31.825	mm
Code R Dimension,	R = (C-B)/2 - g1	36.000	mm
Gasket Contact Width,	N = (Go - Gi) / 2	24.500	mm
Basic Gasket Width,	bo = N / 2	12.250	mm
Effective Gasket Width,	b = Cb sqrt(bo)	8.820	mm

Gasket Reaction Diameter, G = Go (Self-Energizing) 122.000 mm

Basic Flange and Bolt Loads:

Hydrostatic End Load due to Pressure [H]:
= 0.785 * G² * Peq
= 0.785 * 122² * 0.65
= 7598.032 N
Contact Load on Gasket Surfaces [Hp]:
= 2 * b * Pi * G * m * P
= 2 * 8.82 * 3.142 * 122 * 0 * 0.65
= 0.000 N
Hydrostatic End Load at Flange ID [Hd]:
= Pi * Bcor² * P / 4
= 3.142 * 73² *0.65/4
= 2720.365 N
Pressure Force on Flange Face [Ht]:
= H - Hd
= 7598 - 2720
= 4877.667 N
Operating Bolt Load [Wm1]:
= max(H + Hg + Hr, 0)
= max(7598 + 0 + 0, 0)
= 7598.032 N
Gasket Seating Bolt Load [Wm2]:
= Pi * G * b' * y + yPart * bPart * lp
= 3.141*122*8.82*0+0*0*0
= 0.000 N
Required Bolt Area [Am]:
= Maximum of Wm1/Sb, Wm2/Sa
= Maximum of 7598/226995, 0/226995
= 0.000 m²

Bolt Spacing Correction Factor per TEMA, PD:5500 or EN-13445 [cF]:
= max(sqrt(Deltab /(2 * dB + 6 * e / (m + 0.5)); 1.0)
= max(sqrt(55.49/(2 * 15.88 + 6 * 31.83/(0 + 0.5)); 1.0)
= max(0.366 ; 1.0)
= 1

where the actual circumferential spacing is [Deltab]:
= C * sin(Pi / n)
= 145 * sin(3.142/8)
= 55.49 mm

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

	Minimum	Actual	Maximum
Bolt Area, m²	0.000	0.001	
Radial Distance between Hub and Bolts:	19.050	36.000	
Radial Distance between Bolts and Edge:	19.050	20.000	
Circ. Spacing between the Bolts:	38.100	55.489	413.650

Flange Design Bolt Load, Gasket Seating [W]:
= Sa * (Am + Ab) / 2
= 226995 * (0.33465E-04 + 0.00104)/2
= 122125.79 N
Gasket Load for the Operating Condition [HG]:
= Wm1 - H
= 7598 - 7598
= 0.00 N

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:
= (C - G) / 2
= (145 - 122)/2
= 11.5000 mm
Distance to Face Pressure Reaction [ht]:
= (hD + hG) / 2
= (36 + 11.5)/2
= 23.7500 mm
Distance to End Pressure Reaction [hd]:
= (C - Bcor)/ 2
= (145 - 73)/2
= 36.0000 mm

Summary of Moments for Internal Pressure: (N-m)

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	2720.	36.0000	1.0000	98.
Face Pressure,	Mt	4878.	23.7500	1.0000	116.
Gasket Load,	Mg	0.	11.5000	1.0000	0.
Gasket Seating,	Matm	122126.	11.5000	1.0000	1405.

Total Moment for Operation, Mop 214. N-m
Total Moment for Gasket seating, Matm 1405. N-m

Effective Hub Length, ho = 0.000 mm
Hub Ratio, h/h0 = Defined as 0.0 0.000
Thickness Ratio, g1/g0 = Defined as 0.0 0.000
Factors from Figure 2-7.1 K = 2.534
T = 1.329 U = 2.437
Y = 2.218 Z = 1.369

Tangential Flange Stress, Operating [Sto]:
= (Y * Mo)/(t² * Bcor)
= (2.218*213.9)/(31.83²*73)
= 6413.29 kPa
Tangential Flange Stress, Seating [STa]:
= (Y * Matm)/(t² * Bcor)
= (2.218*1405)/(31.83²*73)
= 42133.10 kPa

Bolt Stress, Operating [BSo]:
= Wm1 / Ab
= 7598/0.00104
= 7287.93 kPa
Bolt Stress, Seating [BSa]:
= (Wm2 / Ab)
= (0/0.00104)
= 0.00 kPa

Flange Stress Analysis Results: kPa

	Operating		Gasket Seating	
	Actual	Allowed	Actual	Allowed
Tangential Flange	6413.	174996.	42133.	174996.
Bolting	7288.	226995.	0.	226995.

Minimum Required Flange Thickness 18.796 mm
Estimated M.A.W.P. (Operating) 17.736 N/mm²
Estimated Finished Weight of Flange at given Thk. 6.2 kgm
Estimated Unfinished Weight of Forging at given Thk 6.2 kgm

Element Thickness, Pressure, Diameter and Allowable Stress :

From	To	Int. Press + Liq. Hd N/mm²	Nominal Thickness mm	Total Corr Allowance mm	Element Diameter mm	Allowable Stress(SE) kPa
10	20	0.65	...	3.175	73	174996

Element Required Thickness and MAWP :

From	To	Design Pressure N/mm²	M.A.W.P. Corroded N/mm²	M.A.P. New & Cold N/mm²	Minimum Thickness mm	Required Thickness mm
10	20	0.65	17.7361	20.2453	35	18.796
Minimum			17.736	20.245		

MAWP: 17.736 N/mm², limited by: Flange.

Internal Pressure Calculation Results :

British Standard PD 5500:2018+A1:2018

Hydrostatic Test Pressure Results:

PD:5500 5.8.5-1, Standard Test Pressure
= 1.25 * P * fa/ft * (t / (t - c)) (per 5.8.5-1)
= 1.25 * 0.65 * 1 * (35/(35 - 3.175))
= 0.894 N/mm²

PD:5500 5.8.5-1, Field Test Pressure
= 1.25 * P * fa/ft (per 5.8.5-1)
= 1.25 * 0.65 * 174996/174996
= 0.812 N/mm²

Lower Bound Test Pressure	ptL	0.894	N/mm²
Upper Bound Test Pressure	ptH	0.894	N/mm²
1.35 times the Specified Design P	1.35*Dsgprs	0.877	N/mm²

Standard Test Pressure, 0.8936 N/mm², used in table below.

Stresses on Elements due to Test Pressure (kPa):

From To	Pressure	Stress	Allowable	Ratio

Elements Suitable for Internal Pressure.

External Pressure Calculation Results :

External Pressure Calculations:

From	To	Section Length m	Outside Diameter mm	Corroded Thickness mm	Factor A	Factor B kPa
10	20	No Calc	...	31.825	No Calc	No Calc

External Pressure Calculations:

From	To	External Actual T. mm	External Required T. mm	External Design Pressure N/mm²	External M.A.W.P. N/mm²
10	20	35	18.5674	...	No Calc

External Pressure Calculations:

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

Elements Suitable for External Pressure.

British Standard PD 5500:2018+A1:2018

Element and Detail Weights:

From	To	Element Metal Wgt. kgm	Element ID Volume m³	Corroded Metal Wgt. kgm	Corroded ID Volume m³	Extra due Misc % kgm
10	20	6.15609	...	6.15609	...	...
Total		6	0.00	6	0.00	0

Weight Summation Results: (kgm)

	Fabricated	Shop Test	Shipping	Erected	Empty	Operating
Main Elements	6.2	6.2	6.2	6.2	6.2	6.2
Totals	6.2	6.2	6.2	6.2	6.2	6.2

Weight Summary:

Fabricated Wt.	- Bare Weight without Removable Internals	6.2 kgm
Shop Test Wt.	- Fabricated Weight + Water (Full)	6.2 kgm
Shipping Wt.	- Fab. Weight + removable Intls.+ Shipping App.	6.2 kgm
Erected Wt.	- Fab. Wt + or - loose items (trays,platforms etc.)	6.2 kgm
Ope. Wt. no Liq	- Fab. Weight + Internals. + Details + Weights	6.2 kgm
Operating Wt.	- Empty Weight + Operating Liq. Uncorroded	6.2 kgm
Field Test Wt.	- Empty Weight + Water (Full)	6.2 kgm
Mass of the Upper 1/3 of the Vertical Vessel		2.1 kgm

Outside Surface Areas of Elements:

From	To	Surface Area m²
10	20	0.043026
Total		0.043 m²

Element and Detail Weights:

From	To	Total Ele. Empty Wgt. kgm	Total. Ele. Oper. Wgt. kgm	Total. Ele. Hydro. Wgt. kgm	Total Dtl. Offset Mom. N-m	Oper. Wgt. No Liquid kgm
10	20	6.15609	6.15609	6.15609	...	6.15609

Cumulative Vessel Weight

From	To	Cumulative Ope Wgt. No Liquid kgm	Cumulative Oper. Wgt. kgm	Cumulative Hydro. Wgt. kgm
10	20	6.15609	6.15609	6.15609

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-m	Cumulative Oper. Mom. N-m	Cumulative Hydro. Mom. N-m
10	20	...	...	...

Shop/Field Installation Options :

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

Center of Gravity of Bare Shell New and Cold	0.024 m
Center of Gravity of Bare Shell Corroded	0.024 m
Vessel CG in the Operating Condition	0.024 m
Vessel CG in the Fabricated (Shop/Empty) Condition	0.024 m

British Standard PD 5500:2018+A1:2018

Diameter Spec : mm ID		
Vessel Design Length, Tangent to Tangent	0.04	m
Distance of Bottom Tangent above Grade	0.00	m
Distance of Base above Grade	0.00	m
Specified Datum Line Distance	0.10	m
Internal Design Temperature	50	°C
Internal Design Pressure	0.650	N/mm²
External Design Temperature	50	°C
Maximum Allowable Working Pressure	17.736	N/mm²
Hydrostatic Test Pressure	0.894	N/mm²
Wind Design Code	ASCE-93	
Earthquake Design Code	UBC-94	

Element Pressures and MAWP (N/mm² & mm):

Element Description or Type	Design Pressure + Stat. head	Ext. Press.	Element M.A.W.P	Corrosion Allowance	Str. Flg. Gov.	In Creep Range
Body Flg	0.650	0.00	17.736	3.1750	N/A	...

Element Types and Properties:

Element Type	"To" Elev m	Element Length m	Nominal Thickness mm	Finished Thickness mm	Reqd Thk Internal mm	Reqd Thk External mm	Long Eff	Circ Eff
Body Flg	-0.1	0.0	...	35.0	18.8	18.6	1.00	1.00

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

Weights:

Fabricated	- Bare W/O Removable Internals	6.2	kgm
Shop Test	- Fabricated + Water (Full)	6.2	kgm
Shipping	- Fab. + Rem. Intls.+ Shipping App.	6.2	kgm
Erected	- Fab. + Rem. Intls.+ Insul. (etc)	6.2	kgm
Empty	- Fab. + Intls. + Details + Wghts.	6.2	kgm
Operating	- Empty + Operating Liquid (No CA)	6.2	kgm
Field Test	- Empty Weight + Water (Full)	6.2	kgm