XGM CONSULTING ENGINEERS

STRESS CALCULATION OF GATTI ICE CREAM 750 HEAT EXCHANGER

ACCORDING TO PD5500 2018

DOCUMENT No. DC_2019-30-01

DRAWING No. 2019-30-01

REPORT PREPARED FOR: CLAWS ENGINEERING

COMPILED BY: LE GREEN (PrTechEng)

TÜV Rheinland
TUV JOB NO: 52070938
DATE: 15/01/20 SIGN:
STATUS: A ☒ B ☐ C ☐ I/O ☐
ACTIVITY: DESIGN ☒ DESIGN REF: XG-ZN-04-12-19-1
WELDING ☐ QA/WELDING REF:
A - PROCEED B- PROCEED, CHANGE AS NOTED & RESUBMIT
C - DO NOT PROCEED, CHANGE AS NOTED & RESUBMIT
I/O - NOT REVIEWED, FOR INFORMATION ONLY
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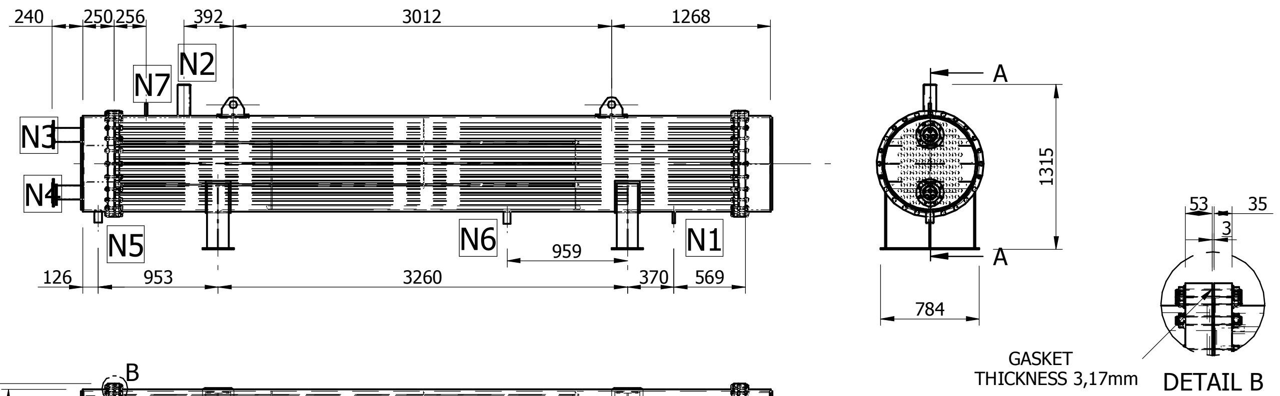
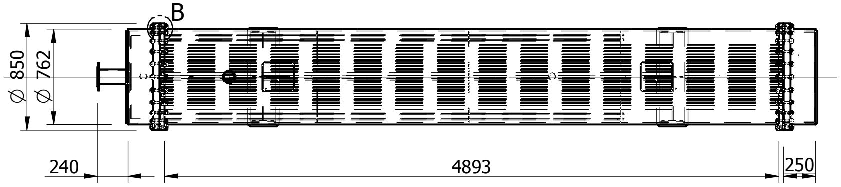
DATE: 18 DECEMBER 2019



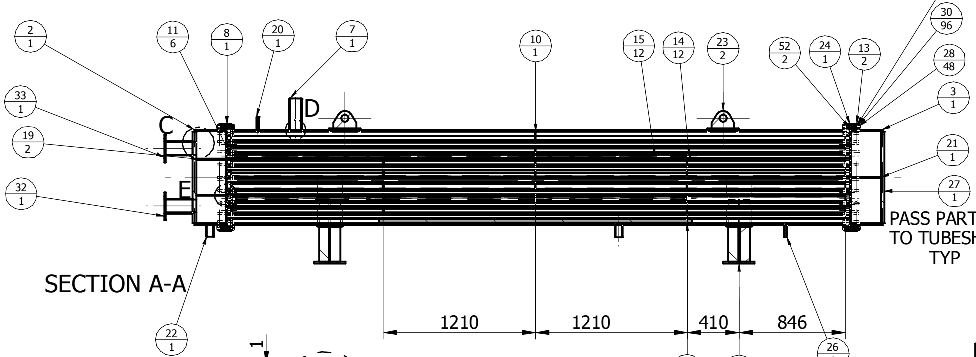


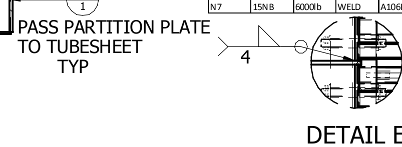
Item Number	Title	Quantity
1	Pipe_750NB_Sch30_4890mm_A 106B/ API 5LB	1
2	Pipe_750NB_Sch30_250mm_A 106B/ API 5LB	1
3	Pipe_750NB_Sch30_250mm_A 106B/ API 5LB	1
4	SADDLE_P355GH	2
7	N2 AMMONIA OUTLET NOZZLE_4"(100NB)_3000lb_A106B	1
8	TUBESHEET 35mm THK_LEFT SIDE_A-516 70	1
9*	BAFFLE BOTTOM PLATE_A-516 70	2
10*	BAFFLE TOP PLATE_A-516 70	1
11*	M10 TIE ROD_3660mm_BMS	6
12*	TUBE_OD 33.4_BWG 11_wt 3.38_4993mm_A-516 70	136
13	750mm BODY FLANGE_A516 Gr 70	2
14*	M10 HEX NUT	12
15*	SPACER_10NB OD17.2 WT 2.87_1204mm_A 106	12
16*	SPACER_10NB OD17.2 WT 2.87_1200mm_A 106	6
17*	BAFFLE STIFFENERS_SABS 62	1
18*	WELDED FLAT HEAD_PLATE 30mm THK OD 729mm_P355 NH	1
19*	PASS PARTITION PLATE LEFT_662x217x6mm_A-516 70	2
20	N7 PRESSURE GAUGE HALF COUPLING 1/2"_6000lb_A106B	1
21*	PASS PARTITION PLATE RIGHT_727x257x6mm_A-516 70	1
22	N5 TUBE SIDE DRAIN + PLUG_2"(50NB)_3000lb_A106B	1
23	LIFTING LUG_P355GH	2
24	TUBESHEET 35mm THK_RIGHT SIDE OD 850mm_A-516 70	1
26*	N1 AMMONIA INLET COUPLING_1 1/4" (32NB)_3000lb_A106B	1
27*	WELDED FLAT HEAD_PLATE 30mm THK OD 729mm_P355 NH	1
28	STUD BOLT M16 x 135mm_SA 193-B7	48
29	Washer M16	96
30	M16 NUT_SA 193-B7	96
31*	GASKET_OD790xID762_3.17mm_SF 5000 COMPRESSED FIBRE SHEET GASKET CARBON ARAMID NBR	2
32	N4 BRINE OUTLET_4"(100NB)-SCH120_A106B	1
33	N3 BRINE INLET_4"(100NB)-SCH120_A106B	1
34	N6 SHELL SIDE DRAIN + PLUG 2"(50NB)_3000lb_A106B	1

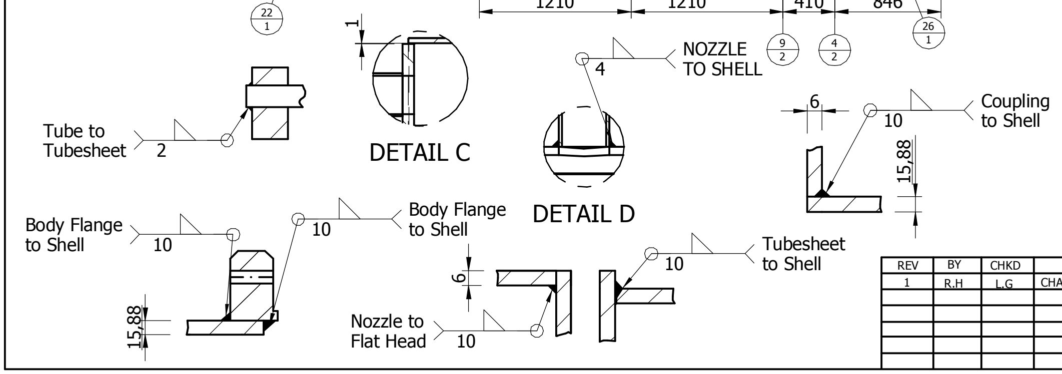
INSPECTION AUTHORITY	ZANGULA	
DESIGN CODE	PD5500 2018 CATEGORY III	
HAZARD CATEGORY (SANS 347)	III	
RADIOGRAPHY	NO	
DESIGN DATA		
	SHELL SIDE	**TUBE SIDE**
OPERATING PRESSURE kPa	1200	900
DESIGN PRESSURE kPa	1300	1000
HYDRAULIC TEST PRESSURE KPa	1950	1500
TEST PROCEDURE	HYDRAULIC	HYDRAULIC
DESIGN FLOW m3/s		
DESIGN TEMPERATURE MAX (deg C)	35	35
DESIGN TEMPERATURE MIN (deg C)	-40	-40
CORROSION ALLOWANCE (mm)	3.25	0
CUBIC CAPACITY m3	9.5	
MEDIUM	AMMONIA	BRINE
PWHT	NO	NO

NOZZLE SCHEDULE

	SIZE	RATING		MATERIAL		QTY
N1	32NB	3000 lb	WELD	A106B	AMMONIA INLET	1
N2	100NB	3000 lb	WELD	A106B	AMMONIA OUTLET	1
N3	100NB	SCH120	WELD	A106B	BRINE INLET	1
N4	100NB	SCH120	WELD	A106B	BRINE OUTLET	1
N5	50NB	3000 lb	WELD	A106B	TS DRAIN+PLUG	1
N6	50NB	3000 lb	WELD	A106B	SS DRAIN+PLUG	1
N7	15NB	6000lb	WELD	A106B	PRESURE GAUGE	1



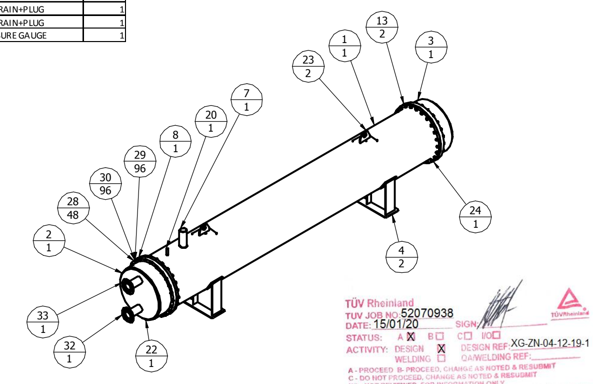




VESSEL DESIGNED ACCORDING
TO PD5500 2018 CATIII

CONFORMITY ASSESMENT
MODULE: B+C1

LESLIE GREEN (PrTechEng)
201470145



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REV	BY	CHKD	REVISION DESCRIPTION
1	R.H	L.G	CHANNELS BROUGHT TO 250mm

XGM Consulting Engineers
UNIT E9 CENTURY SQUARE
CENCURY CITY

	NAME	DATE
CHECKED	L.G	18-12-19
DRAWN	R.H	18-12-19
ENG APPR	L.G	

TITLE: SHELL AND HEAT EXCHANGER

SIZE A1 — FOR APPROVAL — REV 1

DWG No.2019-30-01

SCALE: WEIGHT:

HEAT EXCHANGER NAMEPLATE					
TAG NUMBER			RADIOGRAPHY	SPOT	%
VESSEL TYPE	HEAT EXCHANGER		CAPACITY	9.5	m^3
SERIAL NO	CLA-HE-001		HAZARD CAT. (SANS 347)	III	
DESIGN CODE	PD5500: 2018		MEDIUM	AMMONIA/BRINE	
COUNTRY OF ORIGIN	SOUTH AFRICA		FILL WEIGHT (CONTENT)	3900	kg
	SHELL SIDE	TUBE SIDE	HYDRO TEST DATE		
OPERATING PRESSURE kPa	1200	900	INSPECTION AUTHORITY	TUV RHEINLAND	
DESIGN PRESSURE kPa	1300	1000	INSPECTION DATE		
HYDRO TEST PRESSURE kPa	1950	1500	INSPECTION AUTH. STAMP		
CORROSION ALLOWANCE	NIL	NIL	OPERATING TEMPERATURE	-40 °C	
MIN / MAX DESIGN TEMP °C	-40 / 35	-40 / 35	MANUFACTURER	CLAWS/2019	

VESSEL DESIGNED ACCORDING TO PD5500: 2018

LESLIE GREEN (PrTechEng)

201470150

CONFORMITY ASSESMENT MODULE A1

NOTES:

1. HEIGHT OF ALL LETTERS TO BE 3 MM
2. FOR ALL LETTERS USE "ARIAL NARROW" FONT
3. FINAL ENGRAVING DETAIL FOR THE SPECIFIC VESSEL WILL BE SUPPLIED WITH REQUEST OF QUOTATION
4. TO BE STAMPED ON COMPLETION OF HYDRO TEST

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TITLE: Name Plate_HEAT EXCHANGER				DOCUMENT TYPE: Detail part drawing	REVISION: 1.00
	NAME	SIGNATURE	DATE	DWG NO. 300-2019-GIC-S&T_001	
DRAWN	R.H	L.G	2019-06-26		
CHK'D	L.G	L.G			
APPV'D	L.G	L.G		MATERIAL:	
		GATTI ICE CREAM SHELL & TUBE HE SCALE:1:1		Page size: A3	SHEET 1 OF 1

PV Elite Vessel Analysis Program: Input Data

Exchanger Design Pressures and Temperatures

Shell Side Design Pressure	1.3000	N/mm²
Channel Side Design Pressure	1.0000	N/mm²
Shell Side Design Temperature	-40	°C
Channel Side Design Temperature	-40	°C

Hydrotest Position	Horizontal	
Projection of Nozzle from Vessel Top	0.0000	mm
Projection of Nozzle from Vessel Bottom	0.0000	mm
Miscellaneous Weight Percent	0.0	
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	Y	
Perform a Corroded Hydrotest	Y	
Is this a Heat Exchanger	No	
User Defined Hydro. Press. (Used if > 0)	0.0000	N/mm²
User defined MAWP	0.0000	N/mm²
User defined MAPnc	0.0000	N/mm²

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		0.0000	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 Nozzle for Des. Press. + St. 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	Flat	
Description	Left Head	
Distance "FROM" to "TO"	0.03000	m
Element Outside Diameter	734.00	mm
Element Thickness	30.000	mm
Internal Corrosion Allowance	3.1750	mm
Nominal Thickness	30.000	mm
External Corrosion Allowance	0.0000	mm
Design Internal Pressure	1.0000	N/mm^2
Design Temperature Internal Pressure	-40	°C
Design External Pressure	0.1030	N/mm^2
Design Temperature External Pressure	0	°C
Effective Diameter Multiplier	1.2	
Material Name	P355NH	
Allowable Stress, Ambient	191485.	kPa
Allowable Stress, Operating	191485.	kPa
Material Density	7810.0	kg/m^3
Flat Head Attachment Factor	0.41	
Small diameter if Non-Circular	0.0000	mm

Element From Node	10	
Detail Type	Nozzle	
Detail ID	Noz N1 Fr10	
Dist. from "FROM" Node / Offset dist	200.00	mm
Nozzle Diameter	100.0	mm
Nozzle Schedule	120	
Nozzle Class	150	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.0000	N
Grade of Attached Flange	GR 1.1	
Nozzle Matl	A-106 B	

Element From Node	10	
Detail Type	Nozzle	
Detail ID	Noz N2 Fr10	
Dist. from "FROM" Node / Offset dist	200.00	mm
Nozzle Diameter	100.0	mm
Nozzle Schedule	120	
Nozzle Class	150	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	461.84	N
Grade of Attached Flange	GR 1.1	
Nozzle Matl	A-106 B	

Element From Node	20	
Element To Node	30	
Element Type	Cylinder	
Description	Left Channel Shell	
Distance "FROM" to "TO"	0.2500	m
Element Outside Diameter	762.00	mm
Element Thickness	13.891	mm
Internal Corrosion Allowance	3.1750	mm
Nominal Thickness	13.896	mm
External Corrosion Allowance	0.0000	mm
Design Internal Pressure	1.0000	N/mm²
Design Temperature Internal Pressure	-40	°C
Design External Pressure	0.1030	N/mm²
Design Temperature External Pressure	35	°C
Effective Diameter Multiplier	1.2	
Material Name	A-106 B	
Allowable Stress, Ambient	159996.	kPa
Allowable Stress, Operating	159996.	kPa
Material Density	7810.0	kg/m³

Element From Node	20	
Detail Type	Nozzle	
Detail ID	Noz N1 Fr20	
Dist. from "FROM" Node / Offset dist	0.1400	m
Nozzle Diameter	76.199997	mm
Nozzle Schedule	None	
Nozzle Class	None	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.0000	N
Grade of Attached Flange	None	
Nozzle Matl	A-106 B	

Element From Node	30	
Element To Node	40	
Element Type	Flange	
Description	Flange 30	
Distance "FROM" to "TO"	0.05500	m
Flange Inside Diameter	0.0000	mm
Element Thickness	55.000	mm
Internal Corrosion Allowance	3.1750	mm
Nominal Thickness	0.0000	mm
External Corrosion Allowance	0.0000	mm
Design Internal Pressure	1.0000	N/mm^2
Design Temperature Internal Pressure	-40	°C
Design External Pressure	0.1030	N/mm^2
Design Temperature External Pressure	-40	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	
Allowable Stress, Ambient	153188.	kPa
Allowable Stress, Operating	153188.	kPa
Material Density	7840.0	kg/m^3
Perform Flange Stress Calculation (Y/N)	Y	
Weight of ANSI B16.5/B16.47 Flange	0.0000	N

Class of ANSI B16.5/B16.47 Flange

Grade of ANSI B16.5/B16.47 Flange

Element From Node	40	
Element To Node	50	
Element Type	Cylinder	
Description	Main Shell	
Distance "FROM" to "TO"	4.8400	m
Element Outside Diameter	762.00	mm
Element Thickness	13.891	mm
Internal Corrosion Allowance	3.1750	mm
Nominal Thickness	13.896	mm
External Corrosion Allowance	0.0000	mm
Design Internal Pressure	1.3000	N/mm²
Design Temperature Internal Pressure	-40	°C
Design External Pressure	0.1030	N/mm²
Design Temperature External Pressure	-40	°C
Effective Diameter Multiplier	1.2	
Material Name	A-106 B	
Allowable Stress, Ambient	159996.	kPa
Allowable Stress, Operating	159996.	kPa
Material Density	7810.0	kg/m³

Element From Node	40	
Detail Type	Saddle	
Detail ID	New Sdl	
Dist. from "FROM" Node / Offset dist	4.2000	m
Width of Saddle	204.00	mm
Height of Saddle at Bottom	572.00	mm
Saddle Contact Angle	120.0	
Height of Composite Ring Stiffener	0.0000	mm
Width of Wear Plate	306.00	mm
Thickness of Wear Plate	10.000	mm
Contact Angle, Wear Plate (degrees)	132.0	

Element From Node	40	
Detail Type	Saddle	
Detail ID	Sdl 2 Fr40	
Dist. from "FROM" Node / Offset dist	0.7000	m
Width of Saddle	204.00	mm
Height of Saddle at Bottom	572.00	mm
Saddle Contact Angle	120.0	
Height of Composite Ring Stiffener	0.0000	mm
Width of Wear Plate	306.00	mm
Thickness of Wear Plate	10.000	mm
Contact Angle, Wear Plate (degrees)	132.0	

Element From Node	40	
Detail Type	Nozzle	
Detail ID	Noz N1 Fr40	
Dist. from "FROM" Node / Offset dist	0.2000	m
Nozzle Diameter	139.7	mm
Nozzle Schedule	None	
Nozzle Class	None	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	279.80	N
Grade of Attached Flange	None	
Nozzle Matl	A-106 B	

Element From Node	40	
Detail Type	Nozzle	
Detail ID	Noz N2 Fr40	
Dist. from "FROM" Node / Offset dist	0.4500	m
Nozzle Diameter	38.099998	mm
Nozzle Schedule	None	
Nozzle Class	None	
Layout Angle	90.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.0000	N

Grade of Attached Flange	None	
Nozzle Matl	A-106 B	

Element From Node	40	
Detail Type	Nozzle	
Detail ID	Noz N3 Fr40	
Dist. from "FROM" Node / Offset dist	2.5000	m
Nozzle Diameter	76.199997	mm
Nozzle Schedule	None	
Nozzle Class	None	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.0000	N
Grade of Attached Flange	None	
Nozzle Matl	A-106 B	

Element From Node	40	
Detail Type	Nozzle	
Detail ID	Noz N4 Fr40	
Dist. from "FROM" Node / Offset dist	4.5500	m
Nozzle Diameter	57.150002	mm
Nozzle Schedule	None	
Nozzle Class	None	
Layout Angle	270.0	
Blind Flange (Y/N)	N	
Weight of Nozzle (Used if > 0)	0.0000	N
Grade of Attached Flange	None	
Nozzle Matl	A-106 B	

Element From Node	50	
Element To Node	60	
Element Type	Flange	
Description	Flange 50	
Distance "FROM" to "TO"	0.05500	m

Flange Inside Diameter	748.13	mm
Element Thickness	55.000	mm
Internal Corrosion Allowance	3.1750	mm
Nominal Thickness	0.0000	mm
External Corrosion Allowance	0.0000	mm
Design Internal Pressure	1.0000	N/mm²
Design Temperature Internal Pressure	40	°C
Design External Pressure	0.1030	N/mm²
Design Temperature External Pressure	35	°C
Effective Diameter Multiplier	1.2	
Material Name	SA-516 70	
Allowable Stress, Ambient	153188.	kPa
Allowable Stress, Operating	153188.	kPa
Material Density	7840.0	kg/m³
Perform Flange Stress Calculation (Y/N)	Y	
Weight of ANSI B16.5/B16.47 Flange	0.0000	N
Class of ANSI B16.5/B16.47 Flange		
Grade of ANSI B16.5/B16.47 Flange		

Element From Node	60	
Element To Node	70	
Element Type	Cylinder	
Description	Right Channel	
Distance "FROM" to "TO"	0.2500	m
Element Outside Diameter	762.00	mm
Element Thickness	13.891	mm
Internal Corrosion Allowance	3.1750	mm
Nominal Thickness	13.896	mm
External Corrosion Allowance	0.0000	mm
Design Internal Pressure	1.0000	N/mm²
Design Temperature Internal Pressure	-40	°C
Design External Pressure	0.1030	N/mm²
Design Temperature External Pressure	-40	°C
Effective Diameter Multiplier	1.2	

Material Name	A-106 B	
Allowable Stress, Ambient	159996.	kPa
Allowable Stress, Operating	159996.	kPa
Material Density	7810.0	kg/m³

Element From Node	70	
Element To Node	80	
Element Type	Flat	
Description	Right head	
Distance "FROM" to "TO"	0.03000	m
Element Outside Diameter	733.00	mm
Element Thickness	30.000	mm
Internal Corrosion Allowance	3.1750	mm
Nominal Thickness	30.000	mm
External Corrosion Allowance	0.0000	mm
Design Internal Pressure	1.0000	N/mm²
Design Temperature Internal Pressure	-40	°C
Design External Pressure	0.1030	N/mm²
Design Temperature External Pressure	-40	°C
Effective Diameter Multiplier	1.2	
Material Name	P355NH	
Allowable Stress, Ambient	191485.	kPa
Allowable Stress, Operating	191485.	kPa
Material Density	7810.0	kg/m³
Flat Head Attachment Factor	0.41	
Small diameter if Non-Circular	0.0000	mm

XY Coordinate Calculations

From	To	X (Horiz.) m	Y (Vert.) m	DX (Horiz.) m	DY (Vert.) m
Left Head		0.030000	...	0.030000	...
Left Chann		0.28000	...	0.25000	...
Flange 30		0.28000	...	-0.055000	...
Main Shell		5.15600	...	4.84000	...
Flange 50		5.24700	...	0.055000	...
Right Chan		5.44200	...	0.25000	...
Right head		5.47200	...	0.030000	...

Flange Input Data Values Description: New Flange :

Flange 30

Description of Flange Geometry (Type)		Integral Ring	
Design Pressure	P	1.00	N/mm²
Design Temperature		-40	°C
Internal Corrosion Allowance	ci	3.1750	mm
External Corrosion Allowance	ce	0.0000	mm
Use Corrosion Allowance in Thickness Calcs.		No	
Attached Shell Inside Diameter	B	762.0000	mm
Integral Ring Inside Diameter		789.7920	mm
Flange Outside Diameter	A	850.000	mm
Flange Thickness	t	55.0000	mm
Flange Material		SA-516 70	
Flange Allowable Stress At Temperature	Sfo	153188.00	kPa
Flange Allowable Stress At Ambient	Sfa	153188.00	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	810.000	mm
Nominal Bolt Diameter	db	16.0000	mm
Diameter of Bolt Hole	dh	19.0000	mm
Type of Threads		TEMA Metric	
Number of Bolts		24	
Flange Face Outside Diameter	Fod	790.000	mm
Flange Face Inside Diameter	Fid	762.000	mm

Flange Facing Sketch		1, Code Sketch 1a	
Gasket Outside Diameter	Go	790.000	mm
Gasket Inside Diameter	Gi	762.000	mm
Gasket Factor	m	3.7000	
Gasket Design Seating Stress	y	22993.50	kPa
Column for Gasket Seating		2, Code Column II	
Gasket Thickness	tg	3.1750	mm

PD 5500:2018

Corroded Flange ID,	Bcor = B+2*Fcor	768.350	mm
Corroded Large Hub,	g1Cor = g1-ci	0.000	mm
Corroded Small Hub,	g0Cor = go-ci	0.000	mm
Code R Dimension,	R = ((C-Bcor)/2)-g1cor	20.825	mm
Gasket Contact Width,	N = (Go - Gi) / 2	10.825	mm
Basic Gasket Width,	bo = N / 2	5.413	mm
Effective Gasket Width,	b = bo	5.413	mm
Gasket Reaction Diameter,	G = (Go + Gi) / 2	776.000	mm

<u>Basic Flange and Bolt Loads:</u>

Hydrostatic End Load due to Pressure [H]:

= 0.785 * G^2 * Peq

= 0.785 * 776.0000^2 * 1.000

= 472907.719 N

Contact Load on Gasket Surfaces [Hp]:

= 2 * b * Pi * G * m * P

= 2 * 5.4125 * 3.1416 * 776.0000 * 3.7000 * 1.00

= 97634.875 N

Hydrostatic End Load at Flange ID [Hd]:

= Pi * $Bcor^2$ * P / 4

= 3.1416 * 768.3500^2 *1.0000/4

= 463629.562 N

Pressure Force on Flange Face [Ht]:

```
= H - Hd

= 472907 - 463629

= 9278.146 N
```

Operating Bolt Load [Wm1]:

```
= max( H + Hg + Hr, 0 )

= max( 472907 + 97634 + 0 , 0 )

= 570542.562 N
```

Gasket Seating Bolt Load [Wm2]:

```
= Pi * G * b' * y + yPart * bPart * lp

= 3.141*776.00*5.4125*22993.500+0.00*0.0000*0.00

= 303391.656 N
```

Required Bolt Area [Am]:

```
= Maximum of Wm1/Sb, Wm2/Sa

= Maximum of 570542/226994 , 303391/226994

= 0.003 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( 105.726/(2 * 16.000 + 6 * 55.000/(3.700 + 0.5)); 1.0 )

= max( 0.9778 ; 1.0 )

= 1.0000
```

where the actual circumferential spacing is [Deltab]:

```
= C * sin( Pi / n ) )

= 810.000 * sin( 3.142/24 )

= 105.7262 mm
```

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

```
Distance Across Corners for Nuts                          31.180  mm

Circular Wrench End Diameter                      a        0.000  mm

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

                                           Minimum    Actual     Maximum

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

Bolt Area, m²                               0.003      0.003

Radial distance bet. hub and bolts         20.640     24.000
```

```
Radial distance bet. bolts and the edge     20.640     20.000

 Circumferential spacing between bolts       44.450    105.726    110.571

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

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:

```
  = Ab * Sa/( y * Pi * (Go + Gi) )
  = 0.003 * 226994.81/(22993.50 * 3.14 * (790.000 + 762.00 ) )
  = 6.722 mm
```

Flange Design Bolt Load, Gasket Seating [W]:

```
  = Sa * Ab
  = 226994.81 * 0.0033
  = 753551.69 N
```

Gasket Load for the Operating Condition [HG]:

```
  = Wm1 - H
  = 570542 - 472907
  = 97634.88 N
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
  = (C - G ) / 2
  = ( 810.0000 - 776.0000 )/2
  = 17.0000 mm
```

Distance to Face Pressure Reaction [ht]:

```
  = ( R + g1 + hg ) / 2
  = ( 20.8250 + 0.0000 + 17.0000 )/2
  = 18.9125 mm
```

Distance to End Pressure Reaction [hd]:

```
  = R + ( g1 / 2 )
  = 20.8250 + ( 0.0000/2.0 )
  = 20.8250 mm
```

Summary of Moments for Internal Pressure:

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	463630.	20.8250	1.0000	9659. N-m
Face Pressure,	Mt	9278.	18.9125	1.0000	176. N-m

Gasket Load, Mg	97635.	17.0000	1.0000	1660.	N-m
Gasket Seating, Matm	753552.	17.0000	1.0000	12816.	N-m

```
Total Moment for Operation,      Mop                  11495. N-m
Total Moment for Gasket seating, Matm                 12816. 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 =       1.106
                    T =      1.875           U =      21.090
                    Y =     19.192           Z =       9.936
```

Tangential Flange Stress, Operating [Sto]:

= (Y * Mo)/(t^2 * Bcor)

= (19.1918*11495)/(55.0000^2*768.3500)

= 94880.33 kPa

Tangential Flange Stress, Seating [STa]:

= (Y * Matm)/(t^2 * Bcor)

= (19.1918*12815)/(55.0000^2*768.3500)

= 105780.27 kPa

Bolt Stress, Operating [BSo]:

= (Wm1 / Ab)

= (570542/0.0033)

= 171866.41 kPa

Bolt Stress, Seating [BSa]:

= (Wm2 / Ab)

= (303391/0.0033)

= 91391.66 kPa

Flange Stress Analysis Results:

	Operating		Gasket Seating		
	Actual	Allowed	Actual	Allowed	
Tangential Flange	94880.	153188.	105780.	153188.	kPa

Bolting	171866.	226995.	91392.	226995.	kPa

Minimum Required Flange Thickness	46.533	mm
Estimated M.A.W.P. (Operating)	1.321	N/mm^2
Estimated Finished Weight of Flange at given Thk.	48.0	kgm
Estimated Unfinished Weight of Forging at given Thk	48.0	kgm

Flange Input Data Values Description: FLANGE :

Flange 50

Description of Flange Geometry (Type)		Integral	Ring
Design Pressure	P	1.00	N/mm²
Design Temperature		40	°C
Internal Corrosion Allowance	ci	3.1750	mm
External Corrosion Allowance	ce	0.0000	mm
Use Corrosion Allowance in Thickness Calcs.		No	
Attached Shell Inside Diameter	B	762.0000	mm
Integral Ring Inside Diameter		789.7920	mm
Flange Outside Diameter	A	850.000	mm
Flange Thickness	t	55.0000	mm
Flange Material		SA-516 70	
Flange Allowable Stress At Temperature	Sfo	153187.98	kPa
Flange Allowable Stress At Ambient	Sfa	153187.98	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	810.000	mm
Nominal Bolt Diameter	db	16.0000	mm
Diameter of Bolt Hole	dh	19.0000	mm
Type of Threads		TEMA Metric	
Number of Bolts		24	
Flange Face Outside Diameter	Fod	790.000	mm
Flange Face Inside Diameter	Fid	762.000	mm

```
 Flange Facing Sketch                        1, Code Sketch 1a


 Gasket Outside Diameter                   Go         790.000  mm

 Gasket Inside Diameter                    Gi         762.000  mm

 Gasket Factor                              m          3.7000

 Gasket Design Seating Stress               y        22993.50  kPa


 Column for Gasket Seating                  2, Code Column II

 Gasket Thickness                          tg          3.1750  mm
```

PD 5500:2018

```
 Corroded Flange ID,      Bcor = B+2*Fcor                768.350  mm

 Corroded Large Hub,     g1Cor = g1-ci                     0.000  mm

 Corroded Small Hub,     g0Cor = go-ci                     0.000  mm

 Code R Dimension,           R = ((C-Bcor)/2)-g1cor       20.825  mm


 Gasket Contact Width,       N = (Go - Gi) / 2            10.825  mm

 Basic Gasket Width,        bo = N / 2                     5.413  mm

 Effective Gasket Width,     b = bo                        5.413  mm

 Gasket Reaction Diameter,   G = (Go + Gi) / 2           776.000  mm
```

<u>Basic Flange and Bolt Loads:</u>

Hydrostatic End Load due to Pressure [H]:

```
  = 0.785 * G² * Peq

  = 0.785 * 776.0000² * 1.000

  = 472907.719 N
```

Contact Load on Gasket Surfaces [Hp]:

```
  = 2 * b * Pi * G * m * P

  = 2 * 5.4125 * 3.1416 * 776.0000 * 3.7000 * 1.00

  = 97634.875 N
```

Hydrostatic End Load at Flange ID [Hd]:

```
  = Pi * Bcor² * P  / 4

  = 3.1416 * 768.3500² *1.0000/4

  = 463629.562 N
```

Pressure Force on Flange Face [Ht]:

```
  = H - Hd
  = 472907 - 463629
  = 9278.146 N
```

Operating Bolt Load [Wm1]:

```
  = max( H + Hg + Hr, 0 )
  = max( 472907 + 97634 + 0 , 0 )
  = 570542.562 N
```

Gasket Seating Bolt Load [Wm2]:

```
  = Pi * G * b' * y + yPart * bPart * lp
  = 3.141*776.00*5.4125*22993.500+0.00*0.0000*0.00
  = 303391.656 N
```

Required Bolt Area [Am]:

```
  = Maximum of Wm1/Sb, Wm2/Sa
  = Maximum of 570542/226994 , 303391/226994
  = 0.003 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( 105.726/(2 * 16.000 + 6 * 55.000/(3.700 + 0.5)); 1.0 )
  = max( 0.9778 ; 1.0 )
  = 1.0000
```

where the actual circumferential spacing is [Deltab]:

```
  = C * sin( Pi / n ) )
  = 810.000 * sin( 3.142/24 )
  = 105.7262 mm
```

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

Distance Across Corners for Nuts		31.180	mm
Circular Wrench End Diameter	a	0.000	mm

	Minimum	Actual	Maximum
Bolt Area, m²	0.003	0.003	
Radial distance bet. hub and bolts	20.640	24.000	

```
Radial distance bet. bolts and the edge      20.640     20.000

 Circumferential spacing between bolts       44.450     105.726     110.571

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

Min. Gasket Contact Width (Brownell Young) [Not an ASME Calc] [Nmin]:

```
  = Ab * Sa/( y * Pi * (Go + Gi) )
  = 0.003 * 226994.81/(22993.50 * 3.14 * (790.000 + 762.00 ) )
  = 6.722 mm
```

Flange Design Bolt Load, Gasket Seating [W]:

```
  = Sa * Ab
  = 226994.81 * 0.0033
  = 753551.69 N
```

Gasket Load for the Operating Condition [HG]:

```
  = Wm1 - H
  = 570542 - 472907
  = 97634.88 N
```

Moment Arm Calculations:

Distance to Gasket Load Reaction [hg]:

```
  = (C - G ) / 2
  = ( 810.0000 - 776.0000 )/2
  = 17.0000 mm
```

Distance to Face Pressure Reaction [ht]:

```
  = ( R + g1 + hg ) / 2
  = ( 20.8250 + 0.0000 + 17.0000 )/2
  = 18.9125 mm
```

Distance to End Pressure Reaction [hd]:

```
  = R + ( g1 / 2 )
  = 20.8250 + ( 0.0000/2.0 )
  = 20.8250 mm
```

Summary of Moments for Internal Pressure:

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	463630.	20.8250	1.0000	9659. N-m
Face Pressure,	Mt	9278.	18.9125	1.0000	176. N-m

Gasket Load,	Mg	97635.	17.0000	1.0000	1660. N-m
Gasket Seating,	Matm	753552.	17.0000	1.0000	12816. N-m

Total Moment for Operation, Mop 11495. N-m

Total Moment for Gasket seating, Matm 12816. 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 = 1.106

T = 1.875 U = 21.090

Y = 19.192 Z = 9.936

Tangential Flange Stress, Operating [Sto]:

= (Y * Mo)/(t² * Bcor)

= (19.1918*11495)/(55.0000²*768.3500)

= 94880.33 kPa

Tangential Flange Stress, Seating [STa]:

= (Y * Matm)/(t² * Bcor)

= (19.1918*12815)/(55.0000²*768.3500)

= 105780.27 kPa

Bolt Stress, Operating [BSo]:

= (Wm1 / Ab)

= (570542/0.0033)

= 171866.41 kPa

Bolt Stress, Seating [BSa]:

= (Wm2 / Ab)

= (303391/0.0033)

= 91391.66 kPa

Flange Stress Analysis Results:

	Operating		Gasket Seating		
	Actual	Allowed	Actual	Allowed	
Tangential Flange	94880.	153188.	105780.	153188.	kPa

```
Bolting                171866.   226995.    91392.   226995. kPa
---------------------------------------------------------------------


Minimum Required Flange Thickness                    46.533  mm

Estimated M.A.W.P. ( Operating )                      1.321  N/mm²

Estimated Finished Weight of Flange at given Thk.      48.0  kgm

Estimated Unfinished Weight of Forging at given Thk    48.0  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
Left Head		1.0000	30.000	3.1750	734.00	191485.
Left Chann		1.0000	13.896	3.1750	762.00	159996.
Flange 30		1.0000	...	3.1750	...	153188.
Main Shell		1.3000	13.896	3.1750	762.00	159996.
Flange 50		1.0000	...	3.1750	748.13	153188.
Right Chan		1.0000	13.896	3.1750	762.00	159996.
Right head		1.0000	30.000	3.1750	733.00	191485.

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
Left Head		1.00000	1.87051	1.90302	30.0000	25.1102
Left Chann		1.00000	4.56434	5.94185	13.8906	5.54875
Flange 30		1.00000	1.32074	1.26840	55.0000	46.5328
Main Shell		1.30000	4.56434	5.94185	13.8906	6.25799
Flange 50		1.00000	1.32074	1.26840	55.0000	46.5328
Right Chan		1.00000	4.56434	5.94185	13.8906	5.54875
Right head		1.00000	1.87558	1.90821	30.0000	25.0805

Summary of Heat Exchanger Maximum Allowable Working Pressures :

Note: The MAWPs and MAPs for the Exchanger elements all appear to
be zero or some could not be calculated. Please fill these
values in on the main tubesheet tab.

Internal Pressure Calculation Results :

British Standard PD 5500:2018

Welded Flat Head From 10 To 20 P355NH at -40 °C

Left Head

Thickness Due to Internal Pressure (er):

```
= C * D * sqrt(p/f) per 3.5.5-1
= 0.4100*740.35*sqrt(1.00/191484.98)
= 21.9352 + 3.1750 = 25.1102 mm
```

Max. All. Working Pressure at Given Thickness (MAWP):

```
= f * ( ecor / ( C * Dca ))²
= 191484.98*(26.83/(0.41*740.35))²
= 1.87 N/mm²
```

Maximum Allowable Pressure, New and Cold (MAPNC):

```
= fa * ( e / ( C * D ))²
= 191484.98*(30.00/(0.41*734.00))²
= 1.90 N/mm²
```

Actual Stress at Given Thickness:

```
= 102370.34 kPa
```

Note : For flat heads with openings, C should be the Maximum of CY1 and
0.41*Y2 per 3.5.5-5. d/D <= 0.5.

NOTE: If there are nozzles in the Flat Head,
check the Nozzle Summary for Final Flat Head Thickness
requirement.

As the Minimum Design Temperature is: 50.0 °C , Impact is Not Required
per Annex D

Cylindrical Shell From 20 To 30 A-106 B at -40 °C

Left Channel Shell

Thickness Due to Internal Pressure (er):

```
= ( P * Do ) / ( 2 * f + p ) per 3.5.1.2 Eqn. 3.5.1-2
= (1.00*762.0000)/(2*159996.34+1.00)
= 2.3737 + 3.1750 = 5.5487 mm
```

Max. All. Working Pressure at Given Thickness (MAWP):

```
= ( 2 * f * ecor ) / ( Doca - ecor )
= (2*159996.34*10.72)/(762.00-10.72)
= 4.56 N/mm²
```

Maximum Allowable Pressure, New and Cold (MAPNC):

```
= ( 2 * fa * e ) / ( D - e )
= (2*159996.34*13.89)/(762.00-13.89)
= 5.94 N/mm²
```

Actual Stress at Given Thickness:

```
= ( P * Ri ) / ecor
= (1.00*370.28)/10.7156
= 34553.55 kPa
```

As the Minimum Design Temperature is: 50.0 °C , Impact is Not Required

per Annex D

Cylindrical Shell From 40 To 50 A-106 B at -40 °C

Main Shell

Thickness Due to Internal Pressure (er):

```
= ( P * Do ) / ( 2 * f + p ) per 3.5.1.2 Eqn. 3.5.1-2
= (1.30*762.0000)/(2*159996.34+1.30)
= 3.0830 + 3.1750 = 6.2580 mm
```

Max. All. Working Pressure at Given Thickness (MAWP):

= (2 * f * ecor) / (Doca - ecor)

= (2*159996.34*10.72)/(762.00-10.72)

= 4.56 N/mm²

Maximum Allowable Pressure, New and Cold (MAPNC):

= (2 * fa * e) / (D - e)

= (2*159996.34*13.89)/(762.00-13.89)

= 5.94 N/mm²

Actual Stress at Given Thickness:

= (P * Ri) / ecor

= (1.30*370.28)/10.7156

= 44919.61 kPa

As the Minimum Design Temperature is: 50.0 °C , Impact is Not Required

per Annex D

Cylindrical Shell From 60 To 70 A-106 B at -40 °C

Right Channel

Thickness Due to Internal Pressure (er):

= (P * Do) / (2 * f + p) per 3.5.1.2 Eqn. 3.5.1-2

= (1.00*762.0000)/(2*159996.34+1.00)

= 2.3737 + 3.1750 = 5.5487 mm

Max. All. Working Pressure at Given Thickness (MAWP):

= (2 * f * ecor) / (Doca - ecor)

= (2*159996.34*10.72)/(762.00-10.72)

= 4.56 N/mm²

Maximum Allowable Pressure, New and Cold (MAPNC):

= (2 * fa * e) / (D - e)

= (2*159996.34*13.89)/(762.00-13.89)

= 5.94 N/mm²

Actual Stress at Given Thickness:

= (P * Ri) / ecor

= (1.00*370.28)/10.7156

= 34553.55 kPa

As the Minimum Design Temperature is: 50.0 °C , Impact is Not Required

per Annex D

Welded Flat Head From 70 To 80 P355NH at -40 °C

Right head

Thickness Due to Internal Pressure (er):

= C * D * sqrt(p/f) per 3.5.5-1

= 0.4100*739.35*sqrt(1.00/191484.98)

= 21.9055 + 3.1750 = 25.0805 mm

Max. All. Working Pressure at Given Thickness (MAWP):

= f * (ecor / (C * Dca))²

= 191484.98*(26.83/(0.41*739.35))²

= 1.88 N/mm²

Maximum Allowable Pressure, New and Cold (MAPNC):

= fa * (e / (C * D))²

= 191484.98*(30.00/(0.41*733.00))²

= 1.91 N/mm²

Actual Stress at Given Thickness:

= 102093.97 kPa

Note : For flat heads with openings, C should be the Maximum of CY1 and

0.41*Y2 per 3.5.5-5. d/D <= 0.5.

NOTE: If there are nozzles in the Flat Head,

check the Nozzle Summary for Final Flat Head Thickness

requirement.

As the Minimum Design Temperature is: 50.0 °C , Impact is Not Required

per Annex D

Hydrostatic Test Pressure Results:

PD:5500 5.8.5-1, Standard Test Pressure, Shell Side:

= 1.25 * P * fa/ft * (t / (t - c)) (per 5.8.5-1)

= 1.25 * 1.3000 * 1.000 * (13.891/(13.891 - 3.175))

= 2.1065 N/mm²

PD:5500 5.8.5-1, Field Test Pressure, Shell Side:

= 1.25 * P * fa/ft (per 5.8.5-1)

= 1.25 * 1.3000 * 159996.344/159996.344

= 1.6250 N/mm²

Lower Bound Test Pressure, Shell Side	2.106	N/mm²
Upper Bound Test Pressure, Shell Side	2.106	N/mm²
1.35 times the Specified Design P, Shell Side	1.755	N/mm²
Lower Bound Test Pressure, Channel Side	1.327	N/mm²
Upper Bound Test Pressure, Channel Side	1.620	N/mm²
1.35 times the Specified Design P, Channel Side	1.350	N/mm²

Stresses on Elements due to Test Pressure:

From To	Stress	Allowable (90% of Yield)	Ratio
Left Head	136563.4	274494.7	0.498
Left Channel Shell	35873.9	215994.0	0.166
Main Shell	55865.5	215994.0	0.259

Right Channel	35873.9	215994.0	0.166
Right head	136190.6	274494.7	0.496

Elements Suitable for Internal Pressure.

External Pressure Calculation Results :

British Standard PD 5500:2018

Welded Flat Head

Left Head

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

Cylindrical Shell From 20 to 30

Left Channel Shell

Determine the Stress Yield point [Py]:

```
= Sfact * f * ea / R
= 1.4 * 159996.344 * 10.716/375.64
= 6389.711 kPa
```

Strain Factor [Z]:

```
= pi * R / L
= 3.141 * 375.642/250.00
= 4.720
```

Determine the ratio Pm/Py:

```
= Pm / Py
= 46786.727/6389.711
= 7.000
```

Determine delta from Figure 3.6-4:

```
= 0.639
```

Determine the critical Strain [strain]:

```
= 1/(n²-1+Z²)[1/(n²/Z²+1)²+ea²/(12R²(.91))*(n²-1+Z²)²]

= 0.0078763
```

Where n is the expected number of lobes [n]:

```
= 7
```

Determine the Elastic Instability Pressure [Pm]:

```
= E * ea * strain / R

= 208250.0 * 10.716 * 0.007876/375.64

= 46.789 N/mm²
```

External Allowable Pressure [Pmax]:

```
= delta * Py

= 0.639 * 6.390

= 4.083 N/mm²
```

Cylindrical Shell From 40 to 50

Main Shell

Determine the Stress Yield point [Py]:

```
= Sfact * f * ea / R

= 1.4 * 159996.344 * 10.716/375.64

= 6389.711 kPa
```

Strain Factor [Z]:

```
= pi * R / L

= 3.141 * 375.642/4840.00

= 0.244
```

Determine the ratio Pm/Py:

```
= Pm / Py

= 1803.113/6389.711

= 0.282
```

Determine delta from Figure 3.6-4:

= 0.094

Determine the critical Strain [strain]:

$= 1/(n^2-1+Z^2)[1/(n^2/Z^2+1)^2+ea^2/(12R^2(.91))*(n^2-1+Z^2)^2]$

= 0.0003010

Where n is the expected number of lobes [n]:

= 2

Determine the Elastic Instability Pressure [Pm]:

= E * ea * strain / R

= 210000.0 * 10.716 * 0.000301/375.64

= 1.803 N/mm^2

External Allowable Pressure [Pmax]:

= delta * Py

= 0.094 * 6.390

= 0.599 N/mm^2

Cylindrical Shell From 60 to 70

Right Channel

Determine the Stress Yield point [Py]:

= Sfact * f * ea / R

= 1.4 * 159996.344 * 10.716/375.64

= 6389.711 kPa

Strain Factor [Z]:

= pi * R / L

= 3.141 * 375.642/250.00

= 4.720

Determine the ratio Pm/Py:

= Pm / Py

= 47179.891/6389.711

= 7.000

Determine delta from Figure 3.6-4:

= 0.639

Determine the critical Strain [strain]:

$= 1/(n^2-1+Z^2)[1/(n^2/Z^2+1)^2+ea^2/(12R^2(.91))*(n^2-1+Z^2)^2]$

= 0.0078763

Where n is the expected number of lobes [n]:

= 7

Determine the Elastic Instability Pressure [Pm]:

= E * ea * strain / R

= 210000.0 * 10.716 * 0.007876/375.64

= 47.183 N/mm^2

External Allowable Pressure [Pmax]:

= delta * Py

= 0.639 * 6.390

= 4.083 N/mm^2

Welded Flat Head

Right head

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

External Pressure Calculations

		Section	Outside	Corroded	Factor	Factor

From	To	Length	Diameter	Thickness	A	B
		m	mm	mm		kPa
10	20	No Calc	...	26.8250	No Calc	No Calc
20	30	0.25000	762.000	10.7156	No Calc	No Calc
30	40	No Calc	...	51.8250	No Calc	No Calc
40	50	4.84000	762.000	10.7156	No Calc	No Calc
50	60	No Calc	...	51.8250	No Calc	No Calc
60	70	0.25000	762.000	10.7156	No Calc	No Calc
70	80	No Calc	...	26.8250	No Calc	No Calc

External Pressure Calculations

		External	External	External	External
From	To	Actual T.	Required T.	Des. Press.	M.A.W.P.
		mm	mm	N/mm²	N/mm²
10	20	30.0000	No Calc	0.10300	No Calc
20	30	13.8906	4.66488	0.10300	4.08326
30	40	55.0000	46.5328	0.10300	No Calc
40	50	13.8906	7.95622	0.10300	0.59949
50	60	55.0000	46.5328	0.10300	No Calc
60	70	13.8906	4.66008	0.10300	4.08326
70	80	30.0000	No Calc	0.10300	No Calc
Minimum					0.599

External Pressure Calculations

		Actual Len.	Allow. Len.	Ring Inertia	Ring Inertia
From	To	Bet. Stiff.	Bet. Stiff.	Required	Available
		m	m	mm**4	mm**4
10	20	No Calc	No Calc	No Calc	No Calc
20	30	0.25000	17.89E+09	No Calc	No Calc
30	40	No Calc	No Calc	No Calc	No Calc
40	50	4.84000	173.0E+09	No Calc	No Calc

50	60	No Calc	No Calc	No Calc	No Calc
60	70	0.25000	19.23E+09	No Calc	No Calc
70	80	No Calc	No Calc	No Calc	No Calc

Elements Suitable for External Pressure.

Element and Detail Weights

From	To	Element Metal Wgt. kgm	Element ID Volume m³	Corroded Metal Wgt. kgm	Corroded ID Volume m³	Extra due Misc % kgm
10	20	99.1429	...	88.6503	...	...
20	30	63.7685	0.10587	49.4073	0.10771	...
30	40	48.0423	...	48.0423	...	...
40	50	1234.56	1.47275	956.525	1.50836	...
50	60	48.0423	...	48.0423	...	...
60	70	63.7685	0.10587	49.4073	0.10771	...
70	80	98.8730	...	88.4089	...	...
	Total	1656	1.68	1328	1.72	0

For elements specified as shell side elements, the volume(s) shown above for those elements, reflects the displacement of the tubes.

<u>Weight of Details</u>

From	Type	Weight of Detail kgm	X Offset, Dtl. Cent. m	Y Offset, Dtl. Cent. m	Description
10	Nozl	12.5500	2.40000	0.41302	Noz N1 Fr10
10	Nozl	47.0979	2.40000	0.41302	Noz N2 Fr10
20	Nozl	1.02537	0.14000	0.40521	Noz N1 Fr20
40	Sadl	20.2128	4.20000	0.45761	New Sdl
40	Sadl	20.2128	0.70000	0.45761	Sdl 2 Fr40
40	Nozl	28.5333	0.20000	0.43696	Noz N1 Fr40
40	Nozl	0.24032	0.45000	0.38616	Noz N2 Fr40
40	Nozl	1.02537	2.50000	0.40521	Noz N3 Fr40
40	Nozl	0.53155	4.55000	0.39568	Noz N4 Fr40
30	FTsh	126.044	0.078000	...	Gatti

```
   30|Tube|    1650.38 |    2.51600 |       ... |

   30|RTsh|    126.044 |    4.95400 |       ... |
```

Total Weight of Each Detail Type

Total Weight of Saddles	40.4
Total Weight of Nozzles	91.0
Total Weight of Exchanger Components	1902.5
Sum of the Detail Weights	2033.9 kgm

Weight Summation

Fabricated	Shop Test	Shipping	Erected	Empty	Operating
1656.2	3690.1	1656.2	3690.1	1656.2	3690.1
40.4	1683.5	40.4	...	40.4	...
91.0	...	91.0	...	...	...
...	372.2	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	91.0	...
1902.5	...	1902.5	...	...	...
...	...	...	...	1902.5	...
3690.1	5745.7	3690.1	3690.1	3690.1	3690.1 kgm

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

<u>Weight Summary</u>

Fabricated Wt.	- Bare Weight W/O Removable Internals	3690.1 kgm
Shop Test Wt.	- Fabricated Weight + Water (Full)	5745.7 kgm

Shipping Wt.	- Fab. Wt + Rem. Intls.+ Shipping App.	3690.1 kgm
Erected Wt.	- Fab. Wt + Rem. Intls.+ Insul. (etc)	3690.1 kgm
Ope. Wt. no Liq	- Fab. Wt + Intls. + Details + Wghts.	3690.1 kgm
Operating Wt.	- Empty Wt + Operating Liq. Uncorroded	3690.1 kgm
Oper. Wt. + CA	- Corr Wt. + Operating Liquid	3362.4 kgm
Field Test Wt.	- Empty Weight + Water (Full)	5745.7 kgm

Exchanger Tube Data

Volume of Exchanger tubes :	0.4 m^3
Weight of Ope Liq in tubes :	0.0 kgm
Weight of Water in tubes :	372.2 kgm

Note: The Corroded Weight and thickness are used in the Horizontal
Vessel Analysis (Ope Case) and Earthquake Load Calculations.

Outside Surface Areas of Elements

From	To	Surface Area m^2
10	20	...
20	30	0.59833
30	40	0.25822
40	50	11.5837
50	60	0.25822
60	70	0.59833
70	80	...

Total 13.297 m^2

Nozzle Flange MAWP Results :

Nozzle	----- Flange Rating				
Description	Operating	Ambient	Temperature	Class	Grade|Group
	N/mm²	N/mm²	°C		
Noz N1 Fr10	2.0	2.0	-40	150	GR 1.1
Noz N2 Fr10	2.0	2.0	-40	150	GR 1.1

Shellside Flange Rating

Channelside Flange Rating

Lowest Flange Pressure Rating was (Ope)[TubeSide]: 1.960 N/mm²

Lowest Flange Pressure Rating was (Amb)[TubeSide]: 1.960 N/mm²

Note: ANSI Ratings are per ANSI/ASME B16.5 2009 Metric Edition

Wind Analysis Results

User Entered Importance Factor is	1.000	
Gust Factor (Gh, Gbar) Static Dynamic	1.381	
Shape Factor (Cf) for the Vessel is	0.601	
User Entered Basic Wind Speed	31.3	m/sec
Exposure Category	C	
Table Lookup Value Alpha from Table C6	7.0000	
Table Lookup Value Zg from Table C6	900.0000	
Table Lookup Value Do from Table C6	0.0050	

Wind Load Results per ASCE-7 93:

Sample Calculation for the First Element:

Rougness Factor = 1.000

Values [cf1] and [cf2]

Because RoughFact = 1 and DQZ > 2.5 and H/D > 7.0

Interpolating to find the final cf:

Because H / D < 25.0

CF = CF1 + (CF2-CF1) * (H/D - 7.0)/(25.0 - 7.0)

= 0.600 + (0.700 -0.600) * (7.202 - 7.0)/(25.0 - 7.0)

= 0.601

Value of Alpha, Zg is taken from Table C6-2 [Alpha, Zg]

For Exposure Category C:

Alpha = 7.000 , Zg = 274.320 m

Height of Interest for First Element [z]

= Centroid Hgt + Base Height

= 0.572 + 0.000 = 0.572 m

but: z = Max(4.572 , 0.572) = 4.572 m

Note: Because z < 15 feet, use 15 feet to compute kz.

Velocity Pressure Coefficient [kZ]:

= $2.58(z/zg)^{2/Alpha}$: z is Elevation of First Element

= $2.58(4.572/900)^{2/7.0}$

= 0.801

Determine if Static or Dynamic Gust Factor Applies

Height to Diameter ratio :

= Maximum Height(length)^2 / Sum of Area of the Elements

= 17.953 (^2)/44.755

= 7.202

Vibration Frequency = 33.000 Hz

Because H/D > 5 Or Freqency < 1.0: Dynamic Analysis Implemented

Element O/Dia = 3 m

Vibration Damping Factor (Operating) Beta = 0.01000

For Terrain Category C

S = 1.000 , Gamma = 0.230 , Drag Coeff. = 0.005 , Alpha = 7.000

Compute [fbar]

= 10.5 * Frequency(Hz) * Vessel Height(ft) / (S * Vr(mph))

= 10.5 * 33.000 (Hz) * 17.953 (ft)/S * 1.000 (mph)

= 88.866

Because FBAR > 40: FBAR = 40.000

Wind Pressure - (performed in Imperial Units) [qz]

Importance Factor: I = 1.000

Wind Speed = 31.292 m/sec Converts to 70.000 mph

$qz = 0.00256 * kZ * (I * Vr)^2$

$= 0.00256 * 0.801 *(1.000 * 70.000)^2 = 10.046$ psf

Converts to: 0.481 kPa

Force on the First Element [Fz]

= qz * Gh * CF * Wind Area

= 0.481 * 1.381 * 0.601 * 0.029

= 11.416 N

Element	z	GH	Area	qz	Force
	m		m²	kPa	N
Left Head	0.6	1.381	0.0	0.5	11.4
Left Channel Sh	0.6	1.381	0.2	0.5	91.3
Flange 30	0.6	1.381	0.0	0.5	0.0
Main Shell	0.6	1.381	4.4	0.5	1767.6
Flange 50	0.6	1.381	0.0	0.5	19.7
Right Channel	0.6	1.381	0.2	0.5	91.3
Right head	0.6	1.381	0.0	0.5	11.4

Wind Load Calculation

From	To	Wind Height	Wind Diameter	Wind Area	Wind Pressure	Element Wind Load
		m	m	m²	kPa	N
10	20	0.57200	0.95280	0.028577	0.48101	11.4163
20	30	0.57200	0.91440	0.22854	0.48101	91.3013
30	40	0.57200	...	...	0.48101	...
40	50	0.57200	0.91440	4.42460	0.48101	1767.59
50	60	0.57200	0.89776	0.049364	0.48101	19.7207
60	70	0.57200	0.91440	0.22854	0.48101	91.3013
70	80	0.57200	0.95160	0.028541	0.48101	11.4019

Earthquake Analysis Results

```
The UBC Zone Factor for the Vessel is ............      0.0000
The Importance Factor as Specified by the User is .      1.000
The UBC Frequency and Soil Factor (C)  is .........      2.750
The UBC Force Factor as Specified by the User is ..      3.000
The UBC Total Weight (W) for the Vessel is ........   32971.5  N
The UBC Total Shear (V) for the Vessel is .........       0.0  N
The UBC Top Shear (Ft) for the Vessel is ..........       0.0  N
```

Earthquake Load Calculation

From	To	Earthquake Height m	Earthquake Weight N	Element Ope Load N
10	20	0.36700	3663.50	...
20	30	0.36711	3663.50	...
30	40	...	3663.50	...
40	Sadl	0.36711	3663.50	...
Sadl	50	0.36711	3663.50	...
40	50	0.36711	3663.50	...
50	60	0.37407	3663.50	...
60	70	0.36711	3663.50	...
70	80	0.36650	3663.50	...

Lifting Lug Calculations: Lug(s) on Left End of Vessel

Input Values:

Lifting Lug Material		P355GH	
Lifting Lug Yield Stress	Yield	354991.88	kPa
Total Height of Lifting Lug	w	180.0000	mm
Thickness of Lifting Lug	t	12.0000	mm
Diameter of Hole in Lifting Lug	dh	60.0000	mm
Radius of Semi-Circular Arc of Lifting Lug	r	60.0000	mm
Height of Lug from bottom to Center of Hole	h	90.0000	mm
Offset from Vessel OD to Center of Hole	off	90.0000	mm
Lug Fillet Weld Size	tw	8.0000	mm
Length of weld along side of Lifting Lug	wl	190.0000	mm
Length of Weld along Bottom of Lifting Lug	wb	16.0000	mm
Thickness of Collar (if any)	tc	0.0000	mm
Diameter of Collar (if any)	dc	760.0000	mm
Impact Factor	Impfac	1.50	
Sling Angle from Horizontal		90.0000	deg
Number of Lugs in Group		1	

Lifting Lug Orientation to Vessel: Perpendicular

Lift Orientation : Horizontal Lift

PV Elite does not compute weak axis bending forces on the lugs. It is assumed that a spreader bar is used.

Computed Results:

Force Along Vessel Axis	Fax	0.00	N
Force Normal to Vessel	Fn	26654.40	N
Force Tangential to Vessel	Ft	0.00	N

Converting the weld leg dimension (tw) to the weld throat dimension.

Weld Group Inertia Calculations:

Weld Group Inertia about the Circumferential Axis	Ilc	8198377.000 mm**4
Weld Group Centroid distance in the Long. Direction	Yll	100.656 mm
Dist. of Weld Group Centroid from Lug bottom	Yll_b	95.000 mm
Weld Group Inertia about the Longitudinal Axis	Ill	31215.977 mm**4
Weld Group Centroid Distance in the Circ. Direction	Ylc	6.000 mm

Note: The Impact Factor is applied to the Forces acting on the Lug.

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

$= \text{sqrt}(Fax^2 + Ft^2 + Fn^2)/((2 * (wl + wb)) * tw)$

$= \text{sqrt}(0^2+0^2+26654^2)/((2*(190.0+16.0))*5.6560)$

= 11438.63 kPa

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

= (Fn*(h-Yll_b)) *Yll/Ilc + (Fax*off *Yll/Ilc) + (Ft*off *Ylc/Ill)

= (26654 *(90.000 -95.000)) * 100.656/8198377 +

(0 *90.000 * 100.656/8198377) +

(0 *90.000 * 6.000/31215.977)

= -1636.30 kPa

Total Shear Stress for Combined Loads [St]:

= Ssll + Sblf

= 11438.630 + -1636.300

= 9802.33 kPa

Allowable Shear Stress for Combined Loads [Sta]:

= 0.4 * Yield * Occfac (AISC Shear Allowable)

= 0.4 * 354991 * 1.00

= 141996.75 kPa

Shear Stress in Lug above Hole [Shs]:

$= \text{sqrt}(Pl^2 + Fax^2) / Sha$

$= \text{sqrt}(26654^2 + 0^2)/0.001$

```
  = 37021.00 kPa
```

Allowable Shear Stress in Lug above Hole [Sas]:

```
  = 0.4 * Yield * Occfac
  = 0.4 * 354991 * 1.00
  = 141996.75 kPa
```

Pin Hole Bearing Stress [Pbs]:

```
  = sqrt( Fax² + Fn² ) / ( t * dh )
  = sqrt( 0² + 26654² )/( 12.000 * 60.000 )
  = 37021.00 kPa
```

Allowable Bearing Stress [Pba]:

```
  = min( 0.75 * Yield * Occfac, 0.9 * Yield ) AISC Bearing All.
  = min( 0.75 * 354991 * 1.00 , 319492.7 )
  = 266243.91 kPa
```

Bending Stress at the Base of the Lug [Fbs]:

```
  = Ft * off/(w * t²/6) + Fax * off/(w² * t/6)
  = 0 * 90.000/(180.000 * 12.000²/6) +
    0 * 90.000/(180.000² * 12.000/6)
  = 0.00 kPa
```

Tensile Stress at the Base of the Lug [Fa]:

```
  = Fn / (w * t)
  = 0/(180.000 * 12.000 )
  = 12340.33 kPa
```

Total Combined Stress at the Base of the Lug:

```
  = Fbs + Fa
  = 0.0 + 12340.3
  = 12340.33 kPa
```

Lug Allowable Stress for Bending and Tension:

```
  = min( 0.66 * Yield * Occfac, 0.75 * Yield )
  = min( 0.66 * 354991 * 1.00 , 266243.9 )
```

= 234294.64 kPa

Required Shackle Pin Diameter [Spd]:

$= sqrt[(2 * sqrt(Fn^2 + Fax^2)/(Pi * Sta))]$

$= sqrt[2 * sqrt(26654^2 + 0^2)/(Pi * 141996)]$

= 10.9318 mm

WRC 107/537 Stress Analysis for the Lifting Lug to Shell Junction in

the new and Cold Condition (no corrosion applied).

Note: Since Beta1/Beta2 >= 0.25, C22 (C22p) is adjusted per table 6

in paragraph 4.3 of WRC Bulletin 107.

Input Echo, WRC107/537 Item 1, Description: Lift Lug

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	0.0000	mm
Vessel Diameter	Dv	734.219	mm
Vessel Thickness	Tv	13.891	mm
Design Temperature		37.78	°C
Attachment Type	Type	Rectangular	
Parameter C11	C11	16.00	mm
Parameter C22	C22	64.00	mm
Thickness of Reinforcing Pad	Tpad	8.000	mm
Pad Parameter C11P	C11p	50.000	mm
Pad Parameter C22P	C22p	200.000	mm
Design Internal Pressure	Dp	0.000	N/mm²
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	-26654.4	N

Longitudinal Shear	(SUS)	Vl	0.0	N
Circumferential Shear	(SUS)	Vc	0.0	N
Circumferential Moment	(SUS)	Mc	0.0	N-m
Longitudinal Moment	(SUS)	Ml	0.0	N-m
Torsional Moment	(SUS)	Mt	0.0	N-m

Use Interactive Control No

WRC107 Version Version March 1979

Include Pressure Stress Indices per Div. 2 No

Compute Pressure Stress per WRC-368 No

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	-26654.4	N
Circumferential Shear	VC	0.0	N
Longitudinal Shear	VL	0.0	N
Circumferential Moment	MC	0.0	N-m
Longitudinal Moment	ML	0.0	N-m
Torsional Moment	MT	0.0	N-m

Dimensionless Parameters used : Gamma = 17.27

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.063	4C	3.408	(A,B)
N(PHI) / (P/Rm)	0.063	3C	3.345	(C,D)
M(PHI) / (P)	0.037	2C1	0.219	(A,B)
M(PHI) / (P)	0.037	1C	0.252	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.034	3A	0.060	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.044	1A	0.105	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.053	3B	0.612	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.048	1B	0.063	(A,B,C,D)

N(x) / (P/Rm)	0.051	3C	3.427	(A,B)
N(x) / (P/Rm)	0.051	4C	3.455	(C,D)
M(x) / (P)	0.053	1C1	0.226	(A,B)
M(x) / (P)	0.053	2C	0.186	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.034	4A	0.092	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.061	2A	0.063	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.053	4B	0.148	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.066	2B	0.098	(A,B,C,D)

Stress Concentration Factors Kn = 1.00,   Kb = 1.00

Stresses in the Vessel at the Attachment Junction

Type of Stress Load	Stress Values at (kPa)							
	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	10976	10976	10976	10976	10774	10774	10774	10774
Circ. Bend. P	73157	-73157	73157	-73157	84105	-84105	84105	-84105
Circ. Memb. MC	0	0	0	0	0	0	0	0
Circ. Bend. MC	0	0	0	0	0	0	0	0
Circ. Memb. ML	0	0	0	0	0	0	0	0
Circ. Bend. ML	0	0	0	0	0	0	0	0
Tot. Circ. Str.	84134	-62181	84134	-62181	94879	-73331	94879	-73331
Long. Memb. P	11038	11038	11038	11038	11128	11128	11128	11128
Long. Bend. P	75290	-75290	75290	-75290	62208	-62208	62208	-62208
Long. Memb. MC	0	0	0	0	0	0	0	0
Long. Bend. MC	0	0	0	0	0	0	0	0
Long. Memb. ML	0	0	0	0	0	0	0	0
Long. Bend. ML	0	0	0	0	0	0	0	0
Tot. Long. Str.	86329	-64251	86329	-64251	73336	-51080	73336	-51080

Shear VC	0	0	0	0	0	0	0	0
Shear VL	0	0	0	0	0	0	0	0
Shear MT	0	0	0	0	0	0	0	0
Tot. Shear	0	0	0	0	0	0	0	0
Str. Int.	86329	64251	86329	64251	94879	73331	94879	73331

Dimensionless Parameters used : Gamma = 26.93

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.198	4C	4.010	(A,B)
N(PHI) / (P/Rm)	0.198	3C	2.820	(C,D)
M(PHI) / (P)	0.118	2C1	0.091	(A,B)
M(PHI) / (P)	0.118	1C	0.127	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.106	3A	0.735	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.136	1A	0.094	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.168	3B	2.995	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.149	1B	0.040	(A,B,C,D)
N(x) / (P/Rm)	0.160	3C	3.373	(A,B)
N(x) / (P/Rm)	0.160	4C	4.298	(C,D)
M(x) / (P)	0.167	1C1	0.097	(A,B)
M(x) / (P)	0.167	2C	0.060	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.106	4A	1.033	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.187	2A	0.043	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.168	4B	0.971	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.206	2B	0.049	(A,B,C,D)

Stress Concentration Factors Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad

Type of Stress Load	Stress Values at (kPa)							
	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	20572	20572	20572	20572	14465	14465	14465	14465
Circ. Bend. P	75598	-75598	75598	-75598	105416	-105416	105416	-105416
Circ. Memb. MC	0	0	0	0	0	0	0	0
Circ. Bend. MC	0	0	0	0	0	0	0	0
Circ. Memb. ML	0	0	0	0	0	0	0	0
Circ. Bend. ML	0	0	0	0	0	0	0	0
Tot. Circ. Str.	96170	-55026	96170	-55026	119881	-90950	119881	-90950
Long. Memb. P	17301	17301	17301	17301	22049	22049	22049	22049
Long. Bend. P	80229	-80229	80229	-80229	49900	-49900	49900	-49900
Long. Memb. MC	0	0	0	0	0	0	0	0
Long. Bend. MC	0	0	0	0	0	0	0	0
Long. Memb. ML	0	0	0	0	0	0	0	0
Long. Bend. ML	0	0	0	0	0	0	0	0
Tot. Long. Str.	97530	-62927	97530	-62927	71949	-27850	71949	-27850
Shear VC	0	0	0	0	0	0	0	0
Shear VL	0	0	0	0	0	0	0	0
Shear MT	0	0	0	0	0	0	0	0
Tot. Shear	0	0	0	0	0	0	0	0
Str. Int.	97530	62927	97530	62927	119881	90950	119881	90950

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction

Type of Stress Int.	Stress Values at (kPa)							
Location	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	0	0	0	0	0	0	0	0
Circ. Pl (SUS)	10976	10976	10976	10976	10774	10774	10774	10774
Circ. Q (SUS)	73157	-73157	73157	-73157	84105	-84105	84105	-84105
Long. Pm (SUS)	0	0	0	0	0	0	0	0
Long. Pl (SUS)	11038	11038	11038	11038	11128	11128	11128	11128
Long. Q (SUS)	75290	-75290	75290	-75290	62208	-62208	62208	-62208
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	0	0	0	0	0	0	0	0
Shear Q (SUS)	0	0	0	0	0	0	0	0
Pm (SUS)	0	0	0	0	0	0	0	0
Pm+Pl (SUS)	11038	11038	11038	11038	11128	11128	11128	11128
Pm+Pl+Q (Total)	86329	64251	86329	64251	94879	73331	94879	73331

Type of Stress Int.	Max. S.I. kPa	S.I. Allowable	Result
Pm (SUS)	0	159996	Passed
Pm+Pl (SUS)	11128	239994	Passed
Pm+Pl+Q (TOTAL)	94879	479989	Passed

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge

Type of Stress Int.	Stress Values at (kPa)							
Location	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	0	0	0	0	0	0	0	0
Circ. Pl (SUS)	20572	20572	20572	20572	14465	14465	14465	14465
Circ. Q (SUS)	75598	-75598	75598	-75598	105416	-105416	105416	-105416
Long. Pm (SUS)	0	0	0	0	0	0	0	0
Long. Pl (SUS)	17301	17301	17301	17301	22049	22049	22049	22049
Long. Q (SUS)	80229	-80229	80229	-80229	49900	-49900	49900	-49900
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	0	0	0	0	0	0	0	0
Shear Q (SUS)	0	0	0	0	0	0	0	0
Pm (SUS)	0	0	0	0	0	0	0	0
Pm+Pl (SUS)	20572	20572	20572	20572	22049	22049	22049	22049
Pm+Pl+Q (Total)	97530	62927	97530	62927	119881	90950	119881	90950

Type of Stress Int.	Max. S.I. (kPa)	S.I. Allowable (kPa)	Result
Pm (SUS)	0	159996	Passed
Pm+Pl (SUS)	22049	239994	Passed
Pm+Pl+Q (TOTAL)	119881	479989	Passed

Lifting Lug Calculations: Lug(s) on Right End of Vessel

Input Values:

Lifting Lug Material		P355GH	
Lifting Lug Yield Stress	Yield	354991.88	kPa
Total Height of Lifting Lug	w	180.0000	mm
Thickness of Lifting Lug	t	12.0000	mm
Diameter of Hole in Lifting Lug	dh	60.0000	mm
Radius of Semi-Circular Arc of Lifting Lug	r	60.0000	mm
Height of Lug from bottom to Center of Hole	h	90.0000	mm
Offset from Vessel OD to Center of Hole	off	90.0000	mm
Lug Fillet Weld Size	tw	8.0000	mm
Length of weld along side of Lifting Lug	wl	190.0000	mm
Length of Weld along Bottom of Lifting Lug	wb	16.0000	mm
Thickness of Collar (if any)	tc	0.0000	mm
Diameter of Collar (if any)	dc	760.0000	mm
Impact Factor	Impfac	1.50	
Sling Angle from Horizontal		90.0000	deg
Number of Lugs in Group		1	

Lifting Lug Orientation to Vessel: Perpendicular

Lift Orientation : Horizontal Lift

PV Elite does not compute weak axis bending forces on the lugs. It is assumed that a spreader bar is used.

Computed Results:

Force Along Vessel Axis	Fax	0.00	N
Force Normal to Vessel	Fn	27623.14	N
Force Tangential to Vessel	Ft	0.00	N

Converting the weld leg dimension (tw) to the weld throat dimension.

Weld Group Inertia Calculations:

```
Weld Group Inertia about the Circumferential Axis    Ilc  8198377.000 mm**4
Weld Group Centroid distance in the Long. Direction  Yll    100.656 mm
Dist. of Weld Group Centroid from Lug bottom       Yll_b     95.000 mm
Weld Group Inertia about the Longitudinal Axis       Ill  31215.977 mm**4
Weld Group Centroid Distance in the Circ. Direction  Ylc      6.000 mm
```

Note: The Impact Factor is applied to the Forces acting on the Lug.

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

```
= sqrt( Fax² + Ft² + Fn² )/(( 2 * (wl + wb) ) * tw )
= sqrt(0²+0²+27623²)/((2*(190.0+16.0))*5.6560)
= 11854.36 kPa
```

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

```
= (Fn*(h-Yll_b)) *Yll/Ilc + (Fax*off *Yll/Ilc) + (Ft*off *Ylc/Ill)
= (27623 *(90.000 -95.000 )) * 100.656/8198377 +
  (0 *90.000 * 100.656/8198377 ) +
  (0 *90.000 * 6.000/31215.977 )
= -1695.77 kPa
```

Total Shear Stress for Combined Loads [St]:

```
= Ssll + Sblf
= 11854.360 + -1695.770
= 10158.59 kPa
```

Allowable Shear Stress for Combined Loads [Sta]:

```
= 0.4 * Yield * Occfac (AISC Shear Allowable)
= 0.4 * 354991 * 1.00
= 141996.75 kPa
```

Shear Stress in Lug above Hole [Shs]:

```
= sqrt( Pl² + Fax² ) / Sha
= sqrt( 27623² + 0² )/0.001
```

```
  = 38366.51 kPa
```

Allowable Shear Stress in Lug above Hole [Sas]:

```
  = 0.4 * Yield * Occfac
  = 0.4 * 354991 * 1.00
  = 141996.75 kPa
```

Pin Hole Bearing Stress [Pbs]:

```
  = sqrt( Fax² + Fn² ) / ( t * dh )
  = sqrt( 0² + 27623² )/( 12.000 * 60.000 )
  = 38366.51 kPa
```

Allowable Bearing Stress [Pba]:

```
  = min( 0.75 * Yield * Occfac, 0.9 * Yield ) AISC Bearing All.
  = min( 0.75 * 354991 * 1.00 , 319492.7 )
  = 266243.91 kPa
```

Bending Stress at the Base of the Lug [Fbs]:

```
  = Ft * off/(w * t²/6) + Fax * off/(w² * t/6)
  = 0 * 90.000/(180.000 * 12.000²/6) +
    0 * 90.000/(180.000² * 12.000/6)
  = 0.00 kPa
```

Tensile Stress at the Base of the Lug [Fa]:

```
  = Fn / (w * t)
  = 0/(180.000 * 12.000 )
  = 12788.84 kPa
```

Total Combined Stress at the Base of the Lug:

```
  = Fbs + Fa
  = 0.0 + 12788.8
  = 12788.84 kPa
```

Lug Allowable Stress for Bending and Tension:

```
  = min( 0.66 * Yield * Occfac, 0.75 * Yield )
  = min( 0.66 * 354991 * 1.00 , 266243.9 )
```

= 234294.64 kPa

Required Shackle Pin Diameter [Spd]:

= sqrt[(2 * sqrt(Fn² + Fax²)/(Pi * Sta))]

= sqrt[2 * sqrt(27623² + 0²)/(Pi * 141996)]

= 11.1287 mm

WRC 107/537 Stress Analysis for the Lifting Lug to Shell Junction in the new and Cold Condition (no corrosion applied).

Note: Since Beta1/Beta2 >= 0.25, C22 (C22p) is adjusted per table 6 in paragraph 4.3 of WRC Bulletin 107.

Input Echo, WRC107/537 Item 1, Description: Lift Lug

Diameter Basis for Vessel	Vbasis	ID	
Cylindrical or Spherical Vessel	Cylsph	Cylindrical	
Internal Corrosion Allowance	Cas	0.0000	mm
Vessel Diameter	Dv	734.219	mm
Vessel Thickness	Tv	13.891	mm
Design Temperature		37.78	°C
Attachment Type	Type	Rectangular	
Parameter C11	C11	16.00	mm
Parameter C22	C22	64.00	mm
Thickness of Reinforcing Pad	Tpad	8.000	mm
Pad Parameter C11P	C11p	50.000	mm
Pad Parameter C22P	C22p	200.000	mm
Design Internal Pressure	Dp	0.000	N/mm²
Include Pressure Thrust		No	

External Forces and Moments in WRC 107/537 Convention:

Radial Load	(SUS)	P	-27623.1	N

Longitudinal Shear	(SUS)	Vl	0.0	N
Circumferential Shear	(SUS)	Vc	0.0	N
Circumferential Moment	(SUS)	Mc	0.0	N-m
Longitudinal Moment	(SUS)	Ml	0.0	N-m
Torsional Moment	(SUS)	Mt	0.0	N-m

Use Interactive Control		No
WRC107 Version	Version	March 1979

Include Pressure Stress Indices per Div. 2	No
Compute Pressure Stress per WRC-368	No

WRC 107 Stress Calculation for SUStained loads:

Radial Load	P	-27623.1	N
Circumferential Shear	VC	0.0	N
Longitudinal Shear	VL	0.0	N
Circumferential Moment	MC	0.0	N-m
Longitudinal Moment	ML	0.0	N-m
Torsional Moment	MT	0.0	N-m

Dimensionless Parameters used :   Gamma =   17.27

Dimensionless Loads for Cylindrical Shells at Attachment Junction:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.063	4C	3.408	(A,B)
N(PHI) / (P/Rm)	0.063	3C	3.345	(C,D)
M(PHI) / (P)	0.037	2C1	0.219	(A,B)
M(PHI) / (P)	0.037	1C	0.252	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.034	3A	0.060	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.044	1A	0.105	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.053	3B	0.612	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.048	1B	0.063	(A,B,C,D)

N(x)	/ (P/Rm)	0.051	3C	3.427	(A,B)
N(x)	/ (P/Rm)	0.051	4C	3.455	(C,D)
M(x)	/ (P)	0.053	1C1	0.226	(A,B)
M(x)	/ (P)	0.053	2C	0.186	(C,D)
N(x)	/ (MC/(Rm**2 * Beta))	0.034	4A	0.092	(A,B,C,D)
M(x)	/ (MC/(Rm * Beta))	0.061	2A	0.063	(A,B,C,D)
N(x)	/ (ML/(Rm**2 * Beta))	0.053	4B	0.148	(A,B,C,D)
M(x)	/ (ML/(Rm * Beta))	0.066	2B	0.098	(A,B,C,D)

Stress Concentration Factors Kn = 1.00,   Kb = 1.00

Stresses in the Vessel at the Attachment Junction

Type of Stress Load	Stress Values at (kPa)							
	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	11375	11375	11375	11375	11165	11165	11165	11165
Circ. Bend. P	75816	-75816	75816	-75816	87162	-87162	87162	-87162
Circ. Memb. MC	0	0	0	0	0	0	0	0
Circ. Bend. MC	0	0	0	0	0	0	0	0
Circ. Memb. ML	0	0	0	0	0	0	0	0
Circ. Bend. ML	0	0	0	0	0	0	0	0
Tot. Circ. Str.	87191	-64441	87191	-64441	98328	-75996	98328	-75996
Long. Memb. P	11439	11439	11439	11439	11532	11532	11532	11532
Long. Bend. P	78026	-78026	78026	-78026	64469	-64469	64469	-64469
Long. Memb. MC	0	0	0	0	0	0	0	0
Long. Bend. MC	0	0	0	0	0	0	0	0
Long. Memb. ML	0	0	0	0	0	0	0	0
Long. Bend. ML	0	0	0	0	0	0	0	0
Tot. Long. Str.	89466	-66587	89466	-66587	76001	-52936	76001	-52936

Shear VC	0	0	0	0	0	0	0	0
Shear VL	0	0	0	0	0	0	0	0
Shear MT	0	0	0	0	0	0	0	0
Tot. Shear	0	0	0	0	0	0	0	0
Str. Int.	89466	66587	89466	66587	98328	75996	98328	75996

Dimensionless Parameters used : Gamma = 26.93

Dimensionless Loads for Cylindrical Shells at Pad edge:

Curves read for 1979	Beta	Figure	Value	Location
N(PHI) / (P/Rm)	0.198	4C	4.010	(A,B)
N(PHI) / (P/Rm)	0.198	3C	2.820	(C,D)
M(PHI) / (P)	0.118	2C1	0.091	(A,B)
M(PHI) / (P)	0.118	1C	0.127	(C,D)
N(PHI) / (MC/(Rm**2 * Beta))	0.106	3A	0.735	(A,B,C,D)
M(PHI) / (MC/(Rm * Beta))	0.136	1A	0.094	(A,B,C,D)
N(PHI) / (ML/(Rm**2 * Beta))	0.168	3B	2.995	(A,B,C,D)
M(PHI) / (ML/(Rm * Beta))	0.149	1B	0.040	(A,B,C,D)
N(x) / (P/Rm)	0.160	3C	3.373	(A,B)
N(x) / (P/Rm)	0.160	4C	4.298	(C,D)
M(x) / (P)	0.167	1C1	0.097	(A,B)
M(x) / (P)	0.167	2C	0.060	(C,D)
N(x) / (MC/(Rm**2 * Beta))	0.106	4A	1.033	(A,B,C,D)
M(x) / (MC/(Rm * Beta))	0.187	2A	0.043	(A,B,C,D)
N(x) / (ML/(Rm**2 * Beta))	0.168	4B	0.971	(A,B,C,D)
M(x) / (ML/(Rm * Beta))	0.206	2B	0.049	(A,B,C,D)

Stress Concentration Factors Kn = 1.00, Kb = 1.00

Stresses in the Vessel at the Edge of Reinforcing Pad

Type of Stress Load	Stress Values at (kPa) Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Memb. P	21319	21319	21319	21319	14990	14990	14990	14990
Circ. Bend. P	78346	-78346	78346	-78346	109247	-109247	109247	-109247
Circ. Memb. MC	0	0	0	0	0	0	0	0
Circ. Bend. MC	0	0	0	0	0	0	0	0
Circ. Memb. ML	0	0	0	0	0	0	0	0
Circ. Bend. ML	0	0	0	0	0	0	0	0
Tot. Circ. Str.	99666	-57026	99666	-57026	124238	-94256	124238	-94256
Long. Memb. P	17930	17930	17930	17930	22851	22851	22851	22851
Long. Bend. P	83144	-83144	83144	-83144	51713	-51713	51713	-51713
Long. Memb. MC	0	0	0	0	0	0	0	0
Long. Bend. MC	0	0	0	0	0	0	0	0
Long. Memb. ML	0	0	0	0	0	0	0	0
Long. Bend. ML	0	0	0	0	0	0	0	0
Tot. Long. Str.	101075	-65214	101075	-65214	74564	-28862	74564	-28862
Shear VC	0	0	0	0	0	0	0	0
Shear VL	0	0	0	0	0	0	0	0
Shear MT	0	0	0	0	0	0	0	0
Tot. Shear	0	0	0	0	0	0	0	0
Str. Int.	101075	65214	101075	65214	124238	94256	124238	94256

WRC 107/537 Stress Summations:

Vessel Stress Summation at Attachment Junction

Type of Stress Int.	Stress Values at (kPa)							
Location	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	0	0	0	0	0	0	0	0
Circ. Pl (SUS)	11375	11375	11375	11375	11165	11165	11165	11165
Circ. Q (SUS)	75816	-75816	75816	-75816	87162	-87162	87162	-87162
Long. Pm (SUS)	0	0	0	0	0	0	0	0
Long. Pl (SUS)	11439	11439	11439	11439	11532	11532	11532	11532
Long. Q (SUS)	78026	-78026	78026	-78026	64469	-64469	64469	-64469
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	0	0	0	0	0	0	0	0
Shear Q (SUS)	0	0	0	0	0	0	0	0
Pm (SUS)	0	0	0	0	0	0	0	0
Pm+Pl (SUS)	11439	11439	11439	11439	11532	11532	11532	11532
Pm+Pl+Q (Total)	89466	66587	89466	66587	98328	75996	98328	75996

Type of Stress Int.	Max. S.I.	S.I. Allowable	Result
	kPa		
Pm (SUS)	0	159996	Passed
Pm+Pl (SUS)	11532	239994	Passed
Pm+Pl+Q (TOTAL)	98328	479989	Passed

WRC 107/537 Stress Summations:

Vessel Stress Summation at Reinforcing Pad Edge

Type of Stress Int.	Stress Values at (kPa)							
Location	Au	Al	Bu	Bl	Cu	Cl	Du	Dl
Circ. Pm (SUS)	0	0	0	0	0	0	0	0
Circ. Pl (SUS)	21319	21319	21319	21319	14990	14990	14990	14990
Circ. Q (SUS)	78346	-78346	78346	-78346	109247	-109247	109247	-109247
Long. Pm (SUS)	0	0	0	0	0	0	0	0
Long. Pl (SUS)	17930	17930	17930	17930	22851	22851	22851	22851
Long. Q (SUS)	83144	-83144	83144	-83144	51713	-51713	51713	-51713
Shear Pm (SUS)	0	0	0	0	0	0	0	0
Shear Pl (SUS)	0	0	0	0	0	0	0	0
Shear Q (SUS)	0	0	0	0	0	0	0	0
Pm (SUS)	0	0	0	0	0	0	0	0
Pm+Pl (SUS)	21319	21319	21319	21319	22851	22851	22851	22851
Pm+Pl+Q (Total)	101075	65214	101075	65214	124238	94256	124238	94256

Type of Stress Int.	Max. S.I. (kPa)	S.I. Allowable (kPa)	Result
Pm (SUS)	0	159996	Passed
Pm+Pl (SUS)	22851	239994	Passed
Pm+Pl+Q (TOTAL)	124238	479989	Passed

ASME Horizontal Vessel Analysis: Stresses for the Left Saddle

(per ASME Sec. VIII Div. 2 based on the Zick method.)

Horizontal Vessel Stress Calculations : Operating Case

Input and Calculated Values:

Vessel Mean Radius	Rm	375.64	mm
Stiffened Vessel Length per 4.15.6	L	4.84	m
Distance from Saddle to Vessel tangent	a	242.00	mm
Saddle Width	b	204.00	mm
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	306.00	mm
Wear Plate Bearing Angle	theta1	132.00	degrees
Wear Plate Thickness	tr	10.0	mm
Wear Plate Allowable Stress	Sr	186662.33	kPa
Shell Allowable Stress used in Calculation		159996.34	kPa
Head Allowable Stress used in Calculation		153188.00	kPa
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Operating Case		19020.60	N

Horizontal Vessel Analysis Results:	**Actual**	**Allowable**	
Long. Stress at Top of Midspan	18850.32	159996.34	kPa
Long. Stress at Bottom of Midspan	26719.26	159996.34	kPa
Long. Stress at Top of Saddles	22691.75	159996.34	kPa
Long. Stress at Bottom of Saddles	22836.36	159996.34	kPa
Tangential Shear in Shell	4978.86	127997.08	kPa
Circ. Stress at Horn of Saddle	2396.35	199995.42	kPa

```
 Circ. Compressive Stress in Shell        445.42    159996.34  kPa
```

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:

```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.00 * ( 1992.7/2 + 0 ) * 572.0000/650.6314
  = 2627.9 N
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:

```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 263.23 , 0.00 , 0 ) * 572.0000/3499.9995
  = 43.0 N
```

Load Combination Results for Q + Wind or Seismic [Q]:

```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 16392 + Max( 43 , 2627 , 0 , 0 )
  = 19020.6 N
```

Summary of Loads at the base of this Saddle:

```
 Vertical Load (including saddle weight)          19218.81   N
 Transverse Shear Load Saddle                       996.37   N
 Longitudinal Shear Load Saddle                     263.23   N
```

Formulas and Substitutions for Horizontal Vessel Analysis:

Note: Wear Plate is Welded to the Shell, k = 0.1

The Computed K values from Table 4.15.1:

```
 K1  = 0.1066      K2  = 1.1707      K3  = 0.8799      K4  = 0.4011
 K5  = 0.7603      K6  = 0.0529      K7  = 0.0246      K8  = 0.3405
 K9  = 0.2711      K10 = 0.0581      K1* = 0.1923      K6p = 0.0434
 K7P = 0.0203
```

The suffix 'p' denotes the values for a wear plate if it exists.

Note: Dimension a is greater than or equal to Rm / 2.

Moment per Equation 4.15.3 [M1]:

```
= -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
= -19020*0.24[1-(1-0.24/4.84+(0.376²-0.000²)/
  (2*0.24*4.84))/(1+(4*0.00)/(3*4.84))]
= 47.1 N-m
```

Moment per Equation 4.15.4 [M2]:

```
= Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
= 19020*4/4(1+2(0²-0²)/(4²))/(1+(4*0)/
  (3*4))-4*0/4
= 18696.8 N-m
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:

```
= P * Rm/(2t) - M2/(pi*Rm²t)
= 1.300 * 375.642/(2*10.716 ) - 18696.8/(pi*375.6²*10.716 )
= 18850.32 kPa
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:

```
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 1.300 * 375.642/(2 * 10.716 ) + 18696.8/(pi * 375.6² * 10.716 )
= 26719.26 kPa
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:

```
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 1.300*375.642/(2*10.716)-47.1/(0.1066*pi*375.6²*10.716)
= 22691.75 kPa
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:

```
= P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
= 1.300*375.642/(2*10.716)+47.1/(0.1923*pi*375.6²*10.716)
= 22836.36 kPa
```

Maximum Shear Force in the Saddle (4.15.5) [T]:

```
= Q(L-2a)/(L+(4*h2/3))
= 19020 ( 4.84 - 2 * 0.24 )/(4.84 + ( 4 * 0.00/3))
= 17118.5 N
```

Shear Stress in the shell no rings, not stiffened (4.15.14)   [tau2]:

```
= K2 * T / ( Rm * t )
= 1.1707 * 17118.54/( 375.6422 * 10.7156 )
= 4978.86 kPa
```

Decay Length (4.15.22)   [x1,x2]:

```
= 0.78 * sqrt( Rm * t )
= 0.78 * sqrt( 375.642 * 10.716 )
= 49.487 mm
```

Circumferential Stress in shell, no rings (4.15.23)   [sigma6]:

```
= -K5 * Q * k / ( t * ( b + X1 + X2 ) )
= -0.7603 * 19020 * 0.1/( 10.716 * ( 204.00 + 49.49 + 49.49 ) )
= -445.42 kPa
```

Effective reinforcing plate width (4.15.1)   [B1]:

```
= min( b + 1.56 * sqrt( Rm * t ), 2a  )
= min( 204.00 + 1.56 * sqrt( 375.642 * 10.716 ), 2 * 0.242 )
= 302.97 mm
```

Wear Plate/Shell Stress ratio (4.15.29)   [eta]:

```
= min( Sr/S, 1 )
= min( 186662.328/159996.344, 1 )
= 1.0000
```

Circumferential Stress at wear plate (4.15.26)   [sigma6,r]:

```
= -K5 * Q * k / ( B1( t + eta * tr ) )
= -0.7603 * 19020 * 0.1/( 302.974 ( 10.716 + 1.000 * 10.000 ) )
= -230.41 kPa
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.27)   [sigma7,r]:

```
= -Q/(4(t+eta*tr)b1) - 3*K7*Q/(2(t+eta*tr)²)
```

= -19020/(4(10.716 + 1.000 * 10.000)302.974) -

3 * 0.025 * 19020/(2(10.716 + 1.000 * 10.000)^2)

= -2396.35 kPa

ASME Horizontal Vessel Analysis: Stresses for the Right Saddle

(per ASME Sec. VIII Div. 2 based on the Zick method.)

Input and Calculated Values:

Vessel Mean Radius	Rm	375.64	mm
Stiffened Vessel Length per 4.15.6	L	4.84	m
Distance from Saddle to Vessel tangent	a	242.00	mm
Saddle Width	b	204.00	mm
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	306.00	mm
Wear Plate Bearing Angle	theta1	132.00	degrees
Wear Plate Thickness	tr	10.0	mm
Wear Plate Allowable Stress	Sr	95145.48	kPa
Shell Allowable Stress used in Calculation		159996.34	kPa
Head Allowable Stress used in Calculation		153187.98	kPa
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Operating Case		19206.60	N

Horizontal Vessel Analysis Results:	**Actual**	**Allowable**	
Long. Stress at Top of Midspan	18811.84	159996.34	kPa
Long. Stress at Bottom of Midspan	26757.74	159996.34	kPa
Long. Stress at Top of Saddles	22690.84	159996.34	kPa
Long. Stress at Bottom of Saddles	22836.86	159996.34	kPa
Tangential Shear in Shell	5027.55	127997.08	kPa

Circ. Stress at Horn of Saddle	3508.86	199995.42	kPa
Circ. Compressive Stress in Shell	449.78	159996.34	kPa

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:

= Ftr * (Ft/Num of Saddles + Z Force Load) * B / E

= 3.00 * (1992.7/2 + 0) * 572.0000/650.6314

= 2627.9 N

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:

= max(Fl, Friction Load, Sum of X Forces) * B / Ls

= max(263.23 , 0.00 , 0) * 572.0000/3499.9995

= 43.0 N

Load Combination Results for Q + Wind or Seismic [Q]:

= Saddle Load + Max(Fwl, Fwt, Fsl, Fst)

= 16578 + Max(43 , 2627 , 0 , 0)

= 19206.6 N

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	19404.80	N
Transverse Shear Load Saddle	996.37	N
Longitudinal Shear Load Saddle	263.23	N

Formulas and Substitutions for Horizontal Vessel Analysis:

Note: Wear Plate is Welded to the Shell, k = 0.1

The Computed K values from Table 4.15.1:

K1 = 0.1066	K2 = 1.1707	K3 = 0.8799	K4 = 0.4011
K5 = 0.7603	K6 = 0.0529	K7 = 0.0246	K8 = 0.3405
K9 = 0.2711	K10 = 0.0581	K1* = 0.1923	K6p = 0.0434
K7P = 0.0203			

The suffix 'p' denotes the values for a wear plate if it exists.

Note: Dimension a is greater than or equal to Rm / 2.

Moment per Equation 4.15.3 [M1]:

```
  = -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
  = -19206*0.24[1-(1-0.24/4.84+(0.376²-0.000²)/
    (2*0.24*4.84))/(1+(4*0.00)/(3*4.84))]
  = 47.6 N-m
```

Moment per Equation 4.15.4 [M2]:

```
  = Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
  = 19206*4/4(1+2(0²-0²)/(4²))/(1+(4*0)/
    (3*4))-4*0/4
  = 18879.6 N-m
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:

```
  = P * Rm/(2t) - M2/(pi*Rm²t)
  = 1.300 * 375.642/(2*10.716 ) - 18879.6/(pi*375.6²*10.716 )
  = 18811.84 kPa
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:

```
  = P * Rm/(2t) + M2/(pi * Rm² * t)
  = 1.300 * 375.642/(2 * 10.716 ) + 18879.6/(pi * 375.6² * 10.716 )
  = 26757.74 kPa
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:

```
  = P * Rm/(2t) - M1/(K1*pi*Rm²t)
  = 1.300*375.642/(2*10.716)-47.6/(0.1066*pi*375.6²*10.716)
  = 22690.84 kPa
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:

```
  = P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
  = 1.300*375.642/(2*10.716)+47.6/(0.1923*pi*375.6²*10.716)
  = 22836.86 kPa
```

Maximum Shear Force in the Saddle (4.15.5)   [T]:

```
= Q(L-2a)/(L+(4*h2/3))
= 19206 ( 4.84 - 2 * 0.24 )/(4.84 + ( 4 * 0.00/3))
= 17285.9 N
```

Shear Stress in the shell no rings, not stiffened (4.15.14)   [tau2]:

```
= K2 * T / ( Rm * t )
= 1.1707 * 17285.94/( 375.6422 * 10.7156 )
= 5027.55 kPa
```

Decay Length (4.15.22)   [x1,x2]:

```
= 0.78 * sqrt( Rm * t )
= 0.78 * sqrt( 375.642 * 10.716 )
= 49.487 mm
```

Circumferential Stress in shell, no rings (4.15.23)   [sigma6]:

```
= -K5 * Q * k / ( t * ( b + X1 + X2 ) )
= -0.7603 * 19206 * 0.1/( 10.716 * ( 204.00 + 49.49 + 49.49 ) )
= -449.78 kPa
```

Effective reinforcing plate width (4.15.1)   [B1]:

```
= min( b + 1.56 * sqrt( Rm * t ), 2a  )
= min( 204.00 + 1.56 * sqrt( 375.642 * 10.716 ), 2 * 0.242 )
= 302.97 mm
```

Wear Plate/Shell Stress ratio (4.15.29)   [eta]:

```
= min( Sr/S, 1 )
= min( 95145.477/159996.344, 1 )
= 0.5947
```

Circumferential Stress at wear plate (4.15.26)   [sigma6,r]:

```
= -K5 * Q * k / ( B1( t + eta * tr ) )
= -0.7603 * 19206 * 0.1/( 302.974 ( 10.716 + 0.595 * 10.000 ) )
= -289.26 kPa
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.27)   [sigma7,r]:

$= -Q/(4(t+eta*tr)b1) - 3*K7*Q/(2(t+eta*tr)^2)$

$= -19206/(4(10.716 + 0.595 * 10.000)302.974) -$

$3 * 0.025 * 19206/(2(10.716 + 0.595 * 10.000)^2)$

= -3508.86 kPa

ASME Horizontal Vessel Analysis: Stresses for the Left Saddle

(per ASME Sec. VIII Div. 2 based on the Zick method.)

Horizontal Vessel Stress Calculations : Test Case

Input and Calculated Values:

Vessel Mean Radius	Rm	374.05	mm
Stiffened Vessel Length per 4.15.6	L	4.84	m
Distance from Saddle to Vessel tangent	a	242.00	mm
Saddle Width	b	204.00	mm
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	306.00	mm
Wear Plate Bearing Angle	theta1	132.00	degrees
Wear Plate Thickness	tr	10.0	mm
Wear Plate Allowable Stress	Sr	186662.33	kPa
Shell Allowable Stress used in Calculation		159996.34	kPa
Head Allowable Stress used in Calculation		159996.34	kPa
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Test Case, no Ext. Forces		29029.85	N

Horizontal Vessel Analysis Results:	**Actual**	**Allowable**	
Long. Stress at Top of Midspan	23738.80	159996.34	kPa
Long. Stress at Bottom of Midspan	33081.17	159996.34	kPa
Long. Stress at Top of Saddles	28304.99	159996.34	kPa
Long. Stress at Bottom of Saddles	28468.18	159996.34	kPa
Tangential Shear in Shell	5886.89	127997.08	kPa
Circ. Stress at Horn of Saddle	2856.97	239994.52	kPa

```
 Circ. Compressive Stress in Shell        502.10     159996.34   kPa
```

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:

```
  = Ftr * ( Ft/Num of Saddles + Z Force Load ) * B / E
  = 3.00 * ( 657.6/2 + 0 ) * 572.0000/647.8818
  = 870.9 N
```

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:

```
  = max( Fl, Friction Load, Sum of X Forces) * B / Ls
  = max( 263.23 , 0.00 , 0 ) * 572.0000/3499.9995
  = 14.2 N
```

Load Combination Results for Q + Wind or Seismic [Q]:

```
  = Saddle Load + Max( Fwl, Fwt, Fsl, Fst )
  = 28158 + Max( 14 , 870 , 0 , 0 )
  = 29029.8 N
```

Summary of Loads at the base of this Saddle:

```
 Vertical Load (including saddle weight)             29228.05   N
 Transverse Shear Load Saddle                          328.80   N
 Longitudinal Shear Load Saddle                         86.86   N
```

Hydrostatic Test Pressure at center of Vessel: 2.110 N/mm²

Formulas and Substitutions for Horizontal Vessel Analysis:

Note: Wear Plate is Welded to the Shell, k = 0.1

The Computed K values from Table 4.15.1:

```
 K1  = 0.1066     K2  = 1.1707     K3  = 0.8799     K4  = 0.4011
 K5  = 0.7603     K6  = 0.0529     K7  = 0.0249     K8  = 0.3405
 K9  = 0.2711     K10 = 0.0581     K1* = 0.1923     K6p = 0.0434
 K7P = 0.0204
```

The suffix 'p' denotes the values for a wear plate if it exists.

Note: Dimension a is greater than or equal to Rm / 2.

Moment per Equation 4.15.3 [M1]:

```
= -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
= -29029*0.24[1-(1-0.24/4.84+(0.374²-0.000²)/
  (2*0.24*4.84))/(1+(4*0.00)/(3*4.84))]
= 68.4 N-m
```

Moment per Equation 4.15.4 [M2]:

```
= Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
= 29029*4/4(1+2(0²-0²)/(4²))/(1+(4*0)/
  (3*4))-4*0/4
= 28532.1 N-m
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:

```
= P * Rm/(2t) - M2/(pi*Rm²t)
= 2.110 * 374.055/(2*13.891 ) - 28532.1/(pi*374.1²*13.891 )
= 23738.80 kPa
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:

```
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 2.110 * 374.055/(2 * 13.891 ) + 28532.1/(pi * 374.1² * 13.891 )
= 33081.17 kPa
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:

```
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 2.110*374.055/(2*13.891)-68.4/(0.1066*pi*374.1²*13.891)
= 28304.99 kPa
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:

```
= P * Rm/(2t) + M1/(K1* * pi * Rm² * t)
= 2.110*374.055/(2*13.891)+68.4/(0.1923*pi*374.1²*13.891)
= 28468.18 kPa
```

Maximum Shear Force in the Saddle (4.15.5)   [T]:

```
  = Q(L-2a)/(L+(4*h2/3))
  = 29029 ( 4.84 - 2 * 0.24 )/(4.84 + ( 4 * 0.00/3))
  = 26126.9 N
```

Shear Stress in the shell no rings, not stiffened (4.15.14)   [tau2]:

```
  = K2 * T / ( Rm * t )
  = 1.1707 * 26126.86/( 374.0547 * 13.8906 )
  = 5886.89 kPa
```

Decay Length (4.15.22)   [x1,x2]:

```
  = 0.78 * sqrt( Rm * t )
  = 0.78 * sqrt( 374.055 * 13.891 )
  = 56.224 mm
```

Circumferential Stress in shell, no rings (4.15.23)   [sigma6]:

```
  = -K5 * Q * k / ( t * ( b + X1 + X2 ) )
  = -0.7603 * 29029 * 0.1/( 13.891 * ( 204.00 + 56.22 + 56.22 ) )
  = -502.10 kPa
```

Effective reinforcing plate width (4.15.1)   [B1]:

```
  = min( b + 1.56 * sqrt( Rm * t ), 2a  )
  = min( 204.00 + 1.56 * sqrt( 374.055 * 13.891 ), 2 * 0.242 )
  = 316.45 mm
```

Wear Plate/Shell Stress ratio (4.15.29)   [eta]:

```
  = min( Sr/S, 1 )
  = min( 186662.328/159996.344, 1 )
  = 1.0000
```

Circumferential Stress at wear plate (4.15.26)   [sigma6,r]:

```
  = -K5 * Q * k / ( B1( t + eta * tr ) )
  = -0.7603 * 29029 * 0.1/( 316.448 ( 13.891 + 1.000 * 10.000 ) )
  = -291.94 kPa
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.27)   [sigma7,r]:

```
 = -Q/(4(t+eta*tr)b1) - 3*K7*Q/(2(t+eta*tr)²)
 = -29029/(4(13.891 + 1.000 * 10.000 )316.448 ) -
    3 * 0.025 * 29029/(2(13.891 + 1.000 * 10.000 )²)
 = -2856.97 kPa
```

ASME Horizontal Vessel Analysis: Stresses for the Right Saddle

(per ASME Sec. VIII Div. 2 based on the Zick method.)

Input and Calculated Values:

Vessel Mean Radius	Rm	374.05	mm
Stiffened Vessel Length per 4.15.6	L	4.84	m
Distance from Saddle to Vessel tangent	a	242.00	mm
Saddle Width	b	204.00	mm
Saddle Bearing Angle	theta	120.00	degrees
Wear Plate Width	b1	306.00	mm
Wear Plate Bearing Angle	theta1	132.00	degrees
Wear Plate Thickness	tr	10.0	mm
Wear Plate Allowable Stress	Sr	95145.48	kPa
Shell Allowable Stress used in Calculation		159996.34	kPa
Head Allowable Stress used in Calculation		159996.34	kPa
Circumferential Efficiency in Plane of Saddle		1.00	
Circumferential Efficiency at Mid-Span		1.00	
Saddle Force Q, Test Case, no Ext. Forces		29054.60	N

Horizontal Vessel Analysis Results:	Actual	Allowable	
Long. Stress at Top of Midspan	23734.82	159996.34	kPa
Long. Stress at Bottom of Midspan	33085.15	159996.34	kPa
Long. Stress at Top of Saddles	28304.90	159996.34	kPa
Long. Stress at Bottom of Saddles	28468.23	159996.34	kPa

Tangential Shear in Shell	5891.91	127997.08	kPa
Circ. Stress at Horn of Saddle	3910.84	239994.52	kPa
Circ. Compressive Stress in Shell	502.53	159996.34	kPa

Intermediate Results: Saddle Reaction Q due to Wind or Seismic

Saddle Reaction Force due to Wind Ft [Fwt]:

= Ftr * (Ft/Num of Saddles + Z Force Load) * B / E

= 3.00 * (657.6/2 + 0) * 572.0000/647.8818

= 870.9 N

Saddle Reaction Force due to Wind Fl or Friction [Fwl]:

= max(Fl, Friction Load, Sum of X Forces) * B / Ls

= max(263.23 , 0.00 , 0) * 572.0000/3499.9995

= 14.2 N

Load Combination Results for Q + Wind or Seismic [Q]:

= Saddle Load + Max(Fwl, Fwt, Fsl, Fst)

= 28183 + Max(14 , 870 , 0 , 0)

= 29054.6 N

Summary of Loads at the base of this Saddle:

Vertical Load (including saddle weight)	29252.80	N
Transverse Shear Load Saddle	328.80	N
Longitudinal Shear Load Saddle	86.86	N

Hydrostatic Test Pressure at center of Vessel: 2.110 N/mm²

Formulas and Substitutions for Horizontal Vessel Analysis:

Note: Wear Plate is Welded to the Shell, k = 0.1

The Computed K values from Table 4.15.1:

K1 = 0.1066	K2 = 1.1707	K3 = 0.8799	K4 = 0.4011
K5 = 0.7603	K6 = 0.0529	K7 = 0.0249	K8 = 0.3405

```
K9  = 0.2711     K10 = 0.0581     K1* = 0.1923     K6p = 0.0434

K7P = 0.0204
```

The suffix 'p' denotes the values for a wear plate if it exists.

Note: Dimension a is greater than or equal to Rm / 2.

Moment per Equation 4.15.3 [M1]:

```
= -Q*a [1 - (1- a/L + (R²-h2²)/(2a*L))/(1+(4h2)/3L)]
= -29054*0.24[1-(1-0.24/4.84+(0.374²-0.000²)/
  (2*0.24*4.84))/(1+(4*0.00)/(3*4.84))]
= 68.4 N-m
```

Moment per Equation 4.15.4 [M2]:

```
= Q*L/4(1+2(R²-h2²)/(L²))/(1+(4h2)/( 3L))-4a/L
= 29054*4/4(1+2(0²-0²)/(4²))/(1+(4*0)/
  (3*4))-4*0/4
= 28556.4 N-m
```

Longitudinal Stress at Top of Shell (4.15.6) [Sigma1]:

```
= P * Rm/(2t) - M2/(pi*Rm²t)
= 2.110 * 374.055/(2*13.891 ) - 28556.4/(pi*374.1²*13.891 )
= 23734.82 kPa
```

Longitudinal Stress at Bottom of Shell (4.15.7) [Sigma2]:

```
= P * Rm/(2t) + M2/(pi * Rm² * t)
= 2.110 * 374.055/(2 * 13.891 ) + 28556.4/(pi * 374.1² * 13.891 )
= 33085.15 kPa
```

Longitudinal Stress at Top of Shell at Support (4.15.10) [Sigma*3]:

```
= P * Rm/(2t) - M1/(K1*pi*Rm²t)
= 2.110*374.055/(2*13.891)-68.4/(0.1066*pi*374.1²*13.891)
= 28304.90 kPa
```

Longitudinal Stress at Bottom of Shell at Support (4.15.11) [Sigma*4]:

```
= P * Rm/(2t) + M1/(K1* * pi * Rm² * t)

= 2.110*374.055/(2*13.891)+68.4/(0.1923*pi*374.1²*13.891)

= 28468.23 kPa
```

Maximum Shear Force in the Saddle (4.15.5)   [T]:

```
= Q(L-2a)/(L+(4*h2/3))

= 29054 ( 4.84 - 2 * 0.24 )/(4.84 + ( 4 * 0.00/3))

= 26149.1 N
```

Shear Stress in the shell no rings, not stiffened (4.15.14)   [tau2]:

```
= K2 * T / ( Rm * t )

= 1.1707 * 26149.14/( 374.0547 * 13.8906 )

= 5891.91 kPa
```

Decay Length (4.15.22)   [x1,x2]:

```
= 0.78 * sqrt( Rm * t )

= 0.78 * sqrt( 374.055 * 13.891 )

= 56.224 mm
```

Circumferential Stress in shell, no rings (4.15.23)   [sigma6]:

```
= -K5 * Q * k / ( t * ( b + X1 + X2 ) )

= -0.7603 * 29054 * 0.1/( 13.891 * ( 204.00 + 56.22 + 56.22 ) )

= -502.53 kPa
```

Effective reinforcing plate width (4.15.1)   [B1]:

```
= min( b + 1.56 * sqrt( Rm * t ), 2a  )

= min( 204.00 + 1.56 * sqrt( 374.055 * 13.891 ), 2 * 0.242 )

= 316.45 mm
```

Wear Plate/Shell Stress ratio (4.15.29)   [eta]:

```
= min( Sr/S, 1 )

= min( 95145.477/159996.344, 1 )

= 0.5947
```

Circumferential Stress at wear plate (4.15.26)   [sigma6,r]:

```
= -K5 * Q * k / ( B1( t + eta * tr ) )
```

```
  = -0.7603 * 29054 * 0.1/( 316.448 ( 13.891 + 0.595 * 10.000 ) )

  = -351.89 kPa
```

Circ. Comp. Stress at Horn of Saddle, L>=8Rm (4.15.27)   [sigma7,r]:

```
  = -Q/(4(t+eta*tr)b1) - 3*K7*Q/(2(t+eta*tr)²)

  = -29054/(4(13.891 + 0.595 * 10.000 )316.448 ) -

     3 * 0.025 * 29054/(2(13.891 + 0.595 * 10.000 )²)

  = -3910.84 kPa
```

INPUT VALUES, Nozzle Description: Noz N1 Fr10 From : 10

Pressure for Reinforcement Calculations	P	1.0000	N/mm²
Temperature for Internal Pressure	Temp	-40	°C
Shell Material		P355NH	
Shell Allowable Stress at Temperature	f	191484.98	kPa
Shell Allowable Stress At Ambient	fa	191484.98	kPa
Outside Diameter of Flat Head	Di	734.00	mm
Large Diameter of Flat Head	Dl	0.0000	mm
Flat Head Attachment Factor	F	0.41	
Head Finished (Minimum) Thickness	ea	30.0000	mm
Head Internal Corrosion Allowance	c	3.1750	mm
Head External Corrosion Allowance	co	0.0000	mm
Distance from Head Centerline	L1	200.0000	mm

Type of Element Connected to the Shell : Nozzle

Material		A-106 B	
Allowable Stress at Temperature	fn	160996.33	kPa
Allowable Stress At Ambient	fna	160996.33	kPa
Diameter Basis (for tr calc only)		ID	
Layout Angle		270.00	deg
Diameter		100.0000	mm.
Size and Thickness Basis		Nominal	
Nominal Thickness	eb	120	
Flange Material		SA-105	
Flange Type		Weld Neck Flange	

```
Corrosion Allowance                          can       3.1750  mm

Loading Factor applied to ers/eps              C         1.00


Outside Projection                            ho     150.0000  mm

Weld leg size between Nozzle and Pad/Shell    Wo      10.0000  mm

Groove weld depth between Nozzle and Vessel Wgnv      11.1252  mm

User Defined Nozzle/Shell Centerline Angle            90.0000  deg.


Class of attached Flange                           150

Grade of attached Flange                           GR 1.1
```

The Pressure Design option was Design Pressure + static head.

Nozzle analysis - Nozzle on the Flat Head:

Nozzle: Noz N1 Fr10 is on a Flat Head:

The analysis is to be found in the Nozzle Summary

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

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```

Abutting/Set-on Nozzle No Pad

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

```
 Actual Inside Diameter Used in Calculation            92.050  mm.

 Actual Thickness Used in Calculation                  11.125  mm
```

Minimum Nozzle Neck thickness per Table 3.5-4, mm

```
 Branch Nominal Size: 114.3000.  Min. thickness for this size: 8.5750   mm
```

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

INPUT VALUES, Nozzle Description: Noz N2 Fr10 From : 10

Pressure for Reinforcement Calculations	P	1.0000	N/mm²
Temperature for Internal Pressure	Temp	-40	°C
Shell Material		P355NH	
Shell Allowable Stress at Temperature	f	191484.98	kPa
Shell Allowable Stress At Ambient	fa	191484.98	kPa
Outside Diameter of Flat Head	Di	734.00	mm
Large Diameter of Flat Head	Dl	0.0000	mm
Flat Head Attachment Factor	F	0.41	
Head Finished (Minimum) Thickness	ea	30.0000	mm
Head Internal Corrosion Allowance	c	3.1750	mm
Head External Corrosion Allowance	co	0.0000	mm
Distance from Head Centerline	L1	200.0000	mm

Type of Element Connected to the Shell : Nozzle

Material		A-106 B	
Allowable Stress at Temperature	fn	160996.33	kPa
Allowable Stress At Ambient	fna	160996.33	kPa
Diameter Basis (for tr calc only)		ID	
Layout Angle		90.00	deg
Diameter		100.0000	mm.
Size and Thickness Basis		Nominal	
Nominal Thickness	eb	120	
Flange Material		SA-105	
Flange Type		Slip on	

```
Corrosion Allowance                          can      3.1750  mm

Loading Factor applied to ers/eps              C        1.00


Outside Projection                            ho    150.0000  mm

Weld leg size between Nozzle and Pad/Shell    Wo     10.0000  mm

Groove weld depth between Nozzle and Vessel Wgnv      0.0000  mm

User Defined Nozzle/Shell Centerline Angle           90.0000  deg.


Class of attached Flange                           150

Grade of attached Flange                           GR 1.1
```

The Pressure Design option was Design Pressure + static head.

Nozzle analysis - Nozzle on the Flat Head:

Nozzle: Noz N2 Fr10 is on a Flat Head:

The analysis is to be found in the Nozzle Summary

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

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```

Abutting/Set-on Nozzle No Pad

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


```
Actual Inside Diameter Used in Calculation            92.050  mm.

Actual Thickness Used in Calculation                  11.125  mm
```

Minimum Nozzle Neck thickness per Table 3.5-4, mm

```
Branch Nominal Size: 114.3000.  Min. thickness for this size: 8.5750   mm
```

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

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

Pressure for Reinforcement Calculations	P	1.0000	N/mm²
Temperature for Internal Pressure	Temp	-40	°C
Design External Pressure	Pext	0.10	N/mm²
Temperature for External Pressure	Tempex	35	°C
Shell Material		A-106 B	
Shell Allowable Stress at Temperature	f	159996.34	kPa
Shell Allowable Stress At Ambient	fa	159996.34	kPa
Inside Diameter of Cylindrical Shell	Di	734.21	mm
Shell Finished (Minimum) Thickness	ea	13.8906	mm
Shell Internal Corrosion Allowance	c	3.1750	mm
Shell External Corrosion Allowance	co	0.0000	mm
Distance from Bottom/Left Tangent		0.1700	m

Type of Element Connected to the Shell : Nozzle

Material		A-106 B	
Allowable Stress at Temperature	fn	160996.33	kPa
Allowable Stress At Ambient	fna	160996.33	kPa
Diameter Basis (for tr calc only)		OD	
Layout Angle		270.00	deg
Diameter		76.2000	mm.
Size and Thickness Basis		Actual	
Actual Thickness	tn	7.9375	mm
Corrosion Allowance	can	3.1750	mm
Loading Factor applied to ers/eps	C	1.00	

Outside Projection	ho	77.7250	mm
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	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
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)

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```

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

Isolated Nozzle Calculation per PD 5500 3.5.4, Description: Noz N1 Fr20

Actual Outside Diameter Used in Calculation	76.200	mm.
Actual Thickness Used in Calculation	7.938	mm

Nozzle input data check completed without errors.

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

= P * D / (2 * fs - P) + Cas + Caext [Cylindrical Shell]

= 1.0000 * 740.5580/(2 * 0.2E+06 - 1.0000) + 3.1750 + 0.0000

= 5.4964 mm

Nozzle required thickness due to Internal Pressure (epb)

```
  = ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1
  = (1.00*66.6750)/(2*160996.33-1.00)
  = 0.2077 + 3.1750 = 3.3827 mm
```

Dist from Center of Nozzle to Nearest Circ. Seam: 110.000 mm

Mean noz dia / Mean Shl Dia d/D: 71.438 / 751.274 = 0.0951

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

```
  = d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))
  = 71.44/751.27 * (751.27/( 2*( 13.89 - 3.17 + 0.00 )))½
  = 0.5630
```

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

```
  = Max( C * ( eas - Cas + Tp ) /  eps, 1 )
  = Max( 1.00 * ( 13.89 - 3.17 + 0.00 )/2.32 , 1 )
  = Min( 4.6160 , 3.10 )
```

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

```
 Which is: 3.100
```

The following are the curves of rho selected for the analysis:

Values of Rho: 0.500 (Curve1), 0.563 (Computed rho), 0.600 (Curve2)

Values of erb/ers for values of rho: 0.500 , 0.000 , 0.600 , 0.000

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: 76.2000.  Min. thickness for this size: 7.0750   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                   147.6375  mm
```

Effective material Thickness limit	Lb	3.8520	mm
Minimum Reqd Effective width adjacent to Nozzle	Ls	35.7188	mm
Thickness Limit for Nozzle Group Calculation	Tlc	18.4451	mm

The Drop for this Nozzle is : 1.9825 mm

The Cut Length for this Nozzle is, Drop + Ho + H + T : 93.5981 mm

INPUT VALUES, Nozzle Description: Noz N1 Fr40 From : 40

Pressure for Reinforcement Calculations	P	1.3000	N/mm²
Temperature for Internal Pressure	Temp	-40	°C
Design External Pressure	Pext	0.10	N/mm²
Temperature for External Pressure	Tempex	-40	°C
Shell Material		A-106 B	
Shell Allowable Stress at Temperature	f	159996.34	kPa
Shell Allowable Stress At Ambient	fa	159996.34	kPa
Inside Diameter of Cylindrical Shell	Di	734.21	mm
Shell Finished (Minimum) Thickness	ea	13.8906	mm
Shell Internal Corrosion Allowance	c	3.1750	mm
Shell External Corrosion Allowance	co	0.0000	mm
Distance from Bottom/Left Tangent		0.4800	m

Type of Element Connected to the Shell : Nozzle

Material		A-106 B	
Allowable Stress at Temperature	fn	160996.33	kPa
Allowable Stress At Ambient	fna	160996.33	kPa
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		139.7000	mm.
Size and Thickness Basis		Actual	
Actual Thickness	tn	12.7000	mm
Corrosion Allowance	can	3.1750	mm
Loading Factor applied to ers/eps	C	1.00	

```
Outside Projection                              ho      112.6500   mm
Weld leg size between Nozzle and Pad/Shell      Wo       10.0000   mm
Groove weld depth between Nozzle and Vessel Wgnv          8.0000   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)

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```

Abutting/Set-on Nozzle No Pad

Isolated Nozzle Calculation per PD 5500 3.5.4, Description: Noz N1 Fr40

```
Actual Outside Diameter Used in Calculation         139.700   mm.
Actual Thickness Used in Calculation                 12.700   mm
```

Nozzle input data check completed without errors.

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

```
  = P * D / ( 2 * fs - P ) + Cas + Caext [Cylindrical Shell]
  = 1.3000 * 740.5580/( 2 * 0.2E+06 - 1.3000 ) + 3.1750 + 0.0000
  = 6.1957 mm
```

Nozzle required thickness due to Internal Pressure (epb)

= (P * Di) / (2 * f - p) per 3.5.1.2 Eqn. 3.5.1-1

= (1.30*120.6500)/(2*160996.33-1.30)

= 0.4891 + 3.1750 = 3.6641 mm

Dist from Center of Nozzle to Nearest Circ. Seam: 200.000 mm

Mean noz dia / Mean Shl Dia d/D: 130.175 / 751.274 = 0.1733

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

= d/D * sqrt(D / (2 * (eas - Cas + Tp)))

= 130.18/751.27 * (751.27/(2*(13.89 - 3.17 + 0.00)))½

= 1.0259

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

= Max(C * (eas - Cas + Tp) / eps, 1)

= Max(1.00 * (13.89 - 3.17 + 0.00)/3.02 , 1)

= Min(3.5474 , 3.10)

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

Which is: 3.100

The following are the curves of rho selected for the analysis:

Values of Rho: 1.000 (Curve1), 1.026 (Computed rho), 1.200 (Curve2)

Values of erb/ers for values of rho: 1.000 , 0.000 , 1.200 , 0.000

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: 139.7000. Min. thickness for this size: 8.5750 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 269.8750 mm

Effective material Thickness limit	Lb	7.9789	mm
Minimum Reqd Effective width adjacent to Nozzle	Ls	65.0875	mm
Thickness Limit for Nozzle Group Calculation	Tlc	35.2125	mm

The Drop for this Nozzle is : 6.7065 mm

The Cut Length for this Nozzle is, Drop + Ho + H + T : 133.2472 mm

INPUT VALUES, Nozzle Description: Noz N2 Fr40 From : 40

Pressure for Reinforcement Calculations	P	1.3000	N/mm²
Temperature for Internal Pressure	Temp	-40	°C
Design External Pressure	Pext	0.10	N/mm²
Temperature for External Pressure	Tempex	-40	°C
Shell Material		A-106 B	
Shell Allowable Stress at Temperature	f	159996.34	kPa
Shell Allowable Stress At Ambient	fa	159996.34	kPa
Inside Diameter of Cylindrical Shell	Di	734.21	mm
Shell Finished (Minimum) Thickness	ea	13.8906	mm
Shell Internal Corrosion Allowance	c	3.1750	mm
Shell External Corrosion Allowance	co	0.0000	mm
Distance from Bottom/Left Tangent		0.7300	m

Type of Element Connected to the Shell : Nozzle

Material		A-106 B	
Allowable Stress at Temperature	fn	160996.33	kPa
Allowable Stress At Ambient	fna	160996.33	kPa
Diameter Basis (for tr calc only)		OD	
Layout Angle		90.00	deg
Diameter		38.1000	mm.
Size and Thickness Basis		Actual	
Actual Thickness	tn	8.3820	mm
Corrosion Allowance	can	3.1750	mm
Loading Factor applied to ers/eps	C	1.00	

```
 Outside Projection                               ho      39.6250   mm

 Weld leg size between Nozzle and Pad/Shell       Wo      10.0000   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

 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)

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```

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

Isolated Nozzle Calculation per PD 5500 3.5.4, Description: Noz N2 Fr40

```
 Actual Outside Diameter Used in Calculation               38.100   mm.

 Actual Thickness Used in Calculation                       8.382   mm
```

Nozzle input data check completed without errors.

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

```
  = P * D / ( 2 * fs - P ) + Cas + Caext [Cylindrical Shell]

  = 1.3000 * 740.5580/( 2 * 0.2E+06 - 1.3000 ) + 3.1750 + 0.0000

  = 6.1957 mm
```

Nozzle required thickness due to Internal Pressure (epb)

= (P * Di) / (2 * f - p) per 3.5.1.2 Eqn. 3.5.1-1

= (1.30*27.6860)/(2*160996.33-1.30)

= 0.1122 + 3.1750 = 3.2872 mm

Dist from Center of Nozzle to Nearest Circ. Seam: 450.000 mm

Mean noz dia / Mean Shl Dia d/D: 32.893 / 751.274 = 0.0438

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

= d/D * sqrt(D / (2 * (eas - Cas + Tp)))

= 32.89/751.27 * (751.27/(2*(13.89 - 3.17 + 0.00)))½

= 0.2592

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

= Max(C * (eas - Cas + Tp) / eps, 1)

= Max(1.00 * (13.89 - 3.17 + 0.00)/3.02 , 1)

= Min(3.5474 , 3.10)

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

Which is: 3.100

The following are the curves of rho selected for the analysis:

Values of Rho: 0.200 (Curve1), 0.259 (Computed rho), 0.300 (Curve2)

Values of erb/ers for values of rho: 0.200 , 0.000 , 0.300 , 0.000

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: 38.1000. Min. thickness for this size: 6.2750 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 70.9930 mm

Effective material Thickness limit	Lb	1.9213	mm
Minimum Reqd Effective width adjacent to Nozzle	Ls	16.4465	mm
Thickness Limit for Nozzle Group Calculation	Tlc	13.0872	mm

The Drop for this Nozzle is : 0.4946 mm

The Cut Length for this Nozzle is, Drop + Ho + H + T : 54.0102 mm

INPUT VALUES, Nozzle Description: Noz N3 Fr40 From : 40

Pressure for Reinforcement Calculations	P	1.3000	N/mm²
Temperature for Internal Pressure	Temp	-40	°C
Design External Pressure	Pext	0.10	N/mm²
Temperature for External Pressure	Tempex	-40	°C
Shell Material		A-106 B	
Shell Allowable Stress at Temperature	f	159996.34	kPa
Shell Allowable Stress At Ambient	fa	159996.34	kPa
Inside Diameter of Cylindrical Shell	Di	734.21	mm
Shell Finished (Minimum) Thickness	ea	13.8906	mm
Shell Internal Corrosion Allowance	c	3.1750	mm
Shell External Corrosion Allowance	co	0.0000	mm
Distance from Bottom/Left Tangent		2.7800	m

Type of Element Connected to the Shell : Nozzle

Material		A-106 B	
Allowable Stress at Temperature	fn	160996.33	kPa
Allowable Stress At Ambient	fna	160996.33	kPa
Diameter Basis (for tr calc only)		OD	
Layout Angle		270.00	deg
Diameter		76.2000	mm.
Size and Thickness Basis		Actual	
Actual Thickness	tn	7.9375	mm
Corrosion Allowance	can	3.1750	mm
Loading Factor applied to ers/eps	C	1.00	

Outside Projection	ho	77.7250	mm
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	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
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)

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

Isolated Nozzle Calculation per PD 5500 3.5.4, Description: Noz N3 Fr40

Actual Outside Diameter Used in Calculation	76.200	mm.
Actual Thickness Used in Calculation	7.938	mm

Nozzle input data check completed without errors.

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

= P * D / (2 * fs - P) + Cas + Caext [Cylindrical Shell]

= 1.3000 * 740.5580/(2 * 0.2E+06 - 1.3000) + 3.1750 + 0.0000

= 6.1957 mm

Nozzle required thickness due to Internal Pressure (epb)

```
= ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1
= (1.30*66.6750)/(2*160996.33-1.30)
= 0.2703 + 3.1750 = 3.4453 mm
```

Dist from Center of Nozzle to Nearest Circ. Seam: 2340.000 mm

Mean noz dia / Mean Shl Dia d/D: 71.438 / 751.274 = 0.0951

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

```
= d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))
= 71.44/751.27 * (751.27/( 2*( 13.89 - 3.17 + 0.00 )))½
= 0.5630
```

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

```
= Max( C * ( eas - Cas + Tp ) /  eps, 1 )
= Max( 1.00 * ( 13.89 - 3.17 + 0.00 )/3.02 , 1 )
= Min( 3.5474 , 3.10 )
```

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

Which is: 3.100

The following are the curves of rho selected for the analysis:

Values of Rho: 0.500 (Curve1), 0.563 (Computed rho), 0.600 (Curve2)

Values of erb/ers for values of rho: 0.500 , 0.000 , 0.600 , 0.000

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: 76.2000. Min. thickness for this size: 7.0750 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 147.6375 mm

Effective material Thickness limit	Lb	4.3940	mm
Minimum Reqd Effective width adjacent to Nozzle	Ls	35.7188	mm
Thickness Limit for Nozzle Group Calculation	Tlc	18.4451	mm

The Drop for this Nozzle is : 1.9825 mm

The Cut Length for this Nozzle is, Drop + Ho + H + T : 93.5981 mm

INPUT VALUES, Nozzle Description: Noz N4 Fr40 From : 40

Pressure for Reinforcement Calculations	P	1.3000	N/mm²
Temperature for Internal Pressure	Temp	-40	°C
Design External Pressure	Pext	0.10	N/mm²
Temperature for External Pressure	Tempex	-40	°C
Shell Material		A-106 B	
Shell Allowable Stress at Temperature	f	159996.34	kPa
Shell Allowable Stress At Ambient	fa	159996.34	kPa
Inside Diameter of Cylindrical Shell	Di	734.21	mm
Shell Finished (Minimum) Thickness	ea	13.8906	mm
Shell Internal Corrosion Allowance	c	3.1750	mm
Shell External Corrosion Allowance	co	0.0000	mm
Distance from Bottom/Left Tangent		4.8300	m

Type of Element Connected to the Shell : Nozzle

Material		A-106 B	
Allowable Stress at Temperature	fn	160996.33	kPa
Allowable Stress At Ambient	fna	160996.33	kPa
Diameter Basis (for tr calc only)		OD	
Layout Angle		270.00	deg
Diameter		57.1500	mm.
Size and Thickness Basis		Actual	
Actual Thickness	tn	7.4930	mm
Corrosion Allowance	can	3.1750	mm
Loading Factor applied to ers/eps	C	1.00	

Outside Projection	ho	58.6750	mm
Weld leg size between Nozzle and Pad/Shell	Wo	10.0000	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
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)

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

Isolated Nozzle Calculation per PD 5500 3.5.4, Description: Noz N4 Fr40

Actual Outside Diameter Used in Calculation	57.150	mm.
Actual Thickness Used in Calculation	7.493	mm

Nozzle input data check completed without errors.

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

= P * D / (2 * fs - P) + Cas + Caext [Cylindrical Shell]

= 1.3000 * 740.5580/(2 * 0.2E+06 - 1.3000) + 3.1750 + 0.0000

= 6.1957 mm

Nozzle required thickness due to Internal Pressure (epb)

```
  = ( P * Di ) / ( 2 * f - p ) per 3.5.1.2 Eqn. 3.5.1-1

  = (1.30*48.5140)/(2*160996.33-1.30)

  = 0.1967 + 3.1750 = 3.3717 mm
```

Dist from Center of Nozzle to Nearest Circ. Seam: 290.000 mm

Mean noz dia / Mean Shl Dia d/D: 52.832 / 751.274 = 0.0703

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

```
  = d/D * sqrt( D / ( 2 * ( eas - Cas + Tp )))

  = 52.83/751.27 * (751.27/( 2*( 13.89 - 3.17 + 0.00 )))½

  = 0.4164
```

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

```
  = Max( C * ( eas - Cas + Tp ) /  eps, 1 )

  = Max( 1.00 * ( 13.89 - 3.17 + 0.00 )/3.02 , 1 )

  = Min( 3.5474 , 3.10 )
```

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

 Which is: 3.100

The following are the curves of rho selected for the analysis:

Values of Rho: 0.400 (Curve1), 0.416 (Computed rho), 0.500 (Curve2)

Values of erb/ers for values of rho: 0.400 , 0.000 , 0.500 , 0.000

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   109.9820 mm

Effective material Thickness limit	Lb	3.2233	mm
Minimum Reqd Effective width adjacent to Nozzle	Ls	26.4160	mm
Thickness Limit for Nozzle Group Calculation	Tlc	15.1039	mm

The Drop for this Nozzle is : 1.1138 mm

The Cut Length for this Nozzle is, Drop + Ho + H + T : 73.6794 mm

Nozzle Schedule:

Description	Nominal Size mm	Flange Sch/Type Cls		Noz. O/Dia mm	Wall Thk mm	Re-Pad ODia mm	Re-Pad Thick mm	Cut Length mm
Noz N2 Fr40	38	-	None	38.100	8.382	-	-	54
Noz N4 Fr40	57	-	None	57.150	7.493	-	-	73
Noz N1 Fr20	76	-	None	76.200	7.938	-	-	93
Noz N3 Fr40	76	-	None	76.200	7.938	-	-	93
Noz N1 Fr10	100	120	WNF	114.300	11.125	-	-	0
Noz N2 Fr10	100	120	SlipOn	114.300	11.125	-	-	0
Noz N1 Fr40	139	-	None	139.700	12.700	-	-	133

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:

Nozzle	Material	Shl Grve Weld mm	Noz Shl/Pad Weld mm	Pad OD Weld mm	Pad Grve Weld mm	Inside Weld mm
Noz N2	A-106 B	8.000	10.000	-	-	-
Noz N4	A-106 B	8.000	10.000	-	-	-
Noz N1	A-106 B	8.000	10.000	-	-	-

Noz N3	A-106 B	8.000	10.000	-	-	-
Noz N1	A-106 B	11.125	10.000	-	-	-
Noz N2	A-106 B	0.000	10.000	-	-	-
Noz N1	A-106 B	8.000	10.000	-	-	-

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

Nozzle Miscellaneous Data:

Nozzle	Elevation/Distance From Datum m	Layout Angle deg.	Projection Outside mm	Projection Inside mm	Installed In Component
Noz N2 Fr40	0.716	90.00	39.62	0.00	Main Shell
Noz N4 Fr40	4.816	270.00	58.67	0.00	Main Shell
Noz N1 Fr20	0.120	270.00	77.72	0.00	Left Channel
Noz N3 Fr40	2.766	270.00	77.72	0.00	Main Shell
Noz N1 Fr10		270.00	150.00	0.00	Left Head
Noz N2 Fr10		90.00	150.00	0.00	Left Head
Noz N1 Fr40	0.466	90.00	112.65	0.00	Main Shell

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	11.13	...	8.58		
Noz N2 Fr10	11.13	...	8.58		
Noz N1 Fr20	7.94	...	7.08	Passed	N/A
Noz N1 Fr40	12.70	...	8.58	Passed	N/A
Noz N2 Fr40	8.38	...	6.28	Passed	N/A
Noz N3 Fr40	7.94	...	7.08	Passed	N/A
Noz N4 Fr40	7.49	...	6.77	Passed	N/A

Check the Spatial Relationship between the Nozzles

From Node	Nozzle Description	X Coordinate,	Layout Angle,	Mean Radius
10	Noz N1 Fr10	0.000	270.000	0.000
10	Noz N2 Fr10	0.000	90.000	0.000
20	Noz N1 Fr20	170.000	270.000	35.719
40	Noz N1 Fr40	480.000	90.000	65.088
40	Noz N2 Fr40	730.000	90.000	16.446
40	Noz N3 Fr40	2780.000	270.000	35.719
40	Noz N4 Fr40	4830.000	270.000	26.416

If any interferences/violations are found, they will be noted below.

No interference violations have been detected !

Checking Multiple Nozzles on Flat Head per PD 5500 Paragraph 3.5.5.3.1(b):

Comparing Nozzles on Element: Left Head

Corroded Diameter of Flat Head	734.0000	mm
Actual Corroded Head Thickness	26.8250	mm
Required Unpierced Thickness of this Flat Head	25.1102	mm

See below for Computed Thickness of Pierced Flat Head

Note: Min. Ligament should be not less than Smaller (of the pair)
of Nozzles OD/4. This is not stated explicitly in the code.

Sample Calculation for the First Pair: Noz N1 Fr10 & Noz N2

Nozzle	O/Dia	Wall	Corr.	ho	hi	Stress	Angle	Offset
	mm	mm	mm	mm	mm	kPa	Deg	mm
Noz N1	114.300	11.125	3.175	150.000	0.000	160996.3	270.	200.000
Noz N2	114.300	11.125	3.175	150.000	0.000	160996.3	90.	200.000

Nozzle	Inserted/Set-On	
Noz N1	Set-On	Type Nozzle
Noz N2	Set-On	Type Nozzle

Head Factor [C1]:

= 0.410000

Distance Between the Nozzle Centers [j]:

$x1 = 0.0000$ $y1 = -200.0000$ $x2 = 0.0000$ $y2 = 200.0000$ mm

$j = \mathrm{Sqrt}((x2^2 - x1^2) + (y2^2 - y1^2))$

$= \mathrm{Sqrt}((0.000^2 - -200.000^2) + (0.000^2 - 200.000^2))$

$= 400.0000$ mm

Required Thickness for Each Nozzle1 [eb]:

$1 = P*di/(2*fn-P) = 1.000 *98.400/(2*160996.3 -1.000)$

$= 0.30653$ mm

$2 = P*di/(2*fn-P) = 1.000 *98.400/(2*160996.3 -1.000)$

$= 0.30653$ mm

Credit Height for each Nozzle Outside [ho]:

```
1 = 0.8*Sqrt((di+eb)*eb) = 0.8*Sqrt((98.400 +7.644 )*7.644 ) = 22.7763 mm
but L = Min(L, ho) = Min(27.970 , 150.000 ) = 27.9696 mm
2 = 0.8*Sqrt((di+eb)*eb) = 0.8*Sqrt((98.400 +7.644 )*7.644 ) = 22.7763 mm
but L = Min(L, ho) = Min(27.970 , 150.000 ) = 27.9696 mm
```

Credit Height for each Nozzle Inside [hi]:

```
1 = 0.8*Sqrt((di+ebi)*ebi = 0.8*Sqrt((98.400 +4.775 )*4.775 = 0.0000 mm
but Lb = Min(Lb, hi) = Min(0.000 , 0.000 ) = 0.0000 mm
2 = 0.8*Sqrt((di+ebi)*ebi = 0.8*Sqrt((98.400 +4.775 )*4.775 = 0.0000 mm
but Lb = Min(Lb, hi) = Min(0.000 , 0.000 ) = 0.0000 mm
```

Areas Credited each Nozzle [A]:

```
1 = L*eb + Lb*(eb-c) = 27.970 *7.644 + 0.000 *4.775 = 0.0002 m²
2 = L*eb + Lb*(eb-c) = 27.970 *7.644 + 0.000 *4.775 = 0.0002 m²
```

Adjust Area for each Nozzle [A']:

```
1 = Min(A,A*fn/f) = Min(0.000 ,0.000 *160996/191484 ) = 0.0002 m²
2 = Min(A,A*fn/f) = Min(0.000 ,0.000 *160996/191484 ) = 0.0002 m²
```

Compute the Effective Diameter for Each Nozzle [d]:

```
1 = di - 2 * A'/e = 98.400 -2*0.000/26.825 = 84.9979 mm
2 = di - 2 * A'/e = 98.400 -2*0.000/26.825 = 84.9979 mm
```

Compute the Mean of Pair of Nozzles [d]:

```
= (d1 + d2)/2 = (84.998 + 84.998 )/2 = 84.9979 mm
```

Compute the Nozzle Factor [Y1]:

```
= Min(2,(j/(j-d))^0.33
= Min(2,(400.000/(400.000 - 84.998 ))^0.33 = 1.0829
```

Compute the Nozzle Factor [Y2]:

```
= sqrt(j/(j-d))= sqrt(400.000/(400.000 -84.998 ))= 1.1269
```

Compute Head Thickness for Nozzle Reinforcement [e]:

```
  = Max(Y1 * eo, 0.41 * Y2 * D * Sqrt( P / f ) ) + c
  = Max(1.083 * 21.935 , 0.41 * 1.127 * 734.000 *
    Sqrt(1.000/191484.984)) + 3.175
  = 27.6810 mm
```

Compute Allowable Ligament (not explicit in code) [Lig]:

```
  Allowable = Min(d1, d2)/4 = Min(114.300 , 114.300 )/4 = 28.5750 mm
  Actual = 285.7000 mm
```

EN 13445 Paragraph 10.6.2 Ligament Checks for Nozzle Pairs :

Nozzle Pair Description	Equivanlent Noz. Dia. mm	Y1	Y2	j mm
Noz N1 Fr10 & Noz N2	84.998	1.0829	1.1269	400.00

EN 13445 Paragraph 10.6.2 Head Required Thickness for Nozzle Pairs :

Nozzle Pair Description	Ligament Width mm	Ligament Allowable mm	Req. thk. mm	Actual thk. mm
Noz N1 Fr10 & Noz N2	285.70	28.575	27.681	30.000

Minimum Required Flat Head Thickness for Nozzle Reinforcement: 27.6810 mm

No Multiple Nozzle spacing violations have been detected !

Input Echo, TubeSheet Item 1, Description: Gatti

Tubesheet Design Code		PD 5500	
Shell Desc.		Main Shell	
Shell Design Pressure	Ps	1.30	N/mm²
Shell Temperature for Internal Pressure	TEMPS	-40.00	°C
Shell Material		A-106 B	
Shell Allowable Stress at Temperature	Sos	160013.92	kPa
Shell Allowable Stress at Ambient	Sas	159996.34	kPa
Shell Thickness	Ts	13.8906	mm
Shell Internal Corrosion Allowance	Cas	3.1750	mm
Inside Diameter of Shell	Ds	734.219	mm
Mean Metal Temperature for Shell	Tm	-40.00	°C

Channel Desc.		Left Channel Shell	
Channel Design Pressure	Pc	1.00	N/mm²
Channel Temperature for Internal Pressure	TEMPC	-40.00	°C
Channel Material		A-106 B	
Channel Material UNS Number			
Channel Allowable Stress at Temperature	Soc	160013.92	kPa
Channel Allowable Stress at Ambient	Sac	159996.34	kPa
Channel Thickness	Tc	13.8906	mm
Channel Corrosion Allowance	Cac	3.1750	mm
Inside Diameter of Channel	Dc	734.219	mm
Mean Metal Temperature for Tubes	tm	-40.00	°C

Tube Design Temperature	Tubtmp	-40.00	°C
Tube Material		A-106 B	
Tube Allowable Stress at Temperature	Sot	160996.33	kPa
Tube Allowable Stress At Ambient	Sat	160996.33	kPa
Tube Yield Stress At Operating Temperature	Syt	240994.48	kPa
Tube Wall Thickness	Tt	3.3800	mm
Tube Corrosion Allowance	Catt	0.0000	mm
Number of Tubes Holes	Ntubs	136	
Tube Layout Pattern		Triangular	

```
Tube Outside Diameter                          do     33.4000  mm
Tube Pitch (Center to Center Spacing)       PTube     48.0000  mm

Fillet Weld Leg                                af      2.0000  mm
Tube-Tubesheet Joint Classification                      b
Tube Joint Reliability Factor                  fr      0.5500

Straight Tube Length, bet. inner tubsht faces RL    4840.000  mm
Unsupported Tube Length for max. (k*SL)        SL   1600.0000  mm
Tube end condition corres. to span (SL)         k      1.0000
Length of Expanded Portion of Tube              l     10.0000  mm

Tube Bundle Effective outer diameter           Do     689.000  mm
Tube hole diameter                             dh     32.0000  mm
Number of Grooves in tube hole            Ngroove           2
Area of untubed Lanes,                          S        0.00  m²

Tubesheet type:  Fixed Tubesheet Exchanger
Tubesheet Design Metal Temperature        TEMPTS      -40.00  °C
Tubesheet Material                                 A-516 70
Tubesheet Allowable Stress at Temperature   Sots   173329.36  kPa
Tubesheet Allowable Stress at Ambient       Sats   173329.36  kPa
Thickness of Tubesheet                       Tts     36.0000  mm
Tubesheet Corr. Allowance (Shell side)      Cats      3.0000  mm
Tubesheet Corr. Allowance (Channel side)    Catc      3.0000  mm
Depth of Groove in Tube Sheet                 hg      6.0000  mm
Tubesheets Clamped:       Stationary Simply  / Floating Clamped
```

Additional Data for Fixed Tubesheet Exchangers

```
Mean Metal Temperature for Tubesheet        Tshm       21.11  °C
Run Multiple Load Cases for Fixed Tubesheets              No
Is this a Kettle-type configuration                       No
```

Additional Data for Tubesheets Extended as Flanges:

```
Outside Diameter of Flanged Portion            A     850.000  mm
```

Diameter of Bolt Circle	C	810.000	mm
Thickness of Extended Portion of Tubesheet	Tf	56.0000	mm
Nominal Bolt Diameter	dB	16.0000	mm
Type of Thread Series	TEMA Metric Thread		
Number of Bolts	n	24	
Bolt Material			
Bolt Allowable Stress At Temperature	Sb	226994.81	kPa
Bolt Allowable Stress At Ambient	Sa	226994.81	kPa
Weld between Flange and Shell/Channel	WLDH	3.0000	mm
Is Bolt Load Transferred to the Tubesheet		Yes	

Additional Data for Gasketed Tubesheets:

Flange Face Outside Diameter	Fod	790.000	mm
Flange Face Inside Diameter	Fid	762.000	mm
Flange Facing Sketch	Code Sketch 1a		
Gasket Outside Diameter	Go	790.000	mm
Gasket Inside Diameter	Gi	762.000	mm
Gasket Factor,	m	3.7000	
Gasket Design Seating Stress	y	22993.50	kPa
Column for Gasket Seating	Code Column II		
Gasket Thickness	tg	3.1750	mm
Full face Gasket Flange Option	Program Selects		
Tubesheet Gasket on which Side	Side	CHANNEL	

Intermediate Calculations For Tubesheets Extended As Flanges:

British Standard PD 5500:2018

Gasket Contact Width,	N = (Goc-Gic) / 2	14.000	mm
Basic Gasket Width,	b0 = N / 2.0	7.000	mm
Effective Gasket Width,	b = SQRT(b0) * 2.5	6.665	mm
Gasket Reaction Diameter,	G = Go-2.0*b	776.671	mm

<u>Basic Flange and Bolt loads:</u>

Hydrostatic End Load due to Pressure[H]:

= 0.785 * G * G * Peq

```
= 0.7854 * 776.6707 *776.6707 *1.0000

= 473725.562 N
```

Contact Load on Gasket Surfaces[Hp]:

```
= 2 * b * PI * G * m * P

= 2 * 6.6647 * 3.1416 * 776.6707 * 3.7000 * 1.00

= 120325.875 N
```

Hydrostatic End Load at Flange ID[Hd]:

```
= 0.785 * Bcor * Bcor * P

= 0.785 * 768.3500 * 768.3500 *1.0000

= 463629.562 N
```

Pressure Force on Flange Face[Ht]:

```
= H - Hd

= 473725 - 463629

= 10095.987 N
```

Operating Bolt Load[Wm1]:

```
= H + Hp +  H'p (cannot be < 0)

= ( 473725 + 120325 + 0 )

= 594051.438 N
```

Gasket Seating Bolt Load[Wm2]:

```
= y * b * PI * G  + yPart * bPart * lp

= 22993.50*6.6647*3.141*776.671+0.00*0.0000*0.00

= 373901.906 N
```

Required Bolt Area[Am]:

```
= Maximum of Wm1/Sb, Wm2/Sa

= Maximum of 594051 / 226994 , 373901 / 226994

= 0.261645E-02 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( 105.726 /(2 * 16.000 + 6 * 56.000 /(3.700 + 0.5)); 1.0 )
```

= max(0.9716 ; 1.0)

= 1.0000

where the actual circumferential spacing is [Deltab]:

= C * sin(Pi / n))

= 810.000 * sin(3.142 / 24)

= 105.7262 mm

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

Distance Across Corners for Nuts		31.180	mm	
Circular Wrench End Diameter	a	0.000	mm	

	Minimum	Actual	Maximum
Bolt Area, m²	0.003	0.003	
Radial distance bet. hub and bolts	20.640	21.000	
Radial distance bet. bolts and the edge	20.640	20.000	
Circumferential spacing between bolts	44.450	105.726	112.000

Flange Design Bolt Load, Gasket Seating[W]:

= Sa * (Am + Ab) / 2.0

= 226994.81 * (0.0026 + 0.0033) / 2.0

= 673801.50 N

Gasket Seating Force[Hg]:

= Wm1 - H

= 594051 - 473725

= 120325.91 N

Moment Arm Calculations:

Distance to Hub Large End[R]:

= (C - Bcor) / 2 - g1cor

= (810.000 - 768.350) / 2 - 0.000

= 20.8250 mm

Distance to Gasket Load Reaction[hg]:

```
= (C - G ) / 2.0
= ( 810.0000 - 776.6707 ) / 2.0
= 16.6647 mm
```

Distance to Face Pressure Reaction[ht]:

```
= ( R + g1cor + hg ) / 2.0
= ( 20.8250 + 0.0000 + 16.6647 ) / 2.0
= 18.7448 mm
```

Distance to End Pressure Reaction[hd]:

```
= R + ( g1cor / 2.0 )
= 20.8250 + ( 0.0000 / 2.0 )
= 20.8250 mm
```

Summary of Moments for Internal Pressure:

Loading		Force	Distance	Bolt Corr	Moment
End Pressure,	Md	463630.	20.8250	1.0000	9659. N-m
Face Pressure,	Mt	10096.	18.7448	1.0000	189. N-m
Gasket Load,	Mg	120326.	16.6647	1.0000	2006. N-m
Gasket Seating,	Ma	673802.	16.6647	1.0000	11233. N-m

```
Total Moment for Operation,       Mo                     11854. N-m
Total Moment for Gasket Seating,  Ma                     11233. N-m
```

```
Tube Properties - Group # 1.10 and S factor: 1.40
Tube alpha at Metal Temp. along len.     -40.0    0.1081E-04 /°C
Tube Elastic Mod. at Metal Temp. length  -40.0    0.2100E+06 N/mm²

Shell Properties - Group # 1.40 and S factor: 1.40
Shell alpha at Metal Temp. along len.    -40.0    0.1081E-04 /°C
Shell Elastic Mod. at Metal Temp. len    -40.0    0.2100E+06 N/mm²

Tubesheet Properties - Group # 1.40 and S factor: 1.40
```

```
 Tubesheet Elastic Mod. at Design Temp.   -40.0    0.2100E+06 N/mm²


 Channel Properties - Group # 1.40 and S factor: 1.40

 Channel Elastic Mod. at Design Temp.     -40.0    0.2100E+06 N/mm²
```

PD 5500:2012, Paragraph 3.9 Flat Heat Exchanger Tubesheets:

```
 Tubesheet Min Thk, for tube od between 30.000-40.000 is : 25.000 mm

    TMIN = 25.0000 mm

 Min. Thickness + CATS + MAX(CATC,GROOVE)

    TREQMIN = 34.0000 mm
```

Paragraph 3.9.4: Tubesheets of Fixed Tubesheet Exchangers

Note: Iterating to compute Tubesheet Required Thickness per 3.9.4.2:

For the Effective Shell Side Pressure - Bending [e]:

```
  = D1 * sqrt(PB1 /( OmegaS * Mu * f * 4 * H ))
  = 740.569 * sqrt(0.361 /(2.000 * 0.353 * 173329.359 * 4 * 6.772 ))
  = 7.735 mm
```

For the Effective Tubeside Pressure - Bending [e]:

```
  = D2 * sqrt(PB2 /( OmegaT * Mu * f * 4 * H ))
  = 776.671 * sqrt(0.567 /(2.000 * 0.353 * 173329.359 * 4 * 6.772 ))
  = 10.166 mm
```

For the Effective Shellside Pressure - Shear [e]:

```
  = 0.155 * Do * PS1 / (Lambda * Tau)
  = 0.155 * 689.000 * 0.361 / (0.304 * 86664.680 )
  = 1.463 mm
```

For the Effective Tubeside Pressure - Shear [e]:

```
  = 0.155 * Do * PS2 / (Lambda * Tau)
  = 0.155 * 689.000 * 0.384 / (0.304 * 86664.680 )
  = 1.555 mm
```

Tubesheet Extension Reqd Thickness per paragraphs 3.9.3.1 & 3.9.4.1 [e1]:

```
= max( (1.909 * W * hg/(G * fa))½, (1.909 * Wm1 * hg/(G * f))½ )
= (1.909 * W * hg/(G * fa))½  (governing in this case)
= (1.909 * 673801 * 16.665 / (776.671 * 173329.359))½
= 12.619 mm
```

Note: Recomputing Effective Pressures at the given thickness.

Equivalent Shell Side Bolting Pressure - Para 3.9.4.3.5 [PBS]:

```
= 2 * PI * MATM / D2^3
= 2 * 3.142 * 11233 / 776.671 ^3
= 0.151 N/mm²
```

Equivalent Tube Side Bolting Pressure - Para 3.9.4.3.5 [PBT]:

```
= 2 * PI * MOP / D1^3
= 2 * 3.142 * 11854 / 740.569 ^3
= 0.183 N/mm²
```

Ligament Efficiency for Bending - paragraph 3.9.2.1 [Mu]:

```
= (P* - d*h) / P*
= (48.000 - 31.074 ) / 48.000
= 0.353
```

Ligament Efficiency for Shear - paragraph 3.9.2.1 [Lambda]:

```
= (P - dh) / P
= (48.000 - 33.400 ) / 48.000
= 0.304
```

Factor k: para 3.9.4.2 [k]:

```
= 4 * N * Et * et * (d - et) / (L * D1²)
= 4 * 136 * 210000.0 * 3.38 (33.40 - 3.38 ) / (4840.00 * 740.57²)
= 4.3665 N /mm³
```

Differential Factor Kc para 3.9.4.2 [Kc]:

```
= Ec * ec^2.5 / ((12(1 - v^2))^0.75 * (D2 + ec)^0.50)
```

```
  = 210000.016 * 10.716 ^2,5 / ((12(1 - 0.300 ^2))^0.75 *

    (776.671 + 10.716 )^0.50)

  = 468236 N
```

Per 3.9.4.2 - There is a gasket on the tubeside thus: Kc = 0

Differential Factor Ks Para 3.9.4.2 [Ks]:

```
  = Es * es^2.5 / ((12(1 - v^2))^0.75 * (D1 + es)^0.50)

  = 210000.016 * 10.716 ^2,5 / ((12(1 - 0.300 ^2))^0.75 *

    (740.569 + 10.716 )^0.50)

  = 479354 N


  KTheta = Kc + Ks

         = 0 + 479354

         = 479354 N
```

Eta from Figure 3.9-7 or 3.9-8 (e <2P or e >2P) [Eta]:

```
  = 0.39201
```

D* per paragraph 3.9.4.2 [D*]:

```
  = Eta * E * e^3 / (12(1-v^2))

  = 0.392 * 210000.016 * 27.000 ^3 / (12(1 - 0.300 ^2))

  = 148431.250 N-m
```

Beta per paragraph 3.9.4.2 [Beta]:

```
  = (2 * k / D*)^0.25

  = (2 * 4.366 / 148431.250)^0.25

  = 0.156E-01 1/mm
```

xa per paragraph 3.9.4.2 [xa]:

```
  = Beta * D1 / 2

  = 0.016 * 740.569 / 2

  = 5.768
```

z per paragraph 3.9.4.2 [z]:

```
  = 2 * Ktheta / (Beta * D*)

  = 2 * 479354.688 / (0.016 * 148431.250)
```

= 0.415

K per pargapraph 3.9.4.2 [K]:

```
= Es * es * (D - es) / (Et * et * N(d - et))
= 210000.016 * 10.716 * (762.000 - 10.716 ) /
  (136 * 33.400 * 3.380 (33.400 - 3.380 ))
= 0.583
```

Fq From Figure 3.9-9 (using z & xa from above) [Fq]:

```
= 3.60950
```

fs per paragraph 3.9.4.3.1 [fs]:

```
= 1 - N * (d / D1)^2
= 1 - 136.000 * (33.400 / 740.569 )^2
= 0.723
```

ft per paragraph 3.9.4.3.2 [ft]:

```
= 1 - N * ((d - 2 * et) / D1)²
= 1 - 136 * ((33.400 - 2 * 3.380 ) / 740.569 )²
= 0.840
```

Ps' per paragraph 3.9.4.3.1 [Ps']:

J = 1 (No Expansion Joint)

```
X = 0.4*J(1.5 + K(1.5 + fs)) - ((1 - J) / 2) * ((DJ / D1)² - 1)
  = 0.4* 0.100E+01(1.5+0.583 (1.5+0.723 ))-((1- 0.100E+01)/2*
    (740.569 /740.569 )²-1)
  = 1.118832

Ps' = p1 * X / (1 + J * K * Fq)
    = 1.300 * 1.119 / (1 + 0.100E+01 * 0.583 * 3.610 )
    = 0.468 N/mm²
```

Pt' per paragraph 3.9.4.3.2 [Pt']:

```
X = p2 * (1 + 0,4 * J * K * (1.5 + ft))
```

= 1.000 * (1 + 0.4 * 0.100E+01 * 0.583 * (1.5 + 0.840))

= 1.546047 N/mm²

Pt' = X / (1 + J * K * Fq)

= 1.546 / (1 + 0.100E+01 * 0.583 * 3.610)

= 0.498 N/mm²

Differential Thermal Expansion Pressure pe per 3.9.4.3.3:

X = Es * es * (as * ThetaS - at * ThetaT)

= 210000.016 * 10.716 * (0.000011 * -50.002 - 0.000011 * -50.002)

= 0.000 N / mm

Y = X / ((D - 3 * es) * (1 + J * K *Fq))

= 0.000 / ((762.000 - 3 * 10.716) * (1 + 0.100E+01 * 0.583 * 3.610

= 0.000 mm

pe = 4 * J * Y

= 4 * 0.100E+01 * 0.000

= 0.000E+00 N/mm²

Calculation of Shell Side Effective Pressure per 3.9.4.3.1:

Note: Absolute values are given below

PSE0 = 0.667 * (ps' - pe)

= 0.667 * (0.468 - 0.000E+00)

= 0.312 N/mm²

PSE1 = Ps'

= 0.468 N/mm²

PSE2 = Pbs

= 0.151 N/mm²

PSE3 = 0.667 * (ps' - pe - Pbs)

= 0.667 * (0.468 - 0.000E+00 - 0.151)

= 0.212 N/mm²

PSE4 = 0.667 * (Pbs + pe)

= 0.667 * (0.151 + 0.000E+00)

= 0.100 N/mm²

PSE5 = Ps' - Pbs

= 0.468 - 0.151

= 0.318 N/mm²

Maximum shell side effective pressure from above - bending:

```
  PB1 = 0.468 N/mm²
```

Maximum shell side effective pressure from above - shear:

```
  PSE6 = 0.667 * (Ps' - Pe)
       = 0.667 * (0.468 - 0.000E+00)
       = 0.312 N/mm²
  PSE7 = Ps'
       = 0.468 N/mm²
  PSE10 = 0.667 * Pe
        = 0.667 * 0.000E+00
        = 0.000 N/mm²

 Maximum effective pressure for shear:
  P1S = 0.468 N/mm²
```

If PB1 is controlled by term containing pe then Omega = 1.5 else 2.0

```
  OmegaS = 2.000
```

Calculation of tube side effective pressure per 3.9.4.3.2:

Note: Absolute values are given below

```
  When ps' > 0 then:
  PTE0 = 0.667 * (pt' + Pbt + pe)
       = 0.667 * (0.498 + 0.183 + 0.000E+00)
       = 0.454 N/mm²
  PTE1 = pt' + Pbt
       = 0.498 + 0.183
       = 0.681 N/mm²

 When ps' < 0 then:
  PTE2 = 0.667(Pt' - Ps' + Pbt + Pe)
       = 0.667(0.498 - 0.468 + 0.183 + 0.000E+00)
       = 0.142 N/mm²
  PTE3 = pt' - ps' + Pbt
       = 0.498 - 0.468 + 0.183
```

= 0.213 N/mm²

Maximum tube side pressure for bending:

PB2 = 0.681 N/mm²

Maximum Shear: eliminate the Pbs term in above equations

PTE4 = 0.667(Pt' + Pe)

= 0.667(0.498 + 0.000E+00)

= 0.332 N/mm²

PTE5 = pt'

= 0.498 N/mm²

PTE6 = 0.667(pt' - ps' + pe)'

= 0.020 N/mm²

PTE7 = pt' - ps'

= 0.498 - 0.468

= 0.029 N/mm²

If ps' > 0 then PS2 = Max(PTE4, PET5) else ps' = Max(PRE6, PTE7):

PS2 = 0.498 N/mm²

If PB2 is controlled by term containing pe then Omega = 1.5 else 2.0

OmegaT = 2.000

The value of H is taken from Figure 3.9-10 or 3.9-11 using z and xa:

H = 5.934

Shell and Tube Longitudinal Stresses per paragraph 3.9.4.4:

Shell Longitudinal Stress Calculations per 3.9.5:

P* has a maximum positive and maximum negative value:

Maximum positive P* = 0.971 N/mm²

Maximum negative P* = 0.000E+00 N/mm²

Calculated Positive Shell Longitudinal Stress [Fpos]:

= Pstar * (D - es) / (4 * es)

= 0.971 * (762.000 - 10.716) / (4 * 10.716)

= 16866.252 kPa

Max. Allowable Postive Long. Shell Stress = 160013.922 kPa

Calculated Negative Shell Longitudinal Stress [Fneg]:

```
= Pstar * (D - es) / (4 * es)
= 0.000 * (762.000 - 10.716 ) / (4 * 10.716 )
= 0.000 kPa
```

Maximum Allowable Negative Long. Stress, f:

```
pyss = 2 * s' * fshell * es / R
     = 2 * 1.400 * 160013.922 * 10.716 / 375.642
     = 12780.827 kPa

pe = 1.21 * Es * es^2 / R^2
   = 1.21 * 210000.016 * 10.716 ^2 / 5555.396 ^2
   = 206.772 N/mm²

K = pe / pyss
  = 206.772 / 12780.827
  = 16.177
```

DELTA, From figure A-2:

```
= 0.551

fallow = DELTA * s' * fshell
  = 0.551 * 1.400 * 160013.922
fallow = 123459.000 kPa
```

Tube Longitudinal Stresses:

P* has both positive and negative values:

```
P* positive = 0.265 kPa
P* negative = -0.208 N/mm²
```

Calculated Positive Tube Longitudinal Stress [PosStress]:

```
= (Pt*) * Fq * D2² / (4* N* (et - ct) * (d - (et - ct) ))
= (0.27 ) * 3.61 * 776.671² / (4* 136 * 3.380 * (33.400 -
  (3.380 - 0.000 ) ))
```

= 10455.822 kPa

Maximum Allowable Positive Stress [fpos]:

= 160996.328 kPa

Calculated Negative Tube Longitudinal Stress [NegStress]:

= (Pt*) * Fq * D2² / (4* N* (et - ct) * (d - (et - ct)))

= (-0.21) * 3.61 * 776.671² / (4* 136 * 3.380 * (33.400 -

(3.380 - 0.000)))

= -8195.981 kPa

Maximum Allowable Compressive Stress :

C = SQRT(2 * Pi * Et / (s' * ftube)) per para 3.9.5

= SQRT(2 * 3.142 * 210000.016 * / (1.400 * 160996.328))

= 135.609

S = 3.25 - 0.50 * Fq per para 3.9.5 (Bet. 1.25 - 2.0)

= 3.25 - 0.50 * 3.610

= 1.445

fneg = pi^2 * r^2 * Et /(S * Lk^2) (When C <= Lk / r)

= 3.142 ^2 * 10.681 ^2 * 210000.016 / (1.445 * 1600.000 ^2)

= 63901.898 kPa

Allowable Load on the Tube/Tubesheet Joint, per 3.9.6 [Fallow]:

= AreaTube * f * Fr (Jt type b Table 3.9-2)

= 0.000 * 160996.328 * 0.550

= 28225.672 N

The actual loading on the tubes is Max of stress * area_tube [ActualLoad]:

= Max(NegStress, PosStress) * area_tube

= Max(-8195.981 , 10455.822)* 0.000

= 3332.912 N

Summary of Tubesheet Results:

Condition	Req Thk (+CA)	Actual Thk (mm)	Actual Stress	Allow (kPa)	Result
Bending	19.166	36.000	67338.64	346658.72	Ok
Shear	10.555	36.000	6473.06	86664.68	Ok
Min. Per code	34.000	36.000	------	------	Ok
Bolted Exten.	12.619	56.000	8801.02	173329.36	Ok

Longitudinal Stresses:

	Compressive		Tensile		
Condition	Actual	Allow	Actual	Allow	Result
Shell	0.000	**********	16866.252	160013.922	Ok
Long Tubes	-8195.981	-63901.898	10455.822	160996.328	Ok
Tube Load			3332.912	28225.672	Ok

British Standard PD 5500:2018

Diameter Spec : 762.000 mm OD

Vessel Design Length, Tangent to Tangent	5.47	m
Specified Datum Line Distance	0.05	m
Shell Material	A-106 B	
Shell Side Design Temperature	-40	°C
Channel Side Design Temperature	-40	°C
Shell Side Design Pressure	1.300	N/mm²
Channel Side Design Pressure	1.000	N/mm²
Shell Side Hydrostatic Test Pressure	2.106	N/mm²
Channel Side Hydrostatic Test Pressure	1.620	N/mm²
Wind Design Code	ASCE-93	
Earthquake Design Code	UBC-94	

Element Pressures and MAWP: N/mm²

Element Desc	Design Pres. + Stat. head	External Pressure	M.A.W.P	Corrosion Allowance
Left Head	1.000	0.103	1.871	3.1750
Left Channel Shell	1.000	0.103	4.564	3.1750
Flange 30	1.000	0.103	1.321	3.1750
Main Shell	1.300	0.103	4.564	3.1750
Flange 50	1.000	0.103	1.321	3.1750
Right Channel	1.000	0.103	4.564	3.1750
Right head	1.000	0.103	1.876	3.1750

Element Type	"To" Elev m	Length m	Element Thk mm	R e q d T h k Int.	Ext.	Joint Eff Long	Circ

Wld Flat	0.0	0.0	30.0	25.1	No Calc	1.00	1.00
Cylinder	0.2	0.2	13.9	5.5	4.7	0.80	1.00
Body Flg	0.2	0.1	55.0	46.5	46.5	1.00	1.00
Cylinder	5.1	4.8	13.9	6.3	8.0	0.80	1.00
Body Flg	5.2	0.1	55.0	46.5	46.5	1.00	1.00
Cylinder	5.4	0.2	13.9	5.5	4.7	1.00	1.00
Wld Flat	5.4	0.0	30.0	25.1	No Calc	1.00	1.00

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

Saddle Parameters:

Saddle Width	204.000	mm
Saddle Bearing Angle	120.000	deg.
Centerline Dimension	572.000	mm
Wear Pad Width	306.000	mm
Wear Pad Thickness	10.000	mm
Wear Pad Bearing Angle	132.000	deg.
Distance from Saddle to Tangent	242.000	mm

Summary of Maximum Saddle Loads, Operating Case :

Maximum Vertical Saddle Load	19404.81	N
Maximum Transverse Saddle Shear Load	996.37	N
Maximum Longitudinal Saddle Shear Load	263.23	N

Summary of Maximum Saddle Loads, Hydrotest Case :

Maximum Vertical Saddle Load	29252.80	N
Maximum Transverse Saddle Shear Load	328.80	N
Maximum Longitudinal Saddle Shear Load	86.86	N

Weights:

Fabricated	- Bare W/O Removable Internals	3690.1	kgm
Shop Test	- Fabricated + Water (Full)	5745.7	kgm
Shipping	- Fab. + Rem. Intls.+ Shipping App.	3690.1	kgm
Erected	- Fab. + Rem. Intls.+ Insul. (etc)	3690.1	kgm
Empty	- Fab. + Intls. + Details + Wghts.	3690.1	kgm

Operating - Empty + Operating Liquid (No CA)	3690.1	kgm
Field Test - Empty Weight + Water (Full)	5745.7	kgm