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Pressure Summary

Pressure Summary for Chamber bounded by Top of vessel and Top of vessel

Identifier	P Design (kPa)	T Design (°C)	MAEP (kPa)	T_e external (°C)	MDMT (°C)	MDMT Exemption		Impact Tested
Cylinder #1	2,071	65.6	696.36	65.6	-196	Note 1		No
Nozzle #1 (A11)	7,400	65.6	2,171	65.6	-196	Nozzle	Note 2	No
						Pad	Note 1	No
A31 (A31)	7,400	65.6	2,171	65.6	-196	Nozzle	Note 2	No
						Pad	Note 1	No

Chamber design MDMT is -105 °C
Chamber rated MDMT is -196 °C @ 2,071 kPa

Chamber Design MAWP hot & corroded is 2,071 kPa

Chamber MAEP is 696.36 kPa @ 65.6 °C
Vacuum rings did not govern the external pressure rating.

Notes for Maximum Pressure Rating:

Note #	Details
1.	Option to calculate MAP was not selected. See the Calculation->General tab of the Set Mode dialog.
2.	Option to calculate MAWP was not selected. See the Calculation->General tab of the Set Mode dialog.

Notes for MDMT Rating:

Note #	Exemption	Details
1.	Rated MDMT per UHA-51(d)(1)(a), (carbon content does not exceed 0.10%) = -196 °C	
2.	Impact test exempt per UHA-51(g)(coincident ratio = 0.225)	

Design notes are available on the Settings Summary page.

Thickness Summary

Component Identifier	Material	Diameter (mm)	Length (mm)	Nominal t (mm)	Design t (mm)	Total Corrosion (mm)	Joint E	Load
Cylinder #1	SA-240 304	3,200 ID	2,133.6	25	24.23	0	1.00	Internal

Nominal t: Vessel wall nominal thickness

Design t: Required vessel thickness due to governing loading + corrosion

Joint E: Longitudinal seam joint efficiency

* Head minimum thickness after forming

Load

internal: Circumferential stress due to internal pressure governs

external: External pressure governs

Wind: Combined longitudinal stress of pressure + weight + wind governs

Seismic: Combined longitudinal stress of pressure + weight + seismic governs

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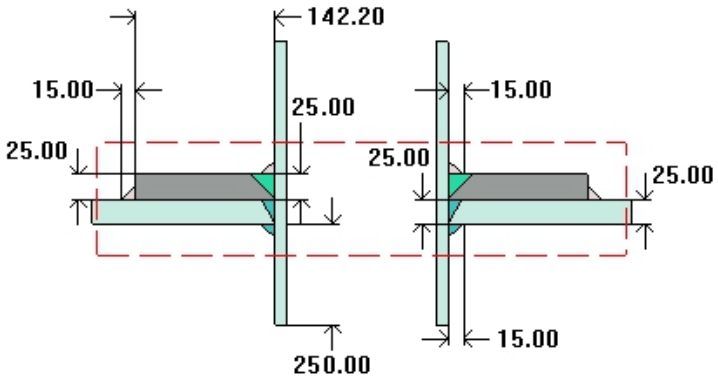

$t_{w(lower)}$ = 25 mm
Leg_{41} = 15 mm
$t_{w(upper)}$ = 25 mm
Leg_{42} = 15 mm
Leg_{43} = 15 mm
h_{new} = 250 mm
D_p = 672.93 mm
t_e = 25 mm

Note: round inside edges per UG-76(c)

Location and Orientation

Located on:	Cylinder #1
Orientation:	0°
Nozzle center line offset to datum line:	600 mm
End of nozzle to shell center:	1,800 mm
Offset from center, Lo:	-650 mm
Passes through a Category A joint:	No

Nozzle

Access opening:	No
Material specification:	SA-312 TP304 Wld & smls pipe (II-D Metric p. 94, ln. 19)
Description:	NPS 14 Sch 80S (XS) DN 350
Inside diameter, new:	330.2 mm
Nominal wall thickness:	12.7 mm
Corrosion allowance:	0 mm
Opening chord length:	359.88 mm
Projection available outside vessel, Lpr:	245.12 mm
Internal projection, h_{new}:	250 mm
Local vessel minimum thickness:	25 mm
Liquid static head included:	0 kPa
Longitudinal joint efficiency:	1

Reinforcing Pad

Material specification:	SA-240 304 (II-D Metric p. 94, ln. 8)
Diameter:	672.93 mm
Is split:	No

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (cm^2) For P = 7,400 kPa @ 65.6 °C *The opening is NOT adequately reinforced*							UG-45 Nozzle Wall Thickness Summary (mm) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
319.0333	89.9483	--	4.0329	8.0645	71.1	6.751	9.15	11.11

UG-41 Weld Failure Path Analysis Summary (N) All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
4,179,556	1,098,943	1,732,947	316,683	3,985,211	1,328,917	3,064,755

UW-16 Weld Sizing Summary			
Weld description	Required weld size (mm)	Actual weld size (mm)	Status
Nozzle to pad fillet (Leg_{41})	6	10.5	weld size is adequate
Pad to shell fillet (Leg_{42})	9.5	10.5	weld size is adequate
Nozzle to pad groove (Upper)	8.89	25	weld size is adequate

Calculations for internal pressure 7,400 kPa @ 65.6 °C

Nozzle Impact test exempt per UHA-51(g)(coincident ratio = 0.225).
Pad rated MDMT per UHA-51(d)(1)(a), (carbon content does not exceed 0.10%) = -196 °C

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(359.88, 179.94 + (12.7 - 0) + (25 - 0))
= 359.88 mm

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(25 - 0), 2.5*(12.7 - 0) + 25)
= 56.75 mm

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(250, 2.5*(25 - 0), 2.5*(12.7 - 0 - 0))
= 31.75 mm

Nozzle required thickness per UG-27(c)(1)

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 7,400*165.1 / (138,000*1 - 0.6*7,400)
= 9.15 mm

Required thickness t_r from UG-37(a)

I think it should be 2071kPa, the shell design pressure

t_r = P*R / (S*E - 0.6*P)
= 7,400*1,600 / (138,000*1 - 0.6*7,400)
= 88.65 mm

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*R / (S*E - 0.6*P)
= 7,400*1,600 / (138,000*1 - 0.6*7,400)
= 88.65 mm

Area required per UG-37(c)

Allowable stresses: S_n = 138, S_v = 138, S_p = 138 MPa

f_{r1} = lesser of 1 or S_n / S_v = 1

f_{r2} = lesser of 1 or S_n / S_v = 1

f_{r3} = lesser of f_{r2} or S_p / S_v = 1

f_{r4} = lesser of 1 or S_p / S_v = 1

A = $d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
= (359.88*88.65*1 + 2*12.7*88.65*1*(1 - 1)) / 100
= 319.0333 cm^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0 cm^2

= $d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= (359.88*(1*25 - 1*88.65) - 2*12.7*(1*25 - 1*88.65)*(1 - 1)) / 100
= -229.0628 cm^2

= $2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= (2*(25 + 12.7)*(1*25 - 1*88.65) - 2*12.7*(1*25 - 1*88.65)*(1 - 1)) / 100
= -47.9915 cm^2

A_2 = smaller of the following= 4.0329 cm^2

= $5*(t_n - t_{rn})*f_{r2}*t$
= (5*(12.7 - 9.15)*1*25) / 100
= 4.4419 cm^2

= $2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
= (2*(12.7 - 9.15)*(2.5*12.7 + 25)*1) / 100

= 4.0329 cm^2

A_3 = smaller of the following= 8.0645 cm^2

= $5*t*t_i*f_{r2}$
= (5*25*12.7*1) / 100
= 15.875 cm^2

= $5*t_i*t_i*f_{r2}$
= (5*12.7*12.7*1) / 100
= 8.0645 cm^2

= $2*h*t_i*f_{r2}$
= (2*250*12.7*1) / 100
= 63.5 cm^2

ti should be replaced by ti-trn

A_{41} = Leg^2*f_{r3}
= $(15^2*1) / 100$
= 2.2503 cm^2

A_{42} = Leg^2*f_{r4}
= $(15^2*1) / 100$
= 2.2503 cm^2

A_{43} = Leg^2*f_{r2}
= $(15^2*1) / 100$
= 2.2503 cm^2

A_5 = $(D_p - d - 2*t_n)*t_e*f_{r4}$
= ((672.93 - 388.53)*25*1) / 100
= 71.1 cm^2

Area = $A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$
= 0 + 4.0329 + 8.0645 + 2.2503 + 2.2503 + 2.2503 + 71.1
= 89.9483 cm^2

***** As Area < A the reinforcement is NOT adequate. *****

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 19 mm or t_n or t_e = 12.7 mm
$t_{c(min)}$ = lesser of 6 mm or $0.7*t_{min}$ = 6 mm
$t_{c(actual)}$ = 0.7*Leg = 0.7*15 = 10.5 mm

Outer fillet: t_{min} = lesser of 19 mm or t_e or t = 19 mm
$t_{w(min)}$ = $0.5*t_{min}$ = 9.5 mm

$t_{w(actual)}$ = 0.7*Leg = 0.7*15 = 10.5 mm

UG-45 Nozzle Neck Thickness Check

$t_{a\ UG-27}$ = P*R / (S*E - 0.6*P) + Corrosion
= 7,400*165.1 / (138,000*1 - 0.6*7,400) + 0
= 9.15 mm

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[9.15 , 0]
= 9.15 mm

t_{b1} = P*R / (S*E - 0.6*P) + Corrosion
= 7,400*1,600 / (138,000*1 - 0.6*7,400) + 0
= 88.65 mm

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[88.65 , 1.5]
= 88.65 mm

t_b = min[t_{b3} , t_{b1}]
= min[8.33 , 88.65]
= 8.33 mm

t_{UG-45} = max[t_a , t_b]
= max[9.15 , 8.33]
= 9.15 mm

Available nozzle wall thickness new, t_n = 0.875*12.7 = 11.11 mm

The nozzle neck thickness is adequate.

Allowable stresses in joints UG-45 and UW-15(c)

Groove weld in tension:	0.74*138 =	102.12 MPa
Nozzle wall in shear:	0.7*138 =	96.6 MPa
Inner fillet weld in shear:	0.49*138 =	67.62 MPa
Outer fillet weld in shear:	0.49*138 =	67.62 MPa
Upper groove weld in tension:	0.74*138 =	102.12 MPa
Lower fillet weld in shear:	0.49*138 =	67.62 MPa

Strength of welded joints:

(1) Inner fillet weld in shear
(π / 2)*Nozzle OD*Leg*S_i = (π / 2)*355.6*15*67.62 = 566,562.87 N

(2) Outer fillet weld in shear
(π / 2)*Pad OD*Leg*S_o = (π / 2)*672.93*15*67.62 = 1,072,149.43 N

(3) Nozzle wall in shear
(π / 2)*Mean nozzle dia*t_n*S_n = (π / 2)*342.9*12.7*96.6 = 660,797.31 N

(4) Groove weld in tension
$(\pi / 2)$*Nozzle OD*t_w*S_g = $(\pi / 2)$*355.6*25*102.12 = 1,426,042.6 N

(5) Lower fillet weld in shear
$(\pi / 2)$*Nozzle OD*Leg*S_l = $(\pi / 2)$*355.6*15*67.62 = 566,562.87 N

(6) Upper groove weld in tension
$(\pi / 2)$*Nozzle OD*t_w*S_g = $(\pi / 2)$*355.6*25*102.12 = 1,426,042.6 N

Loading on welds per UG-41(b)(1)

$W = (A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r))*S_v$
$= (31,903.33 - 0 + 2*12.7*1*(1*25 - 1*88.65))*138$
$= 4,179,556.15$ N

$W_{1-1} = (A_2 + A_5 + A_{41} + A_{42})*S_v$
$= (403.2895 + 7,110 + 225.0318 + 225.0318)*138$
$= 1,098,942.87$ N

$W_{2-2} = (A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v$
$= (403.2895 + 806.45 + 225.0318 + 225.0318 + 2*12.7*25*1)*138$
$= 316,682.87$ N

$W_{3-3} = (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v$
$= (403.2895 + 806.45 + 7,110 + 225.0318 + 225.0318 + 225.0318 + 2*12.7*25*1)*138$
$= 1,328,917.39$ N

Load for path 1-1 lesser of W or W_{1-1} = 1,098,942.87 N
Path 1-1 through (2) & (3) = 1,072,149.43 + 660,797.31 = 1,732,946.73 N
Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or W_{2-2} = 316,682.87 N
Path 2-2 through (1), (4), (5), (6) = 566,562.87 + 1,426,042.6 + 566,562.87 + 1,426,042.6 = 3,985,210.93 N
Path 2-2 is stronger than W_{2-2} so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or W_{3-3} = 1,328,917.39 N
Path 3-3 through (2), (4), (5) = 1,072,149.43 + 1,426,042.6 + 566,562.87 = 3,064,754.89 N
Path 3-3 is stronger than W_{3-3} so it is acceptable per UG-41(b)(1).

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (cm^2) For Pe = 2,171 kPa @ 65.6 °C *The opening is NOT adequately reinforced*							UG-45 Nozzle Wall Thickness Summary (mm) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
108.9567	92.4038	--	6.4884	8.0645	71.1	6.751	8.33	11.11

UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld size (mm)	Actual weld size (mm)	Status
Nozzle to pad fillet (Leg_{41})	6	10.5	weld size is adequate
Pad to shell fillet (Leg_{42})	9.5	10.5	weld size is adequate
Nozzle to pad groove (Upper)	8.89	25	weld size is adequate

Calculations for external pressure 2,171 kPa @ 65.6 °C

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(360.48, 180.24 + (12.7 - 0) + (25 - 0))
= 360.48 mm

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(25 - 0), 2.5*(12.7 - 0) + 25)
= 56.75 mm

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(250, 2.5*(25 - 0), 2.5*(12.7 - 0 - 0))
= 31.75 mm

Nozzle required thickness per UG-28 t_{rn} = 6.98 mm

From UG-37(d)(1) required thickness t_r = 60.45 mm

Area required per UG-37(d)(1)

Allowable stresses: S_n = 138, S_v = 138, S_p = 138 MPa

f_{r1} = lesser of 1 or S_n / S_v = 1

f_{r2} = lesser of 1 or S_n / S_v = 1

f_{r3} = lesser of f_{r2} or S_p / S_v = 1

f_{r4} = lesser of 1 or S_p / S_v = 1

A = $0.5*(d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1}))$
= $(0.5*(360.48*60.45*1 + 2*12.7*60.45*1*(1 - 1))) / 100$
= 108.9567 cm^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0 cm^2

= $d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= $(360.48*(1*25 - 1*60.45) - 2*12.7*(1*25 - 1*60.45)*(1 - 1)) / 100$
= -127.7933 cm^2

= $2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= $(2*(25 + 12.7)*(1*25 - 1*60.45) - 2*12.7*(1*25 - 1*60.45)*(1 - 1)) / 100$
= -26.7303 cm^2

A_2 = smaller of the following= 6.4884 cm^2

= $5*(t_n - t_{rn})*f_{r2}*t$
= $(5*(12.7 - 6.98)*1*25) / 100$
= 7.1458 cm^2

= $2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
= $(2*(12.7 - 6.98)*(2.5*12.7 + 25)*1) / 100$
= 6.4884 cm^2

A_3 = smaller of the following= 8.0645 cm^2

= $5*t*t_i*f_{r2}$
= $(5*25*12.7*1) / 100$
= 15.875 cm^2

= $5*t_i*t_i*f_{r2}$
= $(5*12.7*12.7*1) / 100$
= 8.0645 cm^2

= $2*h*t_i*f_{r2}$

= (2*250*12.7*1) / 100
= 63.5 cm^2

A_{41} = Leg^2*f_{r3}
= $(15^2*1) / 100$
= 2.2503 cm^2

A_{42} = Leg^2*f_{r4}
= $(15^2*1) / 100$
= 2.2503 cm^2

A_{43} = Leg^2*f_{r2}
= $(15^2*1) / 100$
= 2.2503 cm^2

A_5 = $(D_p - d - 2*t_n)*t_e*f_{r4}$
= ((672.93 - 388.53)*25*1) / 100
= 71.1 cm^2

Area = $A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$
= 0 + 6.4884 + 8.0645 + 2.2503 + 2.2503 + 2.2503 + 71.1
= 92.4038 cm^2

***** As Area < A the reinforcement is NOT adequate. *****

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 19 mm or t_n or t_e = 12.7 mm
$t_{c(min)}$ = lesser of 6 mm or $0.7*t_{min}$ = 6 mm
$t_{c(actual)}$ = 0.7*Leg = 0.7*15 = 10.5 mm

Outer fillet: t_{min} = lesser of 19 mm or t_e or t = 19 mm
$t_{w(min)}$ = $0.5*t_{min}$ = 9.5 mm
$t_{w(actual)}$ = 0.7*Leg = 0.7*15 = 10.5 mm

UG-45 Nozzle Neck Thickness Check

$t_{a\ UG-28}$ = 6.98 mm

t_a = max[$t_{a\ UG-28}$, $t_{a\ UG-22}$]
= max[6.98 , 0]
= 6.98 mm

t_{b2} = P*R / (S*E - 0.6*P) + Corrosion

$= 2{,}171*1{,}600 / (138{,}000*1 - 0.6*2{,}171) + 0$
$= 25.41$ mm

$t_{b2} = \max[\, t_{b2} , t_{b\,UG16} \,]$
$= \max[\, 25.41 , 1.5 \,]$
$= 25.41$ mm

$t_b = \min[\, t_{b3} , t_{b2} \,]$
$= \min[\, 8.33 , 25.41 \,]$
$= 8.33$ mm

$t_{UG\text{-}45} = \max[\, t_a , t_b \,]$
$= \max[\, 6.98 , 8.33 \,]$
$= 8.33$ mm

Available nozzle wall thickness new, $t_n = 0.875*12.7 = 11.11$ mm

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 65.6 °C) UG-28(c)

$L / D_o = 401.65 / 355.6 = 1.1295$
$D_o / t = 355.6 / 6.98 = 50.9192$
From table G: $A = 0.003290$
From table HA-1 Metric: $B = 82.9091$ MPa

$P_a = 4*B / (3*(D_o / t))$
$= 4*82{,}909.1 / (3*(355.6 / 6.98))$
$= 2{,}171$ kPa

Design thickness for external pressure P_a = 2,171 kPa

$t_a = t + \text{Corrosion} = 6.98 + 0 = 6.98$ mm