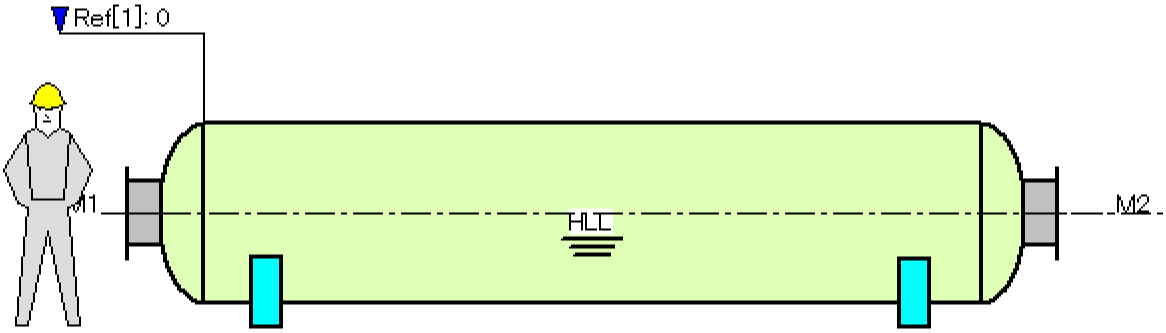
CTC My Address My City	**Design Calculations**	2015-02-19 Revision : C:\...\data\TutorialModel1.emvd



Job Tag :	Description :
Job Name :	Drawing No :

Table of Contents

Update this field to get the table of contents.

Codes, Guidelines and Standards Implemented.

Pressure vessel design code:

ASME VIII DIV.1 2013

Local load design method:

WRC 107 (1979-03)

Standard of flange ratings:

ASME B16.5-2009

Standard for pipes:

ASME B36.10M-2004/B36.19M-2004

Material standard(s) and update(s):

ASME II 2013	SA516GR60	Plate
ASME II 2013	SA106GRB	Seamless pipe
ASME II 2013	SA105	Forging

Units:

SI

g = 9.80665 m/s^2 [Weight (N) = Mass (kg) × g]

Design Conditions.

	Compartment 1	/	/
Internal pressure :	1 MPa	/	/
Required MAWP :		/	/
Design Temperature :	200 °C	/	/
Height of liquid :	500 mm	/	/
Operating fluid spec. gravity :	1	/	/
Corrosion :	3 mm	/	/
External pressure :	-0.103 MPa	/	/
External temperature :	150 °C	/	/
Test Pressure :		/	/
Test fluid spec. gravity :	1	/	/
Insulation Thickness :	100 mm	/	/
Weight/density of insulation :	35 kg/m^3	/	/
Radiography :	Spot	/	/
Weld Type :	Type 1	/	/

Allowable stresses and safety factors

ASME II part D

S	Allowable tensile stress.
S_a	allowable tensile stress under normal conditions.
S_T	Minimum value of tensile strength.
$S_{Y\,0.2}$	Minimum value of yield strength 0.2 %.
$S_{Y\,1.0}$	Minimum value of yield strength 1 %.
S_{Ravg}	Average stress to cause rupture in 100,000 hours at design temperature.
Above room temperature, the value used is the lower of the room and at temperature values.	

Compartment 1		Allowable tensile stress S		
Materials		Normal Conditions	Exceptional and test conditions	Creep
Excluding bolting	Carbon steel	MIN{ $(S_{Y\,0.2} / 1.5)$, $(S_T / 3.5)$ }	$0.9 \times S_{Y\,0.2}$	$S_{Ravg} / 1.5$
	Austenitic stainless steel	MIN{ $(S_{Y\,1.0} / 1.5)$, $(S_T / 3.5)$ }	$0.9 \times S_{Y\,1.0}$	$S_{Ravg} / 1.5$
	Copper	?	$0.9 \times S_{Y\,0.2}$	$S_{Ravg} / 1.5$
	Aluminium	?	$0.9 \times S_{Y\,0.2}$	$S_{Ravg} / 1.5$
	Nickel	?	$0.9 \times S_{Y\,0.2}$	$S_{Ravg} / 1.5$
	Titanium	?	$0.9 \times S_{Y\,0.2}$	$S_{Ravg} / 1.5$
Bolting	Carbon steel	MIN{ $(S_{Y\,0.2} / 4)$, $(S_T / 5)$ }	$S_{Y\,0.2} / 2$	$S_{Ravg} / 1.5$
	Austenitic stainless steel	MIN{ $(S_{Y\,1.0} / 4)$, $(S_T / 5)$ }	$S_T / 3$	$S_{Ravg} / 1.5$
Cast materials		$0.8 \times S$		
Welded pipe		$0.85 \times S$		

Hydraulic Test Pressure

ASME UG-99 (b) : $P_t = 1.3\ MAWP\ (S_a / S)_{min}$
MAWP = maximum allowable pressure *P* = Design Pressure S_a = allowable stress at room temperature, normal operating conditions *S* = allowable stress under normal operating conditions

For each component		*P* (MPa)		S_a (MPa)	*S* (MPa)	*t* (mm)	*c* (mm)	P_t (MPa)
Elliptical Head (01) 30.10		1		118	118	10	3	1.3
Shell (02) 31.05		1		118	118	10	3	1.3
Shell (03) 31.05		1		118	118	10	3	1.3
Shell (04) 31.05		1		118	118	10	3	1.3
Elliptical Head (05) 30.11		1		118	118	10	3	1.3
Nozzle M1	Neck	1		118	118	6.35	3	1.3
	Pad			118	118	10		1.3
	Flange			138	138	42.926		1.3
	Bolting			/	/			/
Nozzle M2	Neck	1		118	118	6.35	3	1.3
	Pad			118	118	10		1.3
	Flange			138	138	42.926		1.3
	Bolting			/	/			/

	Compartment 1	/	/
MAWP	1 MPa	/	/
Test Pressure at the Top :	1.3 MPa	/	/

For vertical vessels with a test in horizontal position : $P_t' = P_t + \Delta P_t$

ΔP_t = additional hydrostatic pressure corresponding to the height of the vertical compartment.

	Compartment 1	/	/
Design Pressure P :	1 MPa	/	/
Test Pressure at the Top :	1.3 MPa	/	/
Hydrostatic pressure ΔP_t :	/	/	/

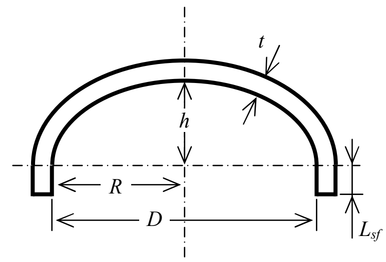
Hydrostatic Pressure

Type of components	Operating				Test							
					Specific Gravity	Horizontal			Vertical			
	Specific Gravity	liquid level	hydrostatic height	Hydrostatic pressure		liquid level	hydrostatic height	Hydrostatic pressure	liquid level	hydrostatic height	Hydrostatic pressure
		(mm)	(mm)	(MPa)		(mm)	(mm)	(MPa)	(mm)	(mm)	(MPa)
Shell(s)											
01 30.10	1	500.00	500.00	0.0049	1	1,380.00	1,380.00	0.0135	0.00	0.00	0.0000
02 31.05	1	500.00	500.00	0.0049	1	1,380.00	1,380.00	0.0135	0.00	0.00	0.0000
03 31.05	1	500.00	500.00	0.0049	1	1,380.00	1,380.00	0.0135	0.00	0.00	0.0000
04 31.05	1	500.00	500.00	0.0049	1	1,380.00	1,380.00	0.0135	0.00	0.00	0.0000
05 30.11	1	500.00	500.00	0.0049	1	1,380.00	1,380.00	0.0135	0.00	0.00	0.0000
Opening(s)											
1 M1	1	/	0.00	0.0000	1	/	690.00	0.0068	/	0.00	0.0000
2 M2	1	/	0.00	0.0000	1	/	690.00	0.0068	/	0.00	0.0000

Element(s) of geometry under internal pressure

Elliptical head (30.10) under internal pressure.

ASME VIII DIV.1 2013



t_n = nominal thickness	E = Weld joint efficiency
S_o= Allowable stress	T = Temperature
S_y = Yield Strength	E_T = modulus of elasticity
t = minimum required thickness	S_a = allowable stress at room temperature
P = internal pressure	S_T = tensile strength at room temperature
D = inside diameter of straight flange	σ = circular stress
R = inside radius of straight flange	P_a = Max. allowable pressure
L = Inside radius Table UG-37	P_h = Hydrostatic pressure
r = Inside radius Table 1-4.4	Ca = corrosion + tolerance
L_{sf} = Straight flange = 50 mm	$Tol_{\%}$ = tolerance for pipes
$t_{min} = (t+Ca)/Tol_{\%}$ shall be $\leq t_n$	$t_s = (t_n \times Tol_{\%})-Ca$ shall be $\geq t$

SA516GR60	Plate				Schedule : /	NPS : /	
t_n = 10.000 mm Seamless	S_T = 414 MPa $D/2h$ = 2	$Tol_{\%}$ = / Cor. = 3 mm	Tol. = 0 mm	UG-16(b) = 1.5 mm	PWHT : No	Radiography : Spot	
	P (MPa)	P_h (MPa)	T (°C)	S_o (MPa)	S_y (MPa)	E_T (MPa)	S_a (MPa)
Operation *N*	1.0049	0.0049	200	118	189	192,000	118
Horizontal test *X*	1.3135	0.0135	20	198.9	221	202,350	198.9
	r (mm)	L (mm)	D_o (mm)	D (mm)	R (mm)	R_o (mm)	h (mm)
Operation *N*	237.600	1,245.000	1,400.000	1,386.000	693.000	700.000	348.000
Horizontal test *X*	237.600	1,245.000	1,400.000	1,386.000	693.000	700.000	348.000

Appendix 1-4 (c)

$K = 1/6\ [2+(D/2h)^2]$

$t = PDK/(2SE-0.2P)$ $\quad \sigma = P\ [DK+ 0.2\ t_s]\ /\ (2E\ t_s)$ $\quad P_a = 2S\ E\ t_s\ /\ [DK+ 0.2\ t_s]$

$t = PD_oK/[2SE+2P(K-0.1)]$ $\quad \sigma = P\ [D_oK - 2t_s(K-0.1)]\ /\ (2E\ t_s)$ $\quad P_a = 2S\ E\ t_s\ /\ [D_oK - 2t_s(K-0.1)]$

	S (MPa)	E	K	t_s (mm)	σ (MPa)	P_a (MPa)	t (mm)	t_{min} (mm)
Operation *N*	118	1	1	7.000	99.59	1.19	5.916	8.916
Horizontal test *X*	198.9	1	1	7.000	130.17	2.01	4.595	7.595

Appendix 1-4 (f) If $0.0005 \leq t_s/L < 0.002$

$r/D \leq 0.08 : C_1 = 9.31r/D-0.086$ $\quad r/D \leq 0.08 : C_2 = 1.25$ $\quad \varphi < \beta : c = a/[\cos(\beta-\varphi)]$

$r/D > 0.08 : C_1 = 0.692r/D+0.605$ $\quad r/D > 0.08 : C_2 = 1.46-2.6r/D$ $\quad \varphi \geq \beta : c = a$

$a = 0.5D-r$ $\quad b = L-r$ $\quad S_e = C_1E_T(t_s/r)$ $\quad R_e = c+r$ $\quad \beta$ = arc cos(a/b), rad $\quad \varphi = (Lt_s)^{0.5}/r$

$$P_e = \frac{S_e t_s}{C_2 R_e\left[(0.5R_e/r)-1\right]} \qquad P_y = \frac{S_y t_s}{C_2 R_e\left[(0.5R_e/r)-1\right]}$$

$P_e/P_y \leq 1.0 : P_{ck} = 0.6P_e$

$1.0 < P_e/P_y \leq 8.29 : P_{ck} = 0.408P_y+0.192P_e$

$P_e/P_y > 8.29 : P_{ck} = 2.0P_y$

$\frac{P_{ck}}{1.5}$ shall be $\geq P$

	t_s/L	C_1	C_2	a (mm)	b (mm)	c (mm)	R_e (mm)
Operation *N*	0.0056	/	/	/	/	/	/
Horizontal test *X*	0.0056	/	/	/	/	/	/
	S_e (MPa)	β (rad)	φ (rad)	P_e (MPa)	P_y (MPa)	P_{ck} (MPa)	$P_{ck}/1.5$ (MPa)
Operation *N*	/	/	/	/	/	/	/
Horizontal test *X*	/	/	/	/	/	/	/

Straight flange

UG-27 (c) $\quad t = PR/(SE-0.6P)$ $\quad \sigma = (PR\ /\ t_s + 0.6P)\ /\ E$ $\quad P_a = S\ E\ t_s\ /\ (R+ 0.6\ t_s)$

Appendix 1-1 (a)(1) $\quad t = PR_o/(SE+0.4P)$ $\quad \sigma = (PR_o\ /\ t_s - 0.4P)\ /\ E$ $\quad P_a = S\ E\ t_s\ /\ (R_o - 0.4\ t_s)$

	S (MPa)	E	t_s (mm)	σ (MPa)	P_a (MPa)	t (mm)	t_{min} (mm)
Operation *N*	118	1	7.000	100.09	1.18	5.941	8.941
Horizontal test *X*	198.9	1	7.000	130.83	2	4.611	7.611

MAWP (200 °C, Corroded) = 1.18 MPa $\quad$ MAWP (20 °C, new) = 1.7 MPa

Table UG-79-1 : Extreme fiber elongation ratio = $75\ t_n\ /\ R_f\ (\ 1 - R_f\ /\ R_o\ )$ = 3.13 % (R_f = 239.6 mm ; $R_o = +\infty$)

Cylindrical shell under internal pressure.

ASME VIII DIV.1 2013

t = minimum required thickness	t_n = nominal thickness	E = Weld joint efficiency
P = internal pressure	S = Allowable stress	T = Temperature
R = Internal Radius	Ca = corrosion + tolerance	σ = circular stress
R_o = outside radius	$Tol_{\%}$ = tolerance for pipes	P_a = maximum allowable pressure
$t_{n,min} = (t+Ca)/Tol_{\%}$ shall be $\leq t_n$	$t_u = (t_n \times Tol_{\%})-Ca$ shall be $\geq t$	P_h = Hydrostatic pressure

UG-27 (c)	$t = P(R+Ca)/(SE\text{-}0.6P)$	$\sigma = (P(R+Ca) / t_u + 0.6P) / E$	$P_a = S\ E\ t_u / ((R+Ca) + 0.6\ t_u)$
Appendix 1-1.(a)(1)	$t = PR_o/(SE+0.4P)$	$\sigma = (PR_o / t_u - 0.4P) / E$	$P_a = S\ E\ t_u / (R_o - 0.4\ t_u)$

Shell (02,03,04) : 31.05 (Barrel)

SA516GR60 Plate — Schedule : / NPS : /

t_n = 10.000 mm — R = 690.00 mm — $Tol_{\%}$ = / — PWHT : No — Radiography : Spot

R_o = 700.00 mm — Cor. = 3 mm — Tol. = 0 mm — UG-16(b) = 1.5 mm

		P (MPa)	P_h (MPa)	T (°C)	S (MPa)	E	t_u (mm)	σ (MPa)	P_a (MPa)	t (mm)	$t_{n,min}$ (mm)
Operation	N	1.0049	0.0049	200	118	0.85	7.000	117.75	1.01	6.985	9.985
Horizontal test	X	1.3135	0.0135	20	198.9	0.85	7.000	153.92	1.7	5.422	8.422

MAWP (200 °C, Corroded) = 1.01 MPa — MAWP (20 °C, new) = 1.44 MPa

Table UG-79-1 : Extreme fiber elongation ratio = $50\ t_n / R_f\ (1 - R_f / R_o)$ = 0.72 % (R_f = 695 mm ; $R_o = +\infty$)

Element(s) of geometry under external pressure

External Pressure – Elliptical Head (Section No. 1) (in operation)

Elements considered :

Tag	Diameter (mm)	Thickness (mm)	modulus of elasticity (MPa)	Vacuum curve	Temperature (°C)
001 30.10 Head	1,400.00	10.000	199,900	CS-2	150.0 °C

ASME VIII DIV.1 2013 UG-33

External Pressure : $P = 0.103$ MPa	modulus of elasticity : $E = 199{,}900$ MPa
Material : SA516GR60	Corrosion : 3 mm
Vacuum curve : CS-2	Tolerance : 0 mm
Thickness as new : $t_n = 10$ mm	External Diameter : $D_o = 1{,}400$ mm
Checked thickness : $t = 7$ mm	outside radius : R_o = /
outside height : $h_o = 355$ mm	Axis ratio : $D_o/(2h_o) = 2$

(*d*) Elliptical heads	
K_o (Table UG-33.1) = 0.887	Equivalent outside radius $R_o = K_o.D_o = 1{,}242.25$ mm
(*a*)(*1*)(*a*) : $E = 1 \Rightarrow P_{a(a)} = 1.67\,P = 0.713$ MPa	
UG-28 (*d*) : $A = \dfrac{0.125}{R_o/t} = 0.000704$	$P_{a(d)} = \dfrac{B}{R_o/t} = 0.4003$ MPa
B (Subpart 3 Section II Part D or $0.0625E/(R_o/t)$) = 71.047 MPa	(*a*)(*1*)(*b*) $P_a = \text{MIN}(P_{a(a)}, P_{a(d)}) = 0.4003 \text{ MPa} \geq P$

External Pressure – Stiffener No. 1 (in operation)

ASME VIII DIV.1 2013

Shell	
External Pressure : P = 0.103 MPa	Temperature : 150 °C
Material : SA516GR60	modulus of elasticity : E = 199,900 MPa
Vacuum curve : CS-2	Corrosion : 3 mm
Thickness as new : t_n = 10 mm	Tolerance : 0 mm
Checked thickness : t = 7 mm	
Calculation length of previous section : L_1 = 3,115 mm	
Calculation length of next section : L_2 = 3,115 mm	

Stiffener	
Type and dimensions : Plate 63.5 × 10	Material : SA516GR60
modulus of elasticity : E = 199,900 MPa	Vacuum curve : CS-2
Cross-sectional area : A_s = 635 mm^2	Diameter of shell at centroid elevation : D_o = 1,400 mm

UG-29 Stiffened elements of cylindrical shells		
t_{s1} = 7 mm	$0.55\sqrt{D_o\, t_{s1}}$ = 54.45 mm	x_1 = 45.36 mm
t_{s2} = 7 mm	$0.55\sqrt{D_o\, t_{s2}}$ = 54.45 mm	x_2 = 45.36 mm
$B = \frac{3}{4}\frac{P\,D_o}{t + A_s / L_s}$ = 544.4722 MPa	$L_s = \frac{L_1 + L_2}{2}$ = 3,115 mm	t_{eq} = 7 mm
A (Subpart 3 Section II Part D FIG.G or $2B/E$) = 0.000168	$I_s = \frac{D_o^2 L_s (t + A_s / L_s) A}{14}$ = 606,082 mm^4	$I_s' = \frac{D_o^2 L_s (t + A_s / L_s) A}{10.9}$ = /
I = 610,479.6 mm^4 $\geq I_s$		

External Pressure - Summary (in operation)

Section	Component(s)		Diameter (mm)	Thickness (mm)
Section No. 1 Length : 0 mm ok (1)	1	[05]	1,400	10

Section	Component(s)		Diameter (mm)	Thickness (mm)
Section No. 2 Length : 3,115 mm ok (1)	1	[05]	1,400	10
	2	[01]	1,400	10
	3	[01]	1,400	10

Section	Component(s)		Diameter (mm)	Thickness (mm)
Section No. 3 Length : 3,115 mm ok (1)	3	[01]	1,400	10
	4	[01]	1,400	10
	5	[05]	1,400	10

Section	Component(s)		Diameter (mm)	Thickness (mm)
Section No. 4 Length : 0 mm ok (1)	5	[05]	1,400	10

(1) : # = unchecked element (revise design)
0 = unchecked element, without external pressure (P=0)
ok = checked element

Vessel under combination loading

Model for analysis of stress due to support.

Reactions per support, bending moment and shear loads are studied using a beam model on simple supported, with one of the supports fixed either to the left or the right of the beam.

The beam is studied using the reduction process which is based on the Falk transmission matrices.

Support conditions allow for resolution of the moment and the rotation which are not subject to discontinuity when crossing the support.

External single load and moment are applied at their acting point and are considered as a discontinuity similar to a change in inertia or modulus of elasticity. Distributed loads do not constitute a discontinuity.

Reference axes are : beam x on the right, y up with positive loads down, moments > 0 from x to y.

Shell, liquid, and bundle own weight are considered as distributed loads while head weight, flange and cover, floating head and nozzle are considered as concentrated loads.

Termination heads are removed and replaced as a concentrated load and an external moment. Hydrostatic height also creates an external moment as a result of the hydrostatic pressure applied to its location

Each design case in analysed in the vertical and/or horizontal plane. The saddle reactions and bending moment used to check shell stresses are the vector sum of the two planes. This also provides the new angle where the shell stress should be checked

Thermal effects are considered by the friction factor to be an additional moment at the saddle location. A fixed saddle balances all horizontal reactions. ($\mu = 0.3$)

Principal stresses are $f_1 = 0.5\left[\sigma_\theta + \sigma_z + \sqrt{(\sigma_\theta - \sigma_z)^2 + 4\,\tau^2}\right]$ and $f_2 = 0.5\left[\sigma_\theta + \sigma_z - \sqrt{(\sigma_\theta - \sigma_z)^2 + 4\,\tau^2}\right]$ and general primary membrane stress intensity is σ_{eq} = , with σ_θ: circumferential stress , σ_z: longitudinal stress and τ: shear stress.

Saddle stresses are studied in the 3 axes.

For the purpose of wind and earthquake design, vibration periods are evaluated using the general modal equation $[k-\omega^2.m]\ \Phi = 0$ and solving the eigenvectors and eigenvalues.

The flexibility matrix 1/k is derived using the beam analysis method, using successive unit loads applied at the mass location.

The resulting dynamic matrix is 1/g.1/k.m where g = acceleration due to gravity and m = mass matrix.

Eigenvectors correspond to the natural modes and eigenvalues to their frequencies.

Subtracting the mode under study from the starting vector allows for study of the higher mode

The Dunkerley method is used for stacked vessels. This enables the global circular frequency to be determined to $1/\omega^2 = 2/\omega_1^2$ where ω_1 is the circular frequency of one vessel. The final period is $T = 2\pi/\omega$

Location of dominant stresses and worst cases.

Cases studied :			
1	**Operation Int.Max.P. (Corroded Weight)**	5	Shutdown (Corroded Weight)
2	Lifting (New Weight)	**6**	**Operation Ext.P. (Corroded Weight)**
3	Erected (New Weight)	7	During test P = 0. (Corroded Weight)
4	During test Int.Max.P. (Corroded Weight)		
(++)	vertical downside and horizontal longitudinal to the right	(−+)	vertical upside and horizontal longitudinal to the right
(+−)	vertical downside and horizontal longitudinal to the left	(−−)	vertical upside and horizontal longitudinal to the left
(+)	vertical downside and horizontal cross	(−)	vertical upside and horizontal cross

Verification of shell between the supports				
1	02[01]	Primary membrane stress intensity (highest point)	60.7 ≤ 118 MPa	(51%)
6	03[01]	Longitudinal compressive stress (highest point)	**6.8 ≤ 90.9 MPa**	**(8%)**
1	03[01]	Primary membrane stress intensity (lowest point)	61.1 ≤ 118 MPa	(52%)
6	02[01]	Longitudinal compressive stress (lowest point)	6.4 ≤ 90.9 MPa	(7%)
6	03[01]	Stability	**0.7761 ≤ 1**	**(78%)**

Verification of shell in the plane of the supports				
1	No. 2	Primary membrane stress intensity (highest point, left)	**59.2 ≤ 118 MPa**	**(50%)**
1	No. 1	Primary membrane stress intensity (highest point, right)	59.2 ≤ 118 MPa	(50%)
1	No. 2	Primary membrane stress intensity (lowest point, left)	**55.2 ≤ 118 MPa**	**(47%)**
1	No. 1	Primary membrane stress intensity (lowest point, right)	55.2 ≤ 118 MPa	(47%)
6	No. 1	Longitudinal compressive stress (highest point, left)	1.5 ≤ 90.9 MPa	(2%)
6	No. 2	Longitudinal compressive stress (highest point, right)	1.5 ≤ 90.9 MPa	(2%)
6	No. 2	Longitudinal compressive stress (lowest point, left)	10.1 ≤ 90.9 MPa	(11%)
6	No. 1	Longitudinal compressive stress (lowest point, right)	10.1 ≤ 90.9 MPa	(11%)
4	No. 2	Tangential shearing stress in the shell	10.4 ≤ 159.1 MPa	(7%)
/	No. /	Tangential shearing stress in the head	/	
/	No. /	Circumferential stress (compression) (edge of support)	/	
4	No. 2	Circumferential stress (compression) (edge of the plate)	17.8 ≤ 198.9 MPa	(9%)
4	No. 2	Circumferential stress (compression + bending) (edge of the support)	60.6 ≤ 248.6 MPa	(24%)
/	No. /	Circumferential stress (compression + bending) (edge of the plate)	/	
/	No. /	Circumferential stress (compression + bending) (edge of the support + stiffener)	/	
/	No. /	Circumferential stress (compression + bending) (edge of the plate + stiffener)	/	
/	No. /	Circumferential stress (compression + bending) in stiffener (edge of the support)	/	
/	No. /	Circumferential stress (compression + bending) in stiffener (edge of the plate)	/	

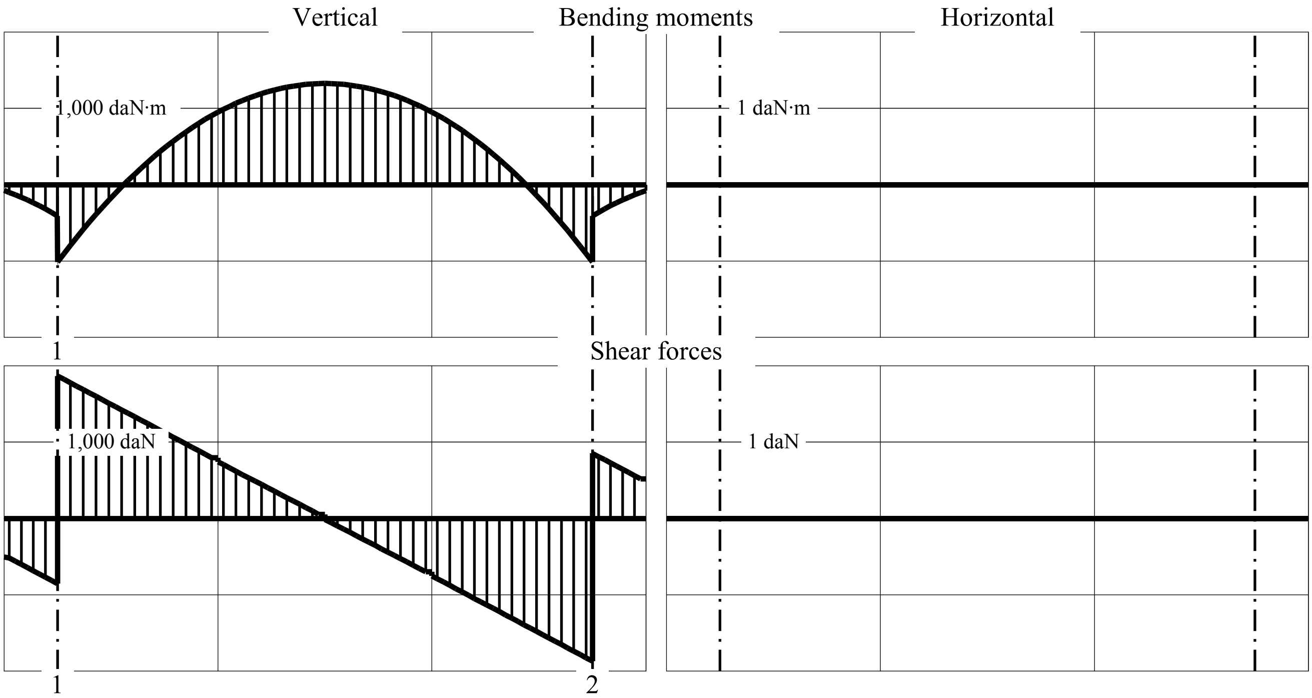
Support check				
4	No. 2	Stress at the low point of the saddle	6.4 ≤ 198.9 MPa	(3%)
1	No. 2	Maximum bending stress	3 ≤ 170.1 MPa	(2%)
4	No. 2	Compressive stress	2.3 ≤ 159.1 MPa	(1%)
1	No. 2	Combined bending and compression	0.0287 ≤ 1	(3%)
2	No. 1	Tensile stress in the bolts	-12.6 ≤ 100 MPa	(-13%)
/	No. /	Stability (Number of ribs ≤ 2)	/	
1	No. 1	Shear stress in the bolts	**6.7 ≤ 100 MPa**	**(7%)**

Case 1 - Operation Int.Max.P. (Corroded Weight) .

Moments and loads in plane of saddles.

No.	Support saddles Location (mm) *Stiffness (daN/mm)*	Vertical			Horizontal				Combined		
		Reactions (daN)	Shear Loads (daN)	Bending moments (daN·m)	Reactions Transverse (daN)	Shear Loads (daN)	Bending moments (daN·m)	Reactions Longitudinal (daN)	Reactions (daN)	Shear Loads (daN)	Bending moments (daN·m)
1	500.0	2,721.0	-852.1 1,869.0	-408.5 -1,012.8	0.0	0.0	0.0	864.7	2,721.0	-852.1 1,869.0	-408.5 -1,012.8
2	5,500.0	2,722.6	-1,869.4 853.1	-1,013.6 -409.3	0.0	0.0	0.0	-864.7	2,722.6	-1,869.4 853.1	-1,013.6 -409.3

Graph of bending moments and shear forces.



Vibration Periods and Center of Gravity.

Mode	1	2	3	4	5	Center of Gravity
Period	12.02659×10^{-3} s	3.337675×10^{-3} s	1.855573×10^{-3} s	1.324342×10^{-3} s	920.195×10^{-6} s	3,001 mm

maximum Longitudinal Bending Stress Verification.

Circumferential stress : $\sigma_\theta = (P+\Delta P_\pm)R / t$ — $\Delta P_\pm$: Hydrostatic pressure — f_t : allowable tensile stress

Longitudinal stress : $\sigma_z = P_m R / 2t \pm M K_{12} / \pi R^2 t$ — P_m : Pressure at the vessel equator — f_c : allowable compressive stress

General primary membrane stress intensity : $\sigma_{eq} = MAX(| \sigma_\theta - \sigma_z | ; | \sigma_z - 0.5 P |)$ — K_{12} : Coef. EN 13445-3 (16.8-11)

Maximum allowable moment : $M_{max} = \pi R^2 t f_c$ — P_{max} : allowable external pressure

Component : 02[01] 31.05 P = 1 MPa

Maximum general primary membrane stress intensity : σ_{eq} shall be $\leq f_t$

Location (mm)		M (daN·m)	R (mm)	K_{12}	P_m (MPa)	σ_θ (MPa)	σ_z (MPa)	σ_{eq} (MPa)	E_l	E_c	f_t (MPa)
500.0	-	-1,014.7	696.5	1.3752	1.00	99.50	51.06	60.66	0.85	0.85	118.00
500.0	+	-1,014.7	696.5	1.3752	1.00	99.50	48.44	60.07	0.85	0.85	118.00

Maximum longitudinal compressive stress : $\sigma_z < 0 \Rightarrow |\sigma_z|$ shall be $\leq$ MIN(f_t ; f_c)

Location (mm)		M (daN·m)	R (mm)	K_{12}	P_m (MPa)	σ_z (MPa)	E	f_t (MPa)	f_c (MPa)
2,050.0	-	988.5	696.5	1.3752	1.00	48.48	1	118.00	82.17
500.0	+	-1,014.7	696.5	1.3752	1.00	48.44	1	118.00	82.17

Proof of stability : $|P| / P_{max} + |M| / M_{max}$ shall be $\leq$ 1.0 ($P > 0 \Rightarrow P = 0$)

Location = 500 mm f_c = 82.17 MPa M = -1,014.7 daN·m M_{max} = 87,662.7 daN·m P_{max} = +∞ MPa Stab. = 0.0116

Component : 03[01] 31.05 P = 1 MPa

Maximum general primary membrane stress intensity : σ_{eq} shall be $\leq f_t$

Location (mm)		M (daN·m)	R (mm)	K_{12}	P_m (MPa)	σ_θ (MPa)	σ_z (MPa)	σ_{eq} (MPa)	E_l	E_c	f_t (MPa)
3,000.0	-	1,328.9	696.5	1.3752	1.00	99.50	48.04	60.54	0.85	0.85	118.00
3,000.0	+	1,328.9	696.5	1.3752	1.00	99.50	51.46	61.13	0.85	0.85	118.00

Maximum longitudinal compressive stress : $\sigma_z < 0 \Rightarrow |\sigma_z|$ shall be $\leq$ MIN(f_t ; f_c)

Location (mm)		M (daN·m)	R (mm)	K_{12}	P_m (MPa)	σ_z (MPa)	E	f_t (MPa)	f_c (MPa)
3,000.0	-	1,328.9	696.5	1.3752	1.00	48.04	1	118.00	82.17
4,050.0	+	912.9	696.5	1.3752	1.00	50.93	1	118.00	82.17

Proof of stability : $|P| / P_{max} + |M| / M_{max}$ shall be $\leq$ 1.0 ($P > 0 \Rightarrow P = 0$)

Location = 3,000 mm f_c = 82.17 MPa M = 1,328.9 daN·m M_{max} = 87,662.7 daN·m P_{max} = +∞ MPa Stab. = 0.0152

Component : 04[01] 31.05 P = 1 MPa

Maximum general primary membrane stress intensity : σ_{eq} shall be $\leq f_t$

Location (mm)		M (daN·m)	R (mm)	K_{12}	P_m (MPa)	σ_θ (MPa)	σ_z (MPa)	σ_{eq} (MPa)	E_l	E_c	f_t (MPa)
5,499.0	-	-1,013.6	696.5	1.3752	1.00	99.50	51.06	60.65	0.85	0.85	118.00
5,499.0	+	-1,013.6	696.5	1.3752	1.00	99.50	48.44	60.07	0.85	0.85	118.00

Maximum longitudinal compressive stress : $\sigma_z < 0 \Rightarrow |\sigma_z|$ shall be $\leq$ MIN(f_t ; f_c)

Location (mm)		M (daN·m)	R (mm)	K_{12}	P_m (MPa)	σ_z (MPa)	E	f_t (MPa)	f_c (MPa)
4,050.0	-	912.9	696.5	1.3752	1.00	48.57	1	118.00	82.17
5,499.0	+	-1,013.6	696.5	1.3752	1.00	48.44	1	118.00	82.17

Proof of stability : $|P| / P_{max} + |M| / M_{max}$ shall be $\leq$ 1.0 ($P > 0 \Rightarrow P = 0$)

Location = 5,499 mm f_c = 82.17 MPa M = -1,013.6 daN·m M_{max} = 87,662.7 daN·m P_{max} = +∞ MPa Stab. = 0.0116

Saddle No. 1

Calculation method : ASME + Zick information	
Material of saddle : SA516GR60	Distance a = 500 mm
Pressure : P = 1 MPa	Length L = 6,000 mm
Horizontal (longitudinal) reaction : Ra_{HL} = 864.7 daN	Weight of saddle : W_s = 159.8 daN
Horizontal (cross) reaction : Ra_H = 0 daN	Vertical Load : Ra_V = 2,721 daN
Maximum shear load : T = 1,869 daN	Reaction at support : Q = 2,721 daN

Shell	Allowable stress	S	118 MPa	Pad (not considered)	Allowable stress	S_r	/
	All. compres. stress	S_c	82.2 MPa		Thickness	t_r	*14 mm*
	Modulus of elasticity	E_y	192,000 MPa		Width	b_1	*250 mm*
	Thickness	t	7 mm		Angle	θ_1	*132.28 °*
	Mean radius	R_m	696.5 mm		$\theta r = \theta_1 - 2.\arctan(\lvert Ra_H\rvert / Ra_V)$		*132.28 °*
Head	Allowable stress	S_h	118 MPa		$b+1.56(R_m.t)^{0.5}$ = *358.9 mm*		
	Thickness	t_h	7 mm		2a = *1,250 mm*	$\theta+12°$ = *132 °*	
	Depth	h_2	355 mm	Saddle	Yield Strength	Leb	189 MPa
Stiffener	Allowable stress	S_s	/		Width	b	250 mm
					Angle	θ	120 °
					$\theta = \theta - 2.\arctan(\lvert Ra_H\rvert / Ra_V)$		120 °

Longitudinal stresses at the saddle level with a support

$$\sigma_3^* = \frac{P.R_m}{2t} - \frac{M_1}{K_1 \pi R_m^2 t} = 53.34 \text{ MPa} / 58.66 \text{ MPa}$$

Si $\sigma^*_3 < 0$ (Compressive) : $\lvert \sigma^*_3 \rvert \le S_c$

σ_{eq} = 53.84 MPa /59.16 MPa $\le$ SE

$$\sigma_4^* = \frac{P.R_m}{2t} + \frac{M_1}{K_1^* \pi R_m^2 t} = 47.76 \text{ MPa} / 44.81 \text{ MPa}$$

Si $\sigma^*_4 < 0$ (Compressive) : $\lvert \sigma^*_4 \rvert \le S_c$

σ_{eq} = 52.23 MPa / 55.17 MPa $\le$ SE

M_1 = -408.54 daN·m / -1,012.83 daN·m ; K_1 = 0.107 ; K^*_1 = 0.192 ; $\sigma_{eq} = \max(\lvert\sigma_\theta - \sigma^*_{3/4}\rvert , \lvert \sigma^*_{3/4} + 0.5P\rvert)$;
$\sigma_\theta = P.R_m / t$ (P = 1.005 MPa) ; E = 1

shear stress

K_2 = 1.1707 — $\tau_2 = K_2.T/(R_m.t)$ = 4.49 MPa $\le$ 94.4 MPa

Circumferential stress

k = 1 — x_1 = 54.5 mm — x_2 = 54.5 mm

K_5 (Table 4.15.1) = 0.7603	$\sigma_6 = (-K_5 Q/(b+x_1+x_2)t)k$ = -8.23 MPa	$\lvert\sigma_6\rvert \le S$
K_7 (Table 4.15.1) = 0.0305	$\sigma_7 = \frac{-Q}{4t(b+x_1+x_2)} - \frac{3K_7 Q}{2t^2}$ = -28.1 MPa	$\lvert\sigma_7\rvert \le 1.25$ S

Saddle check

Stress due to horizontal reaction on the saddle

K = (1+ cos β – 0.5 sin² β) / (π – β + sin β cos β) =0.2035 — β = 2.0944 rad

H = K Q = 5,538 N — A_b = 2,800 mm² — $S_b = H / (2/3\ A_b)$ = 2.97 MPa ≤ (90% Leb) (170.1 MPa)

Bending and compression stresses

H_b = 900 mm $M_{zz} = Ra_H . H_b + Ra_H . (2H_b + H_t)$ — L_{EFF} = 200 mm $M_{xx} = Ra_{HL} . L_{EFF}$

$I_{zz} = 4.773029\times10^9$ mm⁴ $S_{zz} = I_{zz}/v$ = 9,358,883 mm³ — $I_{xx} = 73.1371\times10^6$ mm⁴ $S_{xx} = I_{xx}/v$ = 585,096.8 mm³

$\lvert M_{zz}\rvert$ = 0 daN·m $Sb_z = \lvert M_{zz}\rvert / S_{zz}$ — $\lvert M_{xx}\rvert$ = 172.95 daN·m $Sb_x = \lvert M_{xx}\rvert / S_{xx}$

Sb_z = 0 MPa ≤ (90% Leb) (170.1 MPa) — Sb_x = 2.96 MPa ≤ (90% Leb) (170.1 MPa)

A = 27,496 mm² f_b = 118 MPa $Sb_c = Ra_V / A$ — Sb_c = 0.99 MPa ≤ (0.8 f_b) (94.4 MPa)

$\max(Sb_z ; Sb_x) / (90\% Leb) + Sb_c / (0.8 f_b) \le 1$

Stability of web plate [CODAP C9.3.2.7] [AD S3/2 6.1.1]

h_{b2} = 550 mm l_b = 1,212.4 mm e_{ba} = 14 mm E_b = 192,000 MPa f_b = 90% Leb = 170.1 MPa

$\varepsilon_b = f_b 10^3 / E_b$ $x = h_{b2} / l_b$ K_b = 1.255 φ = 0.522 $Q_{max} = l_b e_{ba} f_b \varphi$ = 150,739.4 daN

Stresses in the bolts (n_b = 4 ; S_b = 324.3 mm² ; x_b = 580 mm)

Max. Tensile : $\sigma_{bT} = \max\{ 0 ; [\lvert M_{zz}\rvert / (x_b. n_b/2) - (Ra_V + W_S)/n_b] / S_b \}$ = -22.21 MPa ≤ 100 MPa

Max. Shear : $\sigma_{bL} = [Ra_{HL}/ S_b] / n_b$ = 6.67 MPa ≤ 100 MPa

Saddle No. 2

Calculation method : ASME + Zick information	
Material of saddle : SA516GR60	Distance a = 500 mm
Pressure : P = 1 MPa	Length L = 6,000 mm
Horizontal (longitudinal) reaction : Ra_{HL} = -864.7 daN	Weight of saddle : W_s = 159.8 daN
Horizontal (cross) reaction : Ra_H = 0 daN	Vertical Load : Ra_V = 2,722.6 daN
Maximum shear load : T = 1,869.4 daN	Reaction at support : Q = 2,722.6 daN

Shell	Allowable stress	S	118 MPa	Pad (not considered)	Allowable stress	S_r	/
	All. compres. stress	S_c	82.2 MPa		Thickness	t_r	*14 mm*
	Modulus of elasticity	E_y	192,000 MPa		Width	b_1	*250 mm*
	Thickness	t	7 mm		Angle	θ_1	*132.28 °*
	Mean radius	R_m	696.5 mm		$\theta r = \theta_1 - 2.\arctan(\lvert Ra_H \rvert / Ra_V)$		*132.28 °*
Head	Allowable stress	S_h	118 MPa		$b+1.56(R_m.t)^{0.5}$ = *358.9 mm*		
	Thickness	t_h	7 mm		2a = *1,250 mm*		$\theta+12°$ = *132 °*
	Depth	h_2	355 mm	Saddle	Yield Strength	Leb	189 MPa
Stiffener	Allowable stress	S_s	/		Width	b	250 mm
					Angle	θ	120 °
					$\theta = \theta - 2.\arctan(\lvert Ra_H \rvert / Ra_V)$		120 °

Longitudinal stresses at the saddle level with a support	
$\sigma_3^* = \frac{P.R_m}{2t} - \frac{M_1}{K_1 \pi R_m^2 t}$ = 58.66 MPa / 53.35 MPa	$\sigma_4^* = \frac{P.R_m}{2t} + \frac{M_1}{K_1^* \pi R_m^2 t}$ = 44.81 MPa / 47.76 MPa
Si $\sigma^*_3 < 0$ (Compressive) : $\lvert \sigma^*_3 \rvert \le S_c$ σ_{eq} = 59.16 MPa /53.85 MPa $\le$ SE	Si $\sigma^*_4 < 0$ (Compressive) : $\lvert \sigma^*_4 \rvert \le S_c$ σ_{eq} = 55.18 MPa / 52.23 MPa $\le$ SE
M_1 = -1,013.56 daN·m / -409.27 daN·m ; K_1 = 0.107 ; K^*_1 = 0.192 ; $\sigma_{eq} = \max(\lvert \sigma_\theta - \sigma^*_{3/4} \rvert , \lvert \sigma^*_{3/4} + 0.5P \rvert)$; $\sigma_\theta = P.R_m / t$ (P = 1.005 MPa) ; E = 1	

shear stress	
K_2 = 1.1707	$\tau_2 = K_2.T/(R_m.t)$ = 4.49 MPa ≤ 94.4 MPa

Circumferential stress		
k = 1	x_1 = 54.5 mm	x_2 = 54.5 mm
K_5 (Table 4.15.1) = 0.7603	$\sigma_6 = (-K_5\, Q/(b+x_1+x_2)t)k$ = -8.24 MPa	$\lvert\sigma_6\rvert \le S$
K_7 (Table 4.15.1) = 0.0305	$\sigma_7 = \frac{-Q}{4t(b+x_1+x_2)} - \frac{3K_7 Q}{2t^2}$ = -28.12 MPa	$\lvert\sigma_7\rvert \le 1.25$ S

Saddle check	
Stress due to horizontal reaction on the saddle	
K = (1+ cos β – 0.5 sin² β) / (π – β + sin β cos β) =0.2035 H = K Q = 5,541 N A_b = 2,800 mm²	β = 2.0944 rad $S_b = H / (2/3\ A_b)$ = 2.97 MPa ≤ (90% Leb) (170.1 MPa)
Bending and compression stresses	
H_b = 900 mm $M_{zz} = Ra_H . H_b + Ra_H . (2H_b + H_t)$ $I_{zz} = 3.422086\times10^9$ mm⁴ $S_{zz} = I_{zz}/v$ = 7,821,914 mm³ $\lvert M_{zz} \rvert$ = 0 daN·m $Sb_z = \lvert M_{zz} \rvert / S_{zz}$ Sb_z = 0 MPa ≤ (90% Leb) (170.1 MPa)	L_{EFF} = 200 mm $M_{xx} = Ra_{HL} . L_{EFF}$ $I_{xx} = 73.10393\times10^6$ mm⁴ $S_{xx} = I_{xx}/v$ = 584,831.6 mm³ $\lvert M_{xx} \rvert$ = 172.95 daN·m $Sb_x = \lvert M_{xx} \rvert / S_{xx}$ Sb_x = 2.96 MPa ≤ (90% Leb) (170.1 MPa)
A = 25,466 mm² f_b = 118 MPa $Sb_c = Ra_V / A$	Sb_c = 1.07 MPa ≤ (0.8 f_b) (94.4 MPa)
$\max(Sb_z ; Sb_x) / (90\%\ Leb) + Sb_c / (0.8 f_b) \le 1$	
Stability of web plate [CODAP C9.3.2.7] [AD S3/2 6.1.1]	
h_{b2} = 550 mm l_b = 1,212.4 mm e_{ba} = 14 mm E_b = 192,000 MPa $\varepsilon_b = f_b\, 10^3 / E_b$ $x = h_{b2} / l_b$ K_b = 1.255 φ = 0.522	f_b = 90% Leb = 170.1 MPa $Q_{max} = l_b\, e_{ba} f_b\, \varphi$ = 150,739.4 daN

Maximum Allowable Working Pressure

Maximum Allowable Pressure(Geometry).

Type / Mark	Diameter	Thickness	Max. allowable pressure		Max. All. Ext. Pressure		Hydrostatic pressure		
			Operating	Test	Operating	Test	Operating	Test	
	(mm)	(mm)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	
01[05] 30.10	1,400.0	10.0	1.1847	1.9970	0.1351	/	0.0049	0.0135	/
02[01] 31.05	1,400.0	10.0	1.0070	1.6974	0.1351	/	0.0049	0.0135	/
03[01] 31.05	1,400.0	10.0	1.0070	1.6974	0.1037	/	0.0049	0.0135	/
04[01] 31.05	1,400.0	10.0	1.0070	1.6974	0.1351	/	0.0049	0.0135	/
05[05] 30.11	1,400.0	10.0	1.1847	1.9970	0.1351	/	0.0049	0.0135	/

Maximum Allowable Pressure (Nozzles).

Tag	Neck		Flange		Hydrostatic pressure		
	Operating	Test	Operating	Test	Operating	Test	
	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	
M1	1.1923	2.1917	1.3800	3.0000	0.0000	0.0068	/
M2	1.1923	2.1917	1.3800	3.0000	0.0000	0.0068	/

Maximum Allowable Pressure (compartment).

Compartment	maximum pressure		Max. External Pressure (shell)
	Operating	Test	
Compartment 1	1.000 MPa (200 °C)	1.680 MPa	0.103 MPa (150 °C)
/	/	/	/
/	/	/	/

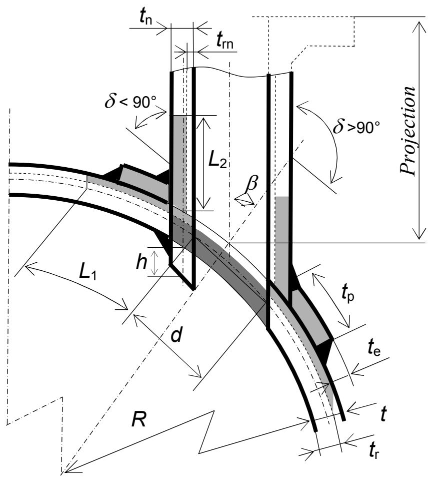
Without any additional pressure due to hydrostatic height.

Isolated Opening(s)

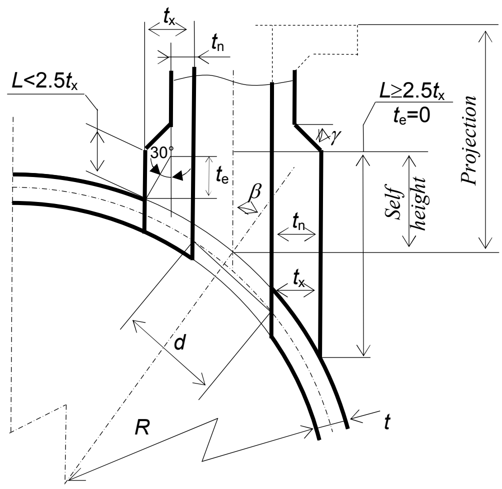
Figures for all configurations, from FIG. UG-37.1 And FIG UG-40.

Shell ($\alpha = 0$) or Cone ($\alpha > 0$) : in longitudinal plane.

Nozzle with or without pad, set-in or set-on



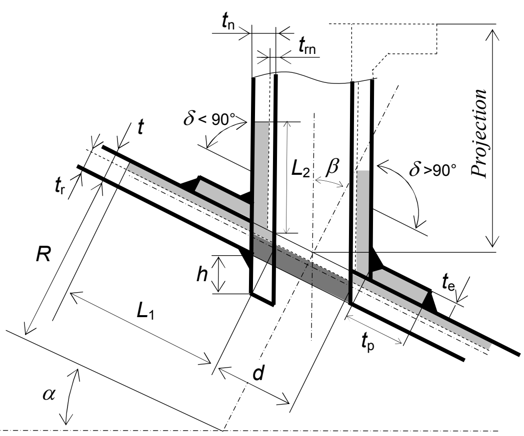
Self-reinforcing nozzle, set-in or set-on



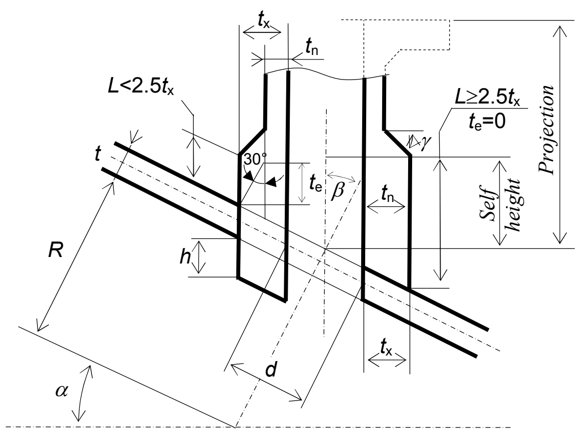
Cylindrical or conical shell: circumferential plane

Head: in the plane that contains the axis of the nozzle and the longitudinal axis of the vessel.

Nozzle with or without pad, set-in or set-on



Self-reinforcing nozzle, set-in or set-on



Opening M1 [in operation Int.P.] *Manhole*

ASME VIII DIV.1

Nozzle with pad (10×230) on Elliptical Head (No. 1)		Set In
Pressure : P = 1 MPa	Temperature : 200 °C	
Shell Joint efficiency : 1 E_1 = 1 Ext. Diameter : D_o = 1,400 mm	Material :SA516GR60 Corrosion + tolerance : Ca_v = 3 mm Thickness as new : 10 mm	Allowable stress : S_v = 118 MPa Allowable stress : S = 118 MPa Tolerance for seamless pipe : /
Nozzle Neck Weld joint efficiency : 1 Ext. Diameter : D_{on} = 508 mm External Projection : 435 mm Inclination : 0 °	Material : SA106GRB Corrosion + tolerance : Ca_n = 3 mm Thickness as new : 6.35 mm Internal Projection : 0 mm Eccentricity : 0 mm	Allowable stress : S_n = 118 MPa Tolerance for seamless pipe : 7/8 (12.5%) NPS 20" Schedule: 10
Flange Rating : (ASME B16.5) 150	Material : SA105 Height : 144.526 mm	Type : WN NPS 20"
Pad Height : 10 mm	Material : SA516GR60 Pad : 230 mm	Allowable stress : S_p = 118 MPa Ext. Diameter : D_{op} = 968 mm
Weld Outside : leg_{41}= 4 mm	outer reinforcement : leg_{42}= 5 mm	Inside : leg_{43}= /

fr_1 =min(1,S_n/S_v) = 1 fr_2 = min(1,S_n/S_v) = 1 fr_3 = min(1,min(S_n, S_p)/S_v) = 1 fr_4 = min(1,S_p/S_v) = 1

Required thickness of the nozzle neck Appendix 1-1

$t_{rn} = P\ R_{on} / (S_n E + 0.4P)$ = 2.145 mm R_{on} = 254 mm E = 1

The nozzle neck thickness is adequate per Appendix 1-1.

Required thickness of the nozzle neck UG-45

$t_a = t_{rn} + Ca_n$= 5.15 mm ; t_{b1} = max[t_{UG-32} , UG-16(b)]+Ca_v= 0 mm ; t_{b3} = Table UG-45+Ca_n= 0 mm

t_{UG-45} = max [t_a , min [t_{b3} , t_{b1}]] = 5.145 mm

The nozzle neck thickness is adequate per UG-45.

Dimensions FIG. UG-40

angle of plane with longitudinal axis : angle of each side / wall of the vessel :	Longitudinal plane : θ= 0° δ= 90 °	 δ= 90 °	Circumferential plane : θ= 90° δ= /	 δ= /
β = deflection angle / normal line	0 °			
d = diameter of the opening	501.3 mm			
R_n = radius of the finished opening	250.65 mm			
t_i = thickness of internal projection	/			
t_p = Reinforcing ring width	230 mm			
t_x = thickness of selfreinforcing	/			
L = height of selfreinforcing	/	/		
Configuration of the reinforcement :	sketch (b-1)	sketch (b-1)		
t_e = thickness or height of the reinforcement	10 mm	10 mm		
t_n = Nozzle thickness	3.35 mm	3.35 mm		
h = height of internal projection	0 mm	0 mm		

Reinforcement checking UG-37 *opening M1 [in operation Int.P.]*

Required thicknesses UG-37(a)		
t_r = 5.28 mm [UG-37(a)(c) + UG-27(d)]	t = 7 mm K_1 (Table UG-37) = 0.9	E = 1
$t_{rn} = P\ R_{on} / (S_n E + 0.4P)$ = 2.145 mm	R_{on} = 254 mm	E = 1

Limits of reinforcement UG-40 :	Longitudinal plane : θ= 0° δ= 90 °	 δ= 90 °	Circumferential plane : θ= 90° δ= /	 δ= /
UG-40 (b) : max [d , R_n+t_n+t] =	501.3 mm	501.3 mm		
UG-40 (c) : min [2.5t , 2.5t_n+t_e] =	17.5 mm	17.5 mm		

Area required UG-37 (c) :	Longitudinal plane : θ= 0°	Circumferential plane : θ= 90°
F = Correction factor FIG.UG-37	1	
$A = d\ t_r\ F + 2\ t_n/\cos(\beta)\ t_r\ F\ (1-f_{r1})$	2,646.8 mm^2	

Lengths and heights of calculation of the areas :	Longitudinal plane : $\theta = 0°$ $\delta = 90°$	$\delta = 90°$	Circumferential plane : $\theta = 90°$ $\delta = /$	$\delta = /$
L_1 = min [UG-40(b)-Radius , length available]	248.93 mm	248.93 mm		
L_2 = min [UG-40(c) , height available]	17.5 mm	17.5 mm		
$L_3 = \min [\ h\ , 2.5t\ , 2.5t_i\ ] =$	0 mm	0 mm		
L_5 = min [UG-40 (b)-R_{on} , t_p , length available]	230 mm	230 mm		

Area available (mm^2) :	Longitudinal plane : $\theta = 0°$ $\delta = 90°$	$\delta = 90°$	Circumferential plane : $\theta = 90°$ $\delta = /$	$\delta = /$
$A_1 = L_1\ (E_1\ t - t_r\ F) - t_n/\cos(\beta)\ (E_1\ t - t_r\ F)\ (1 - f_{r1})$	428.2	428.2		
$A_2 = L_2\ (t_n - t_{rn})\ fr_2$	21.1	21.1		
$A_3 = L_3\ t_i\ f_{r2}$	0	0		
$A_{41} = leg_{41}^2\ /2\ f_{r3}$	8	8		
$A_{42} = leg_{42}^2\ /2\ f_{r4}$	12.5	12.5		
$A_{43} = leg_{43}^2\ /2\ f_{r2}$	0	0		
$A_5 = L_5\ t_e\ f_{r4}$	2,300	2,300		
$A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5 =$	2,769.8 $\geq A/2$	2,769.8 $\geq A/2$		
	5,539.6 $\geq A$			

The opening is adequately reinforced per UG-37.

Weld sizes check UW-16(c). *opening M1 [in operation Int.P.]*

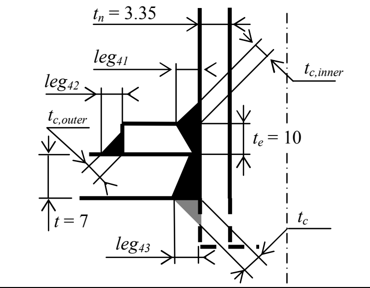
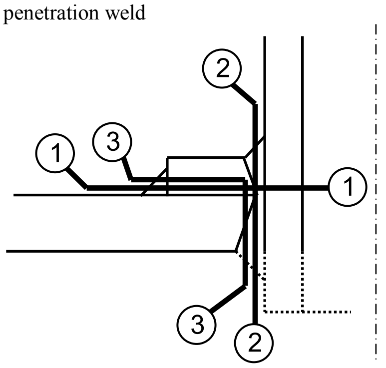


Fig. UW-16.1 (d)+(a-1) full penetration weld		
	Minimum throat required	actual
$t_{c,inner}$	min[¼ in.(6 mm);0.7×$t_{\min}$]= 2.345 mm $t_{\min}$ = min[¾ in.(19 mm) ; t_e , t_n]	0.7×leg_{41} = 2.8 mm
$t_{c,outer}$	0.5 × $t_{\min}$ = 3.5 mm $t_{\min}$ = min[¾ in.(19 mm) ; t_e , t]	0.7×leg_{42} = 3.5 mm
t_c	min[¼ in. (6 mm);0.7×$t_{\min}$]= / $t_{\min}$ = min[¾ in.(19 mm) ; t , t_n]	0.7×leg_{43} − Ca_n = /
Weld sizes are adequate		

Weld loads check UG-41(b). *opening M1 [in operation Int.P.]*

FIG. UG-41.1 (a)
full penetration weld



Allowable Loads UW-15(c) + UG-41(a) + UG-45(c) + L-7

Outer fillet weld in shear :

$s_{w,outer} = \pi/4 \times D_{op} \times leg_{42} \times 0.49 \times \min(\ S_p\ , S_v\ ) = 21{,}979.3$ daN

Inner fillet weld in shear :

$s_{w,inner} = \pi/4 \times D_{on} \times leg_{41} \times 0.49 \times \min(\ S_p\ , S_n\ ) = 9{,}227.7$ daN

Groove weld in shear :

$s_c = \pi/4 \times D_{on} \times leg_{43} \times 0.49 \times \min(\ S_n\ , S_v\ ) = 0$ daN

Lower groove weld in tension :

$s_{g,lower} = \pi/4 \times D_{on} \times t \times 0.74 \times \min(\ S_n\ , S_v\ ) = 24{,}387.4$ daN

Upper groove weld in tension :

$s_{g,upper} = \pi/4 \times D_{on} \times t_e \times 0.74 \times \min(\ S_n\ , S_p\ ) = 34{,}839.1$ daN

Nozzle wall in shear :

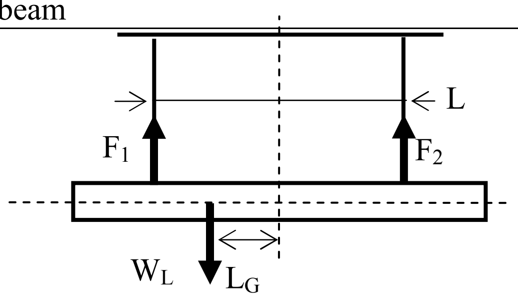
$s_n = \pi/4 \times (D_{on} - t_n) \times t_n \times 0.70 \times S_n = 10{,}967.4$ daN

Loads to be carried by welds Fig. UG-41.1(a)	Longitudinal plane : $\theta = 0°$ $\delta = 90°$	$\delta = 90°$	Circumferential plane : $\theta = 180°$ $\delta =$	$\delta =$
Total : $W = [\ A/2 - A_1 + t_n f_{r1}\ (\ E_1\ t - F\ t_r\ )]\ S_v$	10,631.5 daN	10,631.5 daN		
Path 1-1 : $W_{1\text{-}1} = (A_2 + A_5 + A_{41} + A_{42})\ S_v$	27,630.7 daN	27,630.7 daN		
Path 2-2 : $W_{2\text{-}2} = (A_2 + A_3 + A_{41} + A_{43} + t_n\ t\ f_{r1})\ S_v$	619.9 daN	619.9 daN		
Path 3-3 : $W_{3\text{-}3} = (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + t_n\ t\ f_{r1})\ S_v$	27,907.4 daN	27,907.4 daN		

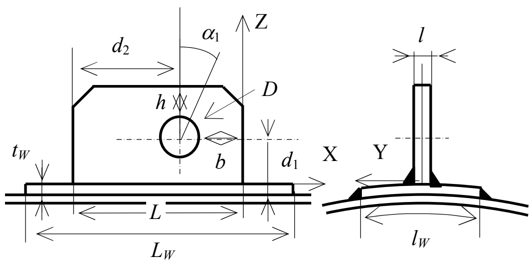
Check weld strength paths	Longitudinal plane : $\theta = 0°$ $\delta = 90°$	$\delta = 90°$	Circumferential plane : $\theta = 180°$ $\delta =$	$\delta =$
Path 1-1 : $\min(W;W_{1\text{-}1}) \leq s_{w,outer} + s_n$	Yes	Yes		
Path 2-2 : $\min(W;W_{2\text{-}2}) \leq s_{w,inner} + s_{g,upper} + s_{g,lower} + s_c$	Yes	Yes		
Path 3-3 : $\min(\ W\ , W_{3\text{-}3}\ ) \leq s_{w,outer} + s_{g,lower} + s_c$	Yes	Yes		

Strength of welded joints is adequate

Lifting accessories

Lifting a horizontal vessel with spreader beam	Weight of vessel : W_L = 3,269.2 daN
	Weight considered W_{LC} = 1.5 W_L = 4,903.9 daN Dist. Apart : L = 5,000 mm L_G = -0.8 mm $F_1 = F_2 = W_L/2$ = 2,451.9 daN

Lug verification. (1)



Allowable stress	σ_a = 198.9 MPa	
Yield Strength	σ_e = 221 MPa	
Lug	L = 200 mm	l = 12 mm
	b = 115 mm	h = 35 mm
	D = 30 mm	
Hole Location	d_1 = 70 mm	d_2 = 70 mm
Pad (Rectangular)	L_W = 200 mm	l_W = 100 mm
	t_W = 10 mm	
Analysis thickness	$a = 0.7\ \min(l\ , t_W)$ = 7 mm	
Reduction Factor	$\alpha = \min\ [0.8\ (1+1/a), 1]$ = 0.914	
Orientation	$\alpha_1 = 0$ °	
Sling load	F_C = 2,451.9 daN	
Components	$F_x = F_C\ sin(\alpha_1)$ = 0 daN	
	$F_y = 0$	
	$F_z = F_C\ cos(\alpha_1)$ = 2,451.9 daN	

Shear stress $S_{sh} = l\ \min[b\ , h]$ = 420 mm^2 $\sigma_{cis} = (4/3)\ F_C / S_{sh}$ = 77.84 MPa $\leq \sigma_a$

Weld stress

Area $A = (L + 2a)\ (l + 2a) - Ll$ = 3,164 mm^2

Inertia I_y = 13,234,070 mm^4 $v_{max} = L / 2$ = 100 mm

Bending stress : $\sigma_{flex} = v\ F_x\ (d_1 - t_W) / I_y$ = 0 MPa shear : $\tau = F_x / A$ = 0 MPa

Normal stress : $\sigma_1 = F_z / A$ = 7.75 MPa

Total stress : $\sigma_{tot} = \sqrt{(\sigma_1 + \sigma_{flex})^2 + 1.8\tau^2}$ = 7.75 MPa $\leq \alpha\sigma_e$ = 202.06 MPa

Weld stress (Pad – Shell)

Area : A_W = 4,396 mm^2 Inertia I_W = 26,436,600 mm^4

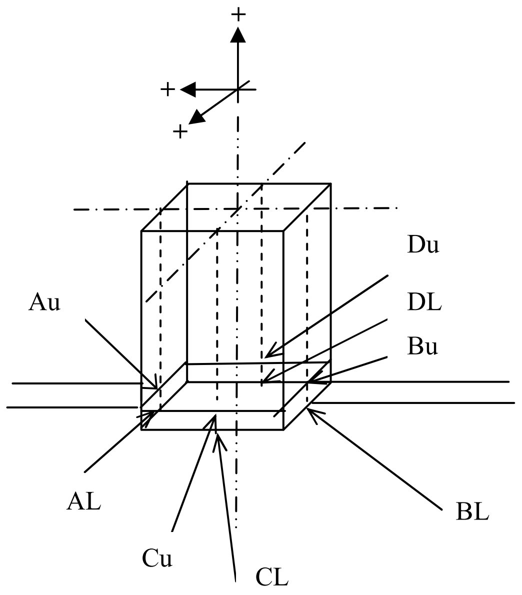
$v_W = (L_W + 2a) / 2$ = 107 mm Normal stress : $\sigma_{1W} = F_z / A_W$ = 5.58 MPa

Bending stress : $\sigma_{flexW} = v_W\ F_x\ d_1 / I_W$= 0 MPa Shear : $\tau_W = F_x / A_W$ = 0 MPa

Total stress : $\sigma_{totW} = \sqrt{(\sigma_{1W} + \sigma_{flexW})^2 + 1.8\tau_W^{\ 2}}$ = 5.58 MPa $\leq \alpha\sigma_e$ = 202.06 MPa

Local loads on cylindrical shell (1) (Lifting Lug.), Loaded Area

WRC Bulletin 107



Design pressure code :	ASME VIII DIV.1 2013	
Design Pressure		/
Existing circular stress		/
Existing longitudinal stress		/
Allowable Stress		f = 118 MPa
Yield Strength		221 MPa
modulus of elasticity		202,350 MPa
Weld joint efficiency		0.85
Membrane stress factor		1.5
Design stress factor		3
<u>Shell dimensions</u>		
Outside radius	R = 700 mm	
Thickness	T_s = 10 mm	
Corrosion allowance	c = 0 mm	
<u>Reinforcing pad dimensions</u>		
Thickness (Tr)	10 mm	
<u>Data Loaded Area</u>		
Fillet radius	0 mm	
1/2 Longitudinal length	c2 = 100 mm	
1/2 Circumferential length	c1 = 6 mm	

<u>Geometric parameters</u>

mean radius $R_m = (R + Tr) - [(Tr + Ts - c)/2] =$ 700 mm $\quad \gamma = R_m / T = 35$

Total thickness $T = Tr + Ts - c = 20$ mm

$\beta_1 = c1 / R_m = 0.0086$ $\quad 0.25 \le \beta_1/\beta_2 \le 4 \Rightarrow$ $\quad \beta_1 = 0.0086$

$\beta_2 = c2 / R_m = 0.1429$ $\quad \beta_2 = 0.0343$

<u>Factor β :</u>

Radial load :

$$\beta = \left[1 - \frac{1}{3}\left(\frac{\beta_1}{\beta_2} - 1\right)(1 - K1)\right]\sqrt{\beta_1 \beta_2} \quad (\text{si } \beta_1 / \beta_2 > 1) \qquad \beta = \left[1 - \frac{4}{3}\left(1 - \frac{\beta_1}{\beta_2}\right)(1 - K2)\right]\sqrt{\beta_1 \beta_2} \quad (\text{si } \beta_1 / \beta_2 < 1)$$

Moment Mc : $\beta = Kc\sqrt[3]{\beta_2 \beta_1^2)}$ $\qquad$ Moment ML : $\beta = KL\sqrt[3]{\beta_1 \beta_2^2)}$

	Radial load P			Bending Moment Mc			Bending Moment ML		
	K1	K2	β	Cc	Kc	β	CL	KL	β
Nϕ	0.91	1.48	0.025	0.253	1.00	0.014	0.64	1.00	0.022
Nx	1.68	1.2	0.021	0.473	1.00	0.014	1.16	1.00	0.022
Mϕ	1.76	0.88	0.015	/	1.27	0.017	/	0.879	0.019
Mx	1.2	1.25	0.021	/	1.714	0.023	/	1.212	0.026

<u>Stress concentration factors</u>

membrane $K_n = 1$

bending $K_b = 1$

<u>Applied loads</u>

Radial Load P = -3,467.561 daN	Bending moment M_c = 0 daN·m
Shear Load V_c = 0 daN	Bending moment M_L = 0 daN·m
Shear Load V_L = 0 daN	Torsional moment M_t = 0 daN·m

Stresses Shell

(MPa)		Au	AL	Bu	BL	Cu	CL	Du	DL
		Points							
Longitudinal stresses									
(1)	$K_n (N_x / P / R_m) . P/ (R_m T)$	-17.36	-17.36	-17.36	-17.36	-16.35	-16.35	-16.35	-16.35
(2)	$K_n (N_x / Mc / R_m^2 \beta) . M_c / (R_m^2 \beta T)$	0	0	0	0	0	0	0	0
(3)	$K_n (N_x / ML / R_m^2 \beta) . M_L / (R_m^2 \beta T)$	0	0	0	0	0	0	0	0
(4)	= (1) + (2) + (3)	-17.36	-17.36	-17.36	-17.36	-16.35	-16.35	-16.35	-16.35
(5)	Pressure	0	0	0	0	0	0	0	0
(6)	$\sigma_{x,m}$ = (4) + (5)	-17.36	-17.36	-17.36	-17.36	-16.35	-16.35	-16.35	-16.35
(7)	$K_b (M_x / P) . 6 P/ T^2$	-104.03	104.03	-104.03	104.03	-78.02	78.02	-78.02	78.02
(8)	$K_b (M_x / M_c / R_m \beta) . 6 M_c / (R_m \beta T^2)$	0	0	0	0	0	0	0	0
(9)	$K_b (M_x / M_L / R_m \beta) . 6 M_L / (R_m \beta T^2)$	0	0	0	0	0	0	0	0
(10)	= (7) + (8) + (9)	-104.03	104.03	-104.03	104.03	-78.02	78.02	-78.02	78.02
Circumferential stresses									
(11)	$K_n (N\phi / P / R_m) . P/ R_m / T$	-16.35	-16.35	-16.35	-16.35	-17.1	-17.1	-17.1	-17.1
(12)	$K_n (N\phi / M_c / R_m^2 \beta) . M_c / (R_m^2 \beta T)$	0	0	0	0	0	0	0	0
(13)	$K_n (N\phi / M_L / R_m^2 \beta) . M_L / (R_m^2 \beta T)$	0	0	0	0	0	0	0	0
(14)	= (11) + (12) + (13)	-16.35	-16.35	-16.35	-16.35	-17.1	-17.1	-17.1	-17.1
(15)	Pressure	0	0	0	0	0	0	0	0
(16)	$\sigma_{\phi,m}$ = (14) + (15)	-16.35	-16.35	-16.35	-16.35	-17.1	-17.1	-17.1	-17.1
(17)	$K_b (M_\phi / P) . 6 P/ T^2$	-80.62	80.62	-80.62	80.62	-104.03	104.03	-104.03	104.03
(18)	$K_b (M_\phi / Mc / R_m \beta) . 6 M_c / (R_m \beta T^2)$	0	0	0	0	0	0	0	0
(19)	$K_b (M_\phi / ML / R_m \beta) . 6 M_L / (R_m \beta T^2)$	0	0	0	0	0	0	0	0
(20)	= (17) + (18) + (19)	-80.62	80.62	-80.62	80.62	-104.03	104.03	-104.03	104.03

Shear stresses	Circular	Rectangular	Au	AL	Bu	BL	Cu	CL	Du	DL
(21)	$V_c / \pi ro T$	$V_c / 4 c1 T$	0	0	0	0	0	0	0	0
(22)	$V_L / \pi ro T$	$V_L / 4 c2 T$	0	0	0	0	0	0	0	0
(23)	$M_t / 2 \pi ro^2 T$		0	0	0	0	0	0	0	0

		Au	AL	Bu	BL	Cu	CL	Du	DL
	σ_x = (4) + (5) + (10)	-121.39	86.67	-121.39	86.67	-94.37	61.67	-94.37	61.67
	σ_ϕ = (14) + (15) + (20)	-96.97	64.27	-96.97	64.27	-121.13	86.93	-121.13	86.93
	τ = (21) + (22) + (23)	0	0	0	0	0	0	0	0
(24)	$0.5\left[\sigma_\phi + \sigma_x + \sqrt{(\sigma_\phi - \sigma_x)^2 + 4\tau^2}\right]$	-96.97	86.67	-96.97	86.67	-94.37	86.93	-94.37	86.93
(25)	$0.5\left[\sigma_\phi + \sigma_x - \sqrt{(\sigma_\phi - \sigma_x)^2 + 4\tau^2}\right]$	-121.39	64.27	-121.39	64.27	-121.13	61.67	-121.13	61.67
(26)	$= (24) - (25) = \sqrt{(\sigma_\phi - \sigma_x)^2 + 4\tau^2}$	24.42	22.39	24.42	22.39	26.76	25.25	26.76	25.25
(27)	$0.5\left[\sigma_{\varphi,m} + \sigma_{x,m} + \sqrt{(\sigma_{\varphi,m} - \sigma_{x,m})^2 + 4\tau^2}\right]$	-16.35	-16.35	-16.35	-16.35	-16.35	-16.35	-16.35	-16.35
(28)	$0.5\left[\sigma_{\varphi,m} + \sigma_{x,m} - \sqrt{(\sigma_{\varphi,m} - \sigma_{x,m})^2 + 4\tau^2}\right]$	-17.36	-17.36	-17.36	-17.36	-17.1	-17.1	-17.1	-17.1
(29)	$= (27) - (28) = \sqrt{(\sigma_{\varphi,m} - \sigma_{x,m})^2 + 4\tau^2}$	1.01	1.01	1.01	1.01	0.75	0.75	0.75	0.75

	actual	Allowable
Total stress	Max [|(24)| , |(25)| , |(26)|] = 121.39 MPa	354 MPa (3 f)
Membrane Stress	Max [|(27)| , |(28)| , |(29)|] = 17.36 MPa	177 MPa (1.5 f)

	Read values	Values used
Fig. 3C γ = 50 Fig. 3C γ = 15	(β = 0.021) 9.9174 (β = 0.021) 3.1328	**(Pts A,B) $N_x/(P/R_m)$ = 7.0097**
Fig. 4C γ = 50 Fig. 4C γ = 35	(β = 0.021) 9.6543 (β = 0.021) 6.6	**(Pts C,D) $N_x/(P/R_m)$ = 6.6**
Fig. 4C γ = 50 Fig. 4C γ = 35	(β = 0.025) 9.6179 (β = 0.025) 6.6	**(Pts A,B) $N_\Phi/(P/R_m)$ = 6.6**
Fig. 3C γ = 50 Fig. 3C γ = 15	(β = 0.025) 9.748 (β = 0.025) 3.1132	**(Pts C,D) $N_\Phi/(P/R_m)$ = 6.9045**
Fig. 2C-1 γ = 50 Fig. 2C-1 γ = 35	(β = 0.015) 0.17 (β = 0.015) 0.155	**(Pts A,B) M_Φ/P = 0.155**
Fig. 1C γ = 50 Fig. 1C γ = 35	(β = 0.015) 0.27 (β = 0.015) 0.2	**(Pts C,D) M_Φ/P = 0.2**
Fig. 1C-1 γ = 50 Fig. 1C-1 γ = 35	(β = 0.021) 0.26 (β = 0.021) 0.2	**(Pts A,B) M_x/P = 0.2**
Fig. 2C γ = 50 Fig. 2C γ = 35	(β = 0.021) 0.2104 (β = 0.021) 0.15	**(Pts C,D) M_x/P = 0.15**

Minimum Design Metal Temperature

ASME VIII DIV.1 2013 UCS-66	
Curve	Fig. UCS-66 (A , B ,C , D).
Er	governing thickness UCS-66.
MDMTs	(Fig. UCS-66 / Impact Test Temperature) unadjusted MDMT
Ratio	(Fig. UCS-66.1)
Re	(Fig. UCS-66.1 / UCS-68(c)) temperature reduction
MDMTa	adjusted MDMT

MDMT for each component.

		Material	Curve	Er (mm)	MDMTs (°C)	Ratio	Re (°C)	MDMTa (°C)
01 [05]	30.10	SA516GR60	C	10	-45.5 / n/a	0.848	8.5 / 0	-48
02 [01]	31.05	SA516GR60	C	10	-45.5 / n/a	0.848	8.5 / 0	-48
03 [01]	31.05	SA516GR60	C	10	-45.5 / n/a	0.848	8.5 / 0	-48
04 [01]	31.05	SA516GR60	C	10	-45.5 / n/a	0.848	8.5 / 0	-48
05 [05]	30.11	SA516GR60	C	10	-45.5 / n/a	0.848	8.5 / 0	-48
Nozzle	M1	SA106GRB	B	5.56	-29 / n/a	0.839	9 / 0	-38
Nozzle	M2	SA106GRB	B	5.56	-29 / n/a	0.839	9 / 0	-38
Flange	M1	SA105	B	5.56	-29 / n/a	0.725	15.4 / 0	-44.4
Flange	M2	SA105	B	5.56	-29 / n/a	0.725	15.4 / 0	-44.4
Pad	M1	SA516GR60	C	10	-45.5 / n/a	0.848	8.5 / 0	-48
Pad	M2	SA516GR60	C	10	-45.5 / n/a	0.848	8.5 / 0	-48

MDMT for each assembly (joining base metal excluded).

		Material	Curve	Er (mm)	MDMTs (°C)	Ratio	Re (°C)	MDMTa (°C)
01 [05] *02 [01]*	30.10 31.05	SA516GR60	C	10	-45.5 / n/a	0.848	8.5 / 0	-48
01 [05] *Pad*	30.10 M1	SA516GR60	C	10	-45.5 / n/a	0.848	8.5 / 0	-48
02 [01] *03 [01]*	31.05 31.05	SA516GR60	C	10	-45.5 / n/a	0.848	8.5 / 0	-48
03 [01] *04 [01]*	31.05 31.05	SA516GR60	C	10	-45.5 / n/a	0.848	8.5 / 0	-48
04 [01] *05 [05]*	31.05 30.11	SA516GR60	C	10	-45.5 / n/a	0.848	8.5 / 0	-48
05 [05] *Pad*	30.11 M2	SA516GR60	C	10	-45.5 / n/a	0.848	8.5 / 0	-48
Nozzle *01 [05]*	M1 30.10	SA106GRB	B	5.56	-29 / n/a	0.839	9 / 0	-38
Nozzle *Pad*	M1 M1	SA106GRB	B	5.56	-29 / n/a	0.839	9 / 0	-38
Nozzle *Flange*	M1 M1	SA106GRB	B	5.56	-29 / n/a	0.839	9 / 0	-38
Nozzle *05 [05]*	M2 30.11	SA106GRB	B	5.56	-29 / n/a	0.839	9 / 0	-38
Nozzle *Pad*	M2 M2	SA106GRB	B	5.56	-29 / n/a	0.839	9 / 0	-38
Nozzle *Flange*	M2 M2	SA106GRB	B	5.56	-29 / n/a	0.839	9 / 0	-38

Rated MDMT of the vessel -38 °C ≤ Design MDMT -15 °C

Circular stresses.

Type Tag	Diameter outside (mm)	Length (mm)	Thickness (mm)	Operating (MPa)	Horizontal test (MPa)	Vertical test (MPa)
01[05] 30.10	1,400.0	405.0	10.000	100.09	130.83	/
02[01] 31.05	1,400.0	2,000.0	10.000	117.75	153.92	/
03[01] 31.05	1,400.0	2,000.0	10.000	117.75	153.92	/
04[01] 31.05	1,400.0	1,900.0	10.000	117.75	153.92	/
05[05] 30.11	1,400.0	405.0	10.000	100.09	130.83	/

Summary

[01]	Shell
[05]	Elliptical Head
[13]	Welding Neck Flange

Summary of nozzles [Location and Dimensions].

Tag	Location				Dimensions (mm)								Flange		
	Loc. (mm)	Ori. (°)	Inc. (°)	Exc. (mm)	Neck Diam.	Neck Thk.	Neck Sch.	Neck NPS	Reinforcement Type	Reinforcement (a)	Reinforcement (b)	Projection	NPS	Rating	Typ.
M1	-100.0	0.00	0.00	0.00	508.00	6.350	10	20	Pad	10.000	230.00	435.00	20	150	[13]
M2	7,000.0	0.00	0.00	0.00	508.00	6.350	10	20	Pad	10.000	230.00	435.00	20	150	[13]

(a),(b) : Pad (ring) = thickness, Width ; Self Reinforcing = Height, over thickness ; Internal Plate = thickness, Height

NB : The external projection and the overthickness height of a self are measured along the axis of the nozzle.

Summary of nozzles [Adjacent Openings, Goose and Material].

Tag	Set-in (+) Set-on(-)	Operating	Adjacent openings	Goose Radius (mm)	Goose Loc. (mm)	hydrostatic height Operating (mm)	hydrostatic height Test (mm)	Material Neck	Material Pad	Material Flange
M1	(+)	H	/	/	/	0.00	690.0	SA106GRB	SA516GR60	SA105
M2	(+)	H	/	/	/	0.00	690.0	SA106GRB	SA516GR60	SA105

Nozzle Type: A = Process, H = manhole, E = With Blind Flange, L = Instrument, AP = Boot, XT = transition by head, CA = Shell Inlet, CS = Shell Outlet, TA = Tubeside inlet, TS = Tubeside Outlet.

Summary of nozzles [Type, Weight and Local Loads].

Tag	Loc. Shell No.	Operating	Mass Nozzle (kg)	Mass Flange (kg)	Longitudinal Shear Load (daN)	Circumferential Shear Load (daN)	Radial Load (daN)	Longitudinal Bending Moment (daN·m)	Circular Bending Moment (daN·m)	Torsional moment (daN·m)
M1	01[05]	H	67.5	215.0	0	0	0	0	0	0
M2	05[05]	H	68.3	215.0	0	0	0	0	0	0

Nozzle Type: A = Process, H = manhole, E = With Blind Flange, L = Instrument, AP = Boot, XT = transition by head, CA = Shell Inlet, CS = Shell Outlet, TA = Tubeside inlet, TS = Tubeside Outlet.

Flange Weight: With blind flange if present.

Summary of Stiffeners.

Stiffener		Location (mm)	Area (mm^2)	Inertia (mm^4)	Type and dimensions (mm)	Remarks
A	1	3,000.0	635.00	213,373	Plate 63.5 × 10	

Stiffener: I = User Input M = Modified A = Added

Summary of Forged Items.

Flange dimensions

Tag	Type (1)	(2)	External Diameter (mm)	Internal Diameter (mm)	Bolt Circle (mm)	Flange thickness (mm)	Hub length (mm)	Cylindrical extension length (mm)	Hub thickness shellside (mm)	Hub thickness flangeside (mm)	Nubbins width (mm)	Stub Thickness (mm)
/	/	/	/	/	/	/	/	/	/	/	/	/

(1) Flange Type : P = slip-on (loose), C = integral with hub, T = lap-type joint (loose),
R = slip-on (integral), G = Integral with hub, swing bolts
O = optional (corner joint), F = lap-joint on split ring, S = lap joint flange with removable segment(s) + compression ring.
(2) Flange face: 0= flat face unconfined, 1= male-female semi-confined, 2= tongue and groove, 3= tongue and groove + nubbins.

Bolting

Tag	(3)	no. $[n_B]$	Designation	Diameter (mm)	Thread length (mm)	Bolt Load $[F_{BO\,nom} / n_B]$ (N)	Bolt torque $[M_{t,nom}]$ (N·mm)	Friction coefficient in nut $[\mu_n]$	Friction coefficient in thread $[\mu_t]$	Thread pitch $[p_t]$ (mm)
/	/	/	/	/	/	/	/	/	/	/

(3) Bolt Type : 1,2,4,6: ISO (1 and 4: Pitch 3 mm for Ø > M24) (1 and 6: Tensile Stress Area; 2,4: Root Area)
3: UNC, Root Area
5: ISO, Reduced Area (DIN 2510)

(4) Bolt torque in accordance with EN 1591-1 Appendix D : $M_{t,nom} = k_B \times F_{BO\,nom} / n_B$, $k_B = p_t/(2\pi) + \mu_t \times d_t/(2\cos\alpha) + \mu_n \times d_n/2$

d_t = pitch diameter of the thread
d_n = mean diameter in the nut (friction)
α = half angle of thread

(5) Bolt torque in accordance with EN 13445-3 Appendix G.8.4 :

(6) Bolt torque in accordance with GOST R 52857.4 Appendix J :

Gaskets

Tag	Diameter (mm)	Width (mm)	Thickness (mm)	Partition rib width (mm)	Ring (mm)		
					Outer Width	Internal Width	Thickness
/	/	/	/	/	/	/	/

Standard Flanges.

Type / Mark		Norm	Diameter Nominal	Rating	Material Group	Temperature (°C)	Pressure (MPa)	Max. allowable pressure (MPa)
[13]	M1	ASME B16.5	NPS 20	150	SA105	200 °C	1	1.38
		ASME B16.5			1.1 1	test	1.307	3
[13]	M2	ASME B16.5	NPS 20	150	SA105	200 °C	1	1.38
		ASME B16.5			1.1 1	test	1.307	3

Summary of Geometry.

Type Tag		Diameter outside (mm)	Length (mm)	Cumulative height (mm)	Thickness (mm)	Angle (°)	Mass (kg)	Flanges ratings	Specific Gravity	Material
01[05]	30.10	1,400.0	405.0	50.0	10.000	0	176.5		7.85	SA516GR60
02[01]	31.05	1,400.0	2,000.0	2,050.0	10.000	0	685.6		7.85	SA516GR60
03[01]	31.05	1,400.0	2,000.0	4,050.0	10.000	0	685.6		7.85	SA516GR60
04[01]	31.05	1,400.0	1,900.0	5,950.0	10.000	0	651.3		7.85	SA516GR60
05[05]	30.11	1,400.0	405.0	5,950.0	10.000	0	176.5		7.85	SA516GR60

Angle : half angle at apex for a concentric cone ; maximum angle between cone and cylinder for an eccentric cone.
Material: (N) = normalized
NB: Italic line indicates an element for which the calculation under pressure has not been done.

Summary of Weights, Capacities and Painting Areas.

Designation		Mass (kg)	Lifted	Erected	Operating	Test	Shutdown
Shells		2,022	X	X	X	X	X
Cones							
Heads		353	X	X	X	X	X
Shell flanges							
Skirts							
Support saddles		326	X	X	X	X	X
Anchor boxes							
Fireproofing							
Man holes		566	X	X	X	X	X
Nozzles							
Piping							
Support Ring							
Trays							
Liquid on trays							
Packing							
Helicoidal plates							
Internal lining							
Insulation supports		43	X	X	X	X	X
Insulation (Vessel)		114			X		X
Insulation (Piping)							
Coil							
Liquid in Coils							
Stiffening rings		23	X	X	X	X	X
Piping Clips							
Structural Clips							
Ladders							
Platforms							
Tubesheets							
Tubes and Tie Rods							
Baffles and Support Baffles							
Floating head flange							
Split ring and splices							
Internals	Operating						
	Test						
	Lifting						
	Erection						
External loads	Operating						
	Test						
	Lifting						
	Erection						

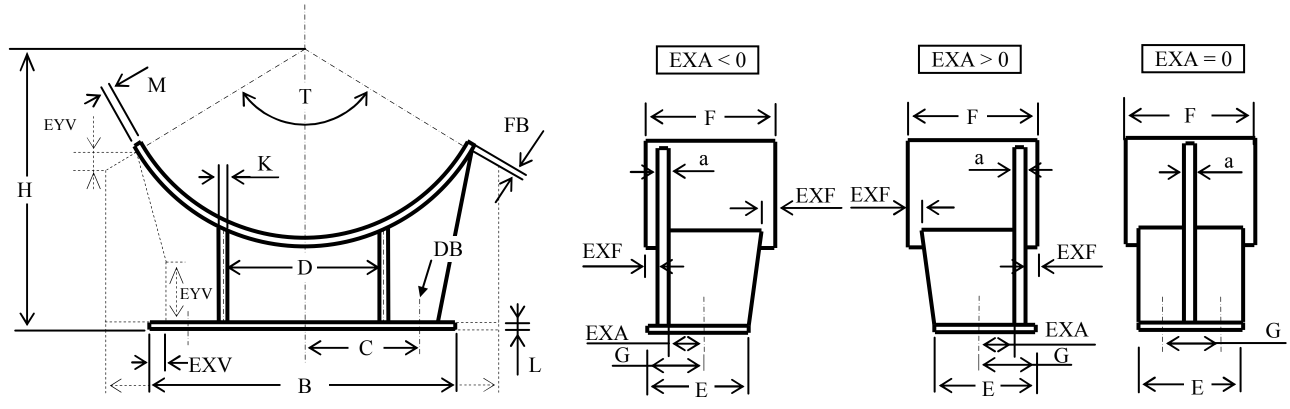
		Compartment	Compartment 1	/	/
Capacity (m^3)			9.662	/	/
Mass (kg)	Liquid	Operating	3,140	/	/
		Test	9,662	/	/
	Total	Test	12,996	/	/

		Vessel
Mass (kg)	Operating	6,587
	Lifted	3,334
	Erected	3,334
	Shutdown	6,587

Area (m^2)	Vessel Tag	32.3
	Support	5.2

NB : New weight.

Summary of saddles.



Standard : APVessel | Number of saddles = 2 | Fixed support No. = 1

Saddle No 1 (left)

Location = 500 mm	Stiffness = /	H = 900 mm		Loose
Diameter =1,400 mm		T = 120 °	Mass = 163 kg	
4 Bolts : Diameter = 24 mm (Hole Diameter = 30 mm)			Border Rib	

Base Plate							2 Ribs		Wear Plate				Web	
E (mm)	B (mm)	L (mm)	C (mm)	G (mm)	EXV (mm)	EYV (mm)	K (mm)	D (mm)	M (mm)	F (mm)	FB (mm)	EXF (mm)	EXA (mm)	a (mm)
250	1,240	16	580	130	110	/	14	340	14	250	75	/	0	14

Saddle No 2 (right)

Location = 5,500 mm	Stiffness = /	H = 900 mm		Loose
Diameter =1,400 mm		T = 120 °	Mass = 163 kg	
4 Bolts : Diameter = 24 mm (Hole Diameter = 30 mm)			Border Rib	

Base Plate							2 Ribs		Wear Plate				Web	
E (mm)	B (mm)	L (mm)	C (mm)	G (mm)	EXV (mm)	EYV (mm)	K (mm)	D (mm)	M (mm)	F (mm)	FB (mm)	EXF (mm)	EXA (mm)	a (mm)
250	1,095	16	580	130	110	/	14	340	14	250	75	/	0	14

Summary of Foundation Loads

		seismic load	
Ra_V :	Vertical reaction in daN	(++)	vertical downside and horizontal longitudinal to the right
Ra_{HT} :	Horizontal (cross) reaction in daN	(+–)	vertical downside and horizontal longitudinal to the left
Ra_{HL} :	Horizontal (longitudinal) reaction in daN	(–+)	vertical upside and horizontal longitudinal to the right
Am_T :	Circumferential bending moment in daN·m	(––)	vertical upside and horizontal longitudinal to the left
Am_L :	Longitudinal bending moment in daN·m	(+)	vertical downside and horizontal cross
Stacked vessels: loads for the combined stack.		(–)	vertical upside and horizontal cross

		Support No.	1	2	3	4	5	6	7	8	9	10
(Corroded Weight)	Operation Int.P. Wind Normal	Ra_V	2,881	2,882								
		Ra_{HT}	0	0								
		Ra_{HL}	865	-865								
		Am_T	0	0								
		Am_L	0	0								
(New Weight)	Lifting	Ra_V	1,634	1,635								
		Ra_{HT}	0	0								
		Ra_{HL}	0	0								
		Am_T	0	0								
		Am_L	0	0								

(New Weight)	Erected	Ra_V	1,634	1,635								
		Ra_{HT}	0	0								
		Ra_{HL}	0	0								
		Am_T	0	0								
		Am_L	0	0								

(Corroded Weight)	During test	Ra_V	6,024	6,026								
		Ra_{HT}	0	0								
		Ra_{HL}	0	0								
		Am_T	0	0								
		Am_L	0	0								

(Corroded Weight)	Shutdown Wind Normal	Ra_V	2,881	2,882								
		Ra_{HT}	0	0								
		Ra_{HL}	865	-865								
		Am_T	0	0								
		Am_L	0	0								

(Corroded Weight)	During test P = 0.	Ra_V	6,024	6,026								
		Ra_{HT}	0	0								
		Ra_{HL}	0	0								
		Am_T	0	0								
		Am_L	0	0								

List of customisable files.

Materials	C:\Users\Public\Documents\AutoPIPE Vessel\Config\Material.emdm (?)
Shapes	C:\Users\Public\Documents\AutoPIPE Vessel\Config\dimsha.doc (Tue Jul 22 18:21:26 2014) *C:\Users\Public\Documents\AutoPIPE Vessel\Config\dimsha.emsd (Tue Jul 22 18:21:28 2014)*
Brackets	/
Saddles	C:\Users\Public\Documents\AutoPIPE Vessel\Config\dimsad.doc (Tue Jul 22 18:21:26 2014) *C:\Users\Public\Documents\AutoPIPE Vessel\Config\dimsad.emsd (Tue Jul 22 18:21:26 2014)*
Anchoring	/
Gussets	/
Legs	/
Reinforcing pads	C:\Users\Public\Documents\AutoPIPE Vessel\Config\dimpad.doc (Tue Jul 22 18:21:26 2014) *C:\Users\Public\Documents\AutoPIPE Vessel\Config\dimpad.emsd (Tue Jul 22 18:21:26 2014)*
Projection of nozzles	C:\Users\Public\Documents\AutoPIPE Vessel\Config\dimpro.doc (Tue Jul 22 18:21:26 2014) *C:\Users\Public\Documents\AutoPIPE Vessel\Config\dimpro.emsd (Tue Jul 22 18:21:26 2014)*
Tubes	C:\Users\Public\Documents\AutoPIPE Vessel\Config\dimpip.doc (Tue Jul 22 18:21:26 2014) *C:\Users\Public\Documents\AutoPIPE Vessel\Config\dimpip.emsd (Tue Jul 22 18:21:26 2014)*
Pipe fittings	/
Trade thickness	/
Flanges	C:\Users\Public\Documents\AutoPIPE Vessel\Config\flangeAS.doc (Tue Jul 22 18:21:28 2014) *C:\Users\Public\Documents\AutoPIPE Vessel\Config\flangeAS.emsd (Tue Jul 22 18:21:28 2014)* C:\Users\Public\Documents\AutoPIPE Vessel\Config\StandardFlangeReferenceTable.doc (Tue Jul 22 18:21:24 2014) *C:\Users\Public\Documents\AutoPIPE Vessel\Config\StandardFlangeReferenceTable.emsd (Tue Jul 22 18:21:24 2014)*
Gaps for exchanger	/
Bolts	C:\Users\Public\Documents\AutoPIPE Vessel\Config\boltUN.doc (Tue Jul 22 18:21:26 2014) *C:\Users\Public\Documents\AutoPIPE Vessel\Config\boltUN.emsd (Tue Jul 22 18:21:26 2014)*

Summary of Errors and Warnings.

No.	Explanation (the number is used for technical support)
	Error (s) : /
	Warning (s) :
159	NOZZLES: no verification of multiple openings.
602	SADDLE n° 1 : the application conditions do not allow to the wear plate to be considered as a reinforcing plate.
602	SADDLE n° 2 : the application conditions do not allow to the wear plate to be considered as a reinforcing plate.
717	LIFTING : Lugs/trunnions are not placed at the same distance from the center of gravity.
Total: 0 error(s) and 4 warning(s).	