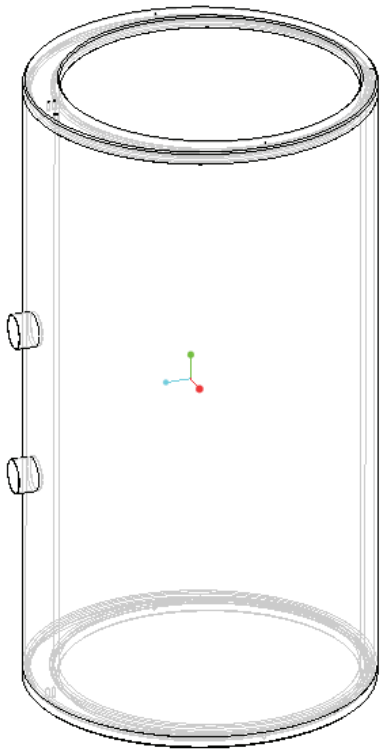
FEA calculation

Aluminum Inner Shell NIKHEF



11-0082C

DeMaCo P100331

Array industries

Client:	**DeMaCo**	Author:	**R. van Ruijven**	Checked:	**J.H. de Groot**
Doc.:	**11-0082C-DOC01**	Rev.:	**A**	Date:	**23-03-2011**

Table of contents

Revision	Date	By	Checked	Issue
A	23-03-2011	RvR	HdG	Fixation pins and load case pressure test added
0	21-03-2011	RvR	HdG	First release

Summary

DeMaCo has to design and fabricate an aluminum inner shell for cryogenic cooling for NIKHEF. In this report stresses are calculated using FEA software. These stresses are checked for compliance with AD 2000 D1 (internal pressure) and D6 (external pressure).

Operating conditions:
- $P_{operating}$ = 1.5 barg
- $T_{operating}$ = -196 to +100°C

Design limits operating:
- P_{design} = 1.5 barg
- T_{design} = +150°C

Leakage testing:
- $P_{eakage\ test}$ = -1.0 barg (Full Vacuum)
- $T_{leakage\ test}$ = 20°C

Test pressure:
- P_{test} = 3.33 barg
- T_{test} = 20°C

Weight of components:
- Weight of vessel (517 kg)
- Nitrogen liquid (216 kg distributed over internal surfaces).
- Bearing load in fixation 4 pins Ø10: 7330 / 4 pins = 1830 N each.

No nozzle loads are defined.

Material type: Aluminum Al 5754

The computed stresses are compared with the maximum allowable stresses according to AD 2000.

Conclusion

- The shell complies with the requirements of AD 2000

1 Introduction

DeMaCo has to design and fabricate an aluminum inner shell for cryogenic cooling for NIKHEF. In this report stresses are calculated using FEA software. These stresses are checked for compliance with AD 2000 D1 (internal pressure) and D6 (external pressure).

All dimensions are in mm

2 Inner shell properties

2.1 Components

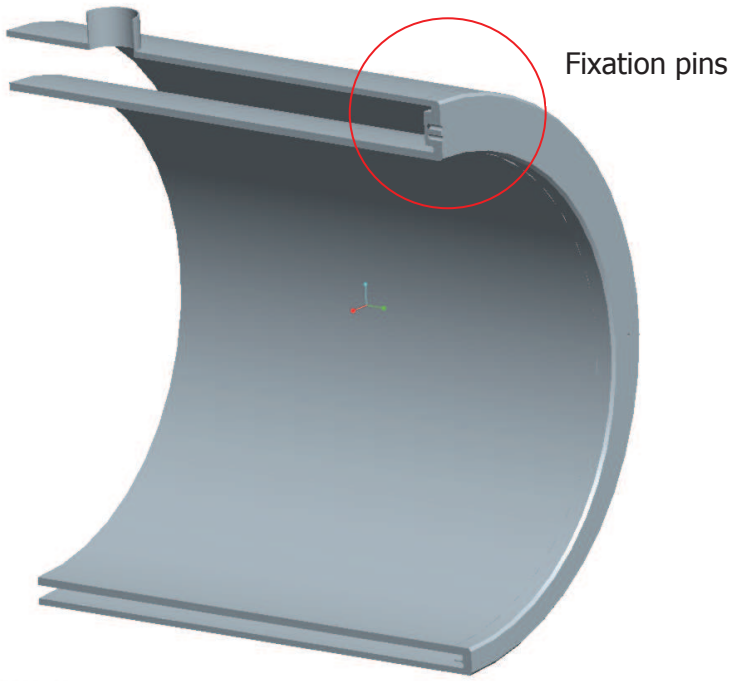
The inner shell consists of two pipes with an 32 mm axis offset.

Inner wall: I.D. Ø950 x 1980 x 15 mm
Outer wall: O.D. Ø1120 x 1980 x 12 mm
Baffle: thickness 40 mm
Nozzle: DN100 x 3

Total weight of shell: 517 kg
Total weight of Nitrogen liquid (density 800 kg/m3): 216 kg

The vessel is fixed by two times two pins connected to the Baffles.

See appendix 1 for a drawing of the model, directly generated from the model.



Figuur 1: FEA model (with two symmetry planes)

2.2 FEA analysis

The FEA analyses are performed using the software package Pro/MECHANICA. The analyses are linear elastic, no plastic material behavior is incorporated. Only solid elements are used, with a maximum element order of 9 after the second calculation step. The 9th order polynomial describes the geometry and stresses with a high level of accuracy, instead of increasing the density of mesh elements like traditional FEA packages do.
All analyses for this project are performed using solid elements.

2.3 Loads

Operating conditions:

- $P_{operating}$ = 1.5 barg
- $T_{operating}$ = -196 to +100°C

Design limits operating:

- P_{design} = 1.5 barg
- T_{design} = +150°C

Leakage testing:

- $P_{eakage\ test}$ = -1.0 barg (Full Vacuum)
- $T_{leakage\ test}$ = 20°C

Test pressure:

- P_{test} = 3.33 barg (PED: 1.25 * 80/45 * 1.5)
- T_{test} = 20°C

No nozzle loads are defined.

Weight of components:

- Weight of vessel (517 kg)
- Nitrogen liquid (216 kg distributed over internal surfaces).
- Bearing load in fixation 4 pins Ø10: 7330 / 4 pins = 1830 N each.

2.4 Material properties

Material type: Aluminum Al 5754

Materials according to AD 2000-Merkblatt W6/1, D1.2003

Temperatures valid between -270°C to + 150°C

Table 2: Al 5754 material properties according to AD 2000

Type and thickness	Condition	0.2% limit -270 to 100 °C [N/mm²]	1.0% limit 150 °C [N/mm²]	Tensile strength [N/mm²]
Tube (0.3 to 10)	0/H111	80	45	180
Plate (25 to 50)	H112	80	45	190

2.5 Corrosion allowances

Corrosion allowance is 0 mm.

2.6 Load cases and evaluation of results

With Pro/MECHANICA, stresses and displacement are computed. The stresses which are shown in the various figures the average stress by the definition of Von Mises.

Load case 1 (Design)
Primary load:

- P_{design} = 1.5 barg
- T_{design} =+150°C
- Weight of components (Weight of vessel and nitrogen. Fixation on 4 pins).

Secondary load

- No secondary loads

Load case 2 (Full Vacuum)
Primary load:

- P_{design} = -1 barg (Full Vacuum)
- T_{design} = 20°C

Secondary load

- No secondary loads

Load case 3 (Hydro test)

- P_{test} = 3.33 barg
- T_{test} = 20°C

Check
According to AD 2000, the following set of checks must be evaluated:

1. $\sigma_{v;pm} \leq$ 1.0% yield stress / S with S (Sicherheitsbeiwert) according to AD2000 B0, table 2: S = 1.5 for normal conditions, S = 1.1 for pressure test

2.7 Additional external pressure check according AD2000 B6

The pressure vessel program BabsyWin is used to check buckling due to external pressure according to AD2000 B6 for both shells. Results can be found in appendix 2.

3 FEA model

Table 1: Components in FEA model

Component	Material type	Corrosion allowance	Effective wall thickness
Inner wall	Tube 15 mm	0 mm	15 mm
Outer wall	Tube 12 mm	0 mm	12 mm
Nozzle	Tube 3 mm	0 mm	3 mm
Baffle	Plate 40 mm	0 mm	40 mm

The FEA model has two symmetry planes, one along the shell axis and one normal to the shell axis.

All elements are solid elements.

3.1 Loadcase 1: design

Table 2: Summary and evaluation of stresses

Load	Maximum calculated stress	Check (T=150°C)	Result
$\sigma_{v;p}$	28 N/mm^2	30 N/mm^2 (1.0% yield/S)	acceptable

Conclusion: the shell complies with the requirements of AD 2000

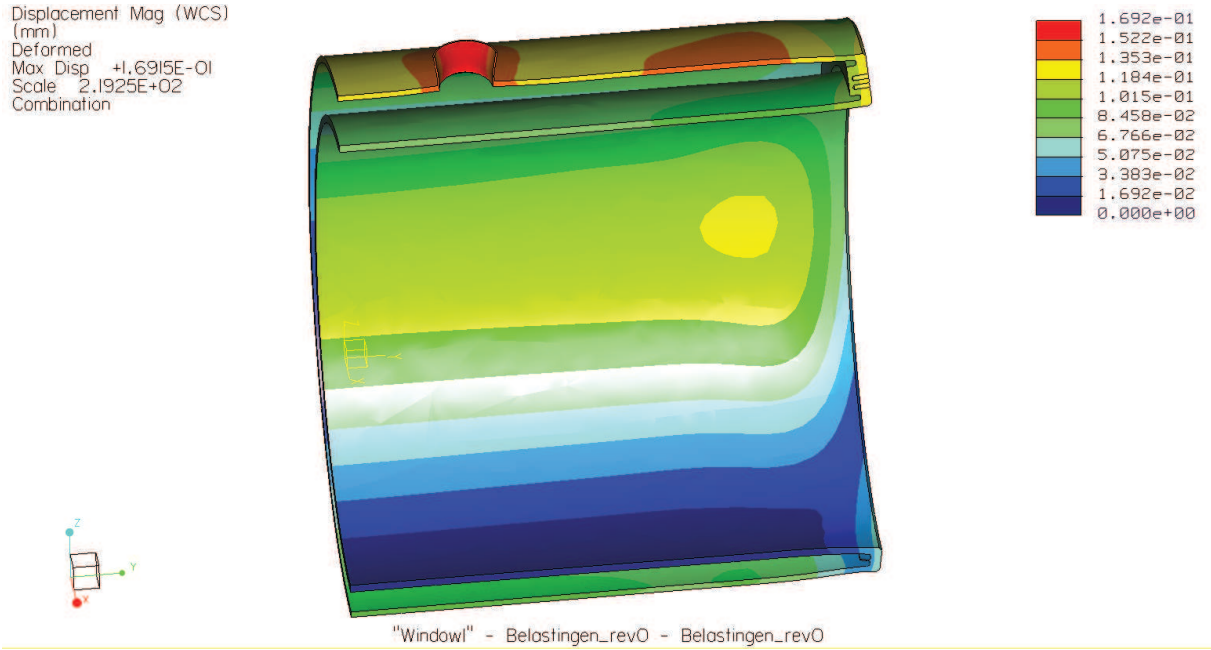


Figure 2: Displacement due to Primary loading (internal pressure). Maximum displacement 0.5 mm.

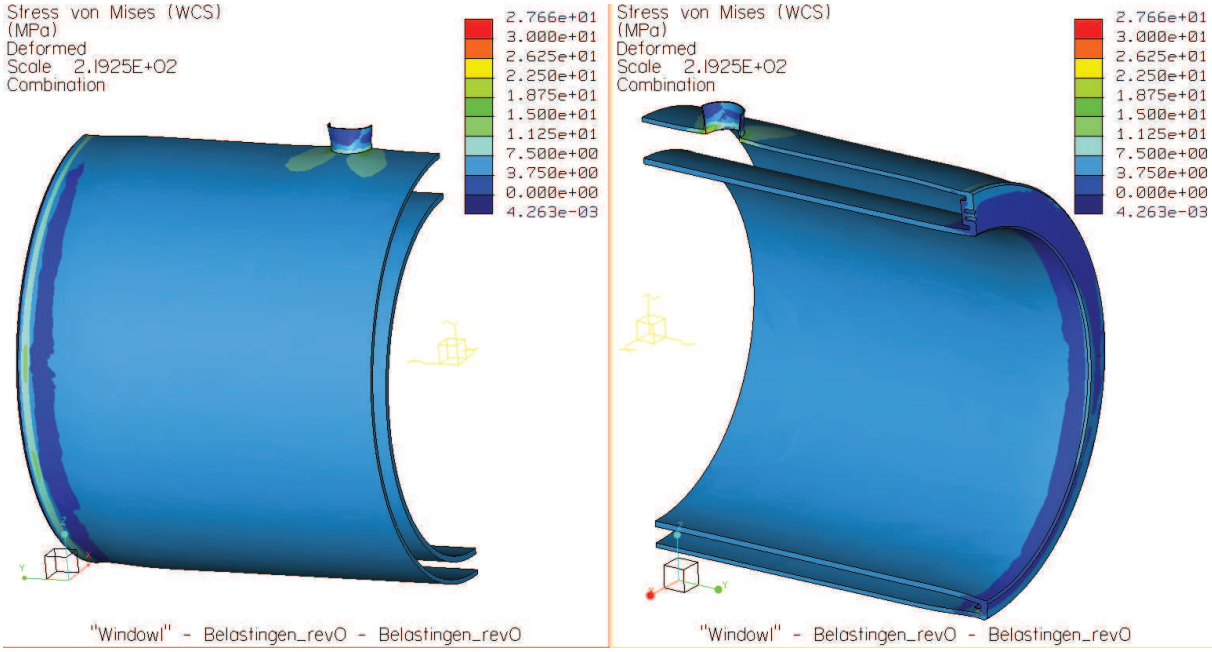


Figure 3: Primary loading (internal pressure only), von Mises stress. $\sigma_{v;pm,max}$ = 28 N/mm^2

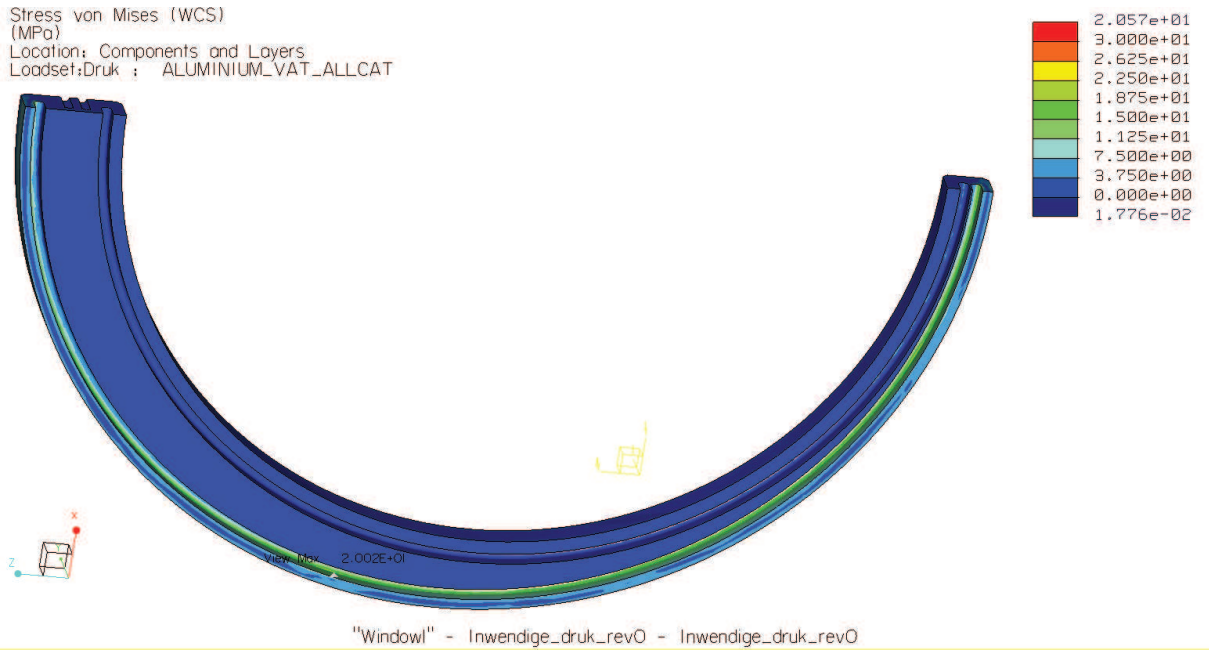


Figure 4: Primary loading (internal pressure only), detail of ring, $\sigma_{v;pm,max}$ = 20 N/mm^2

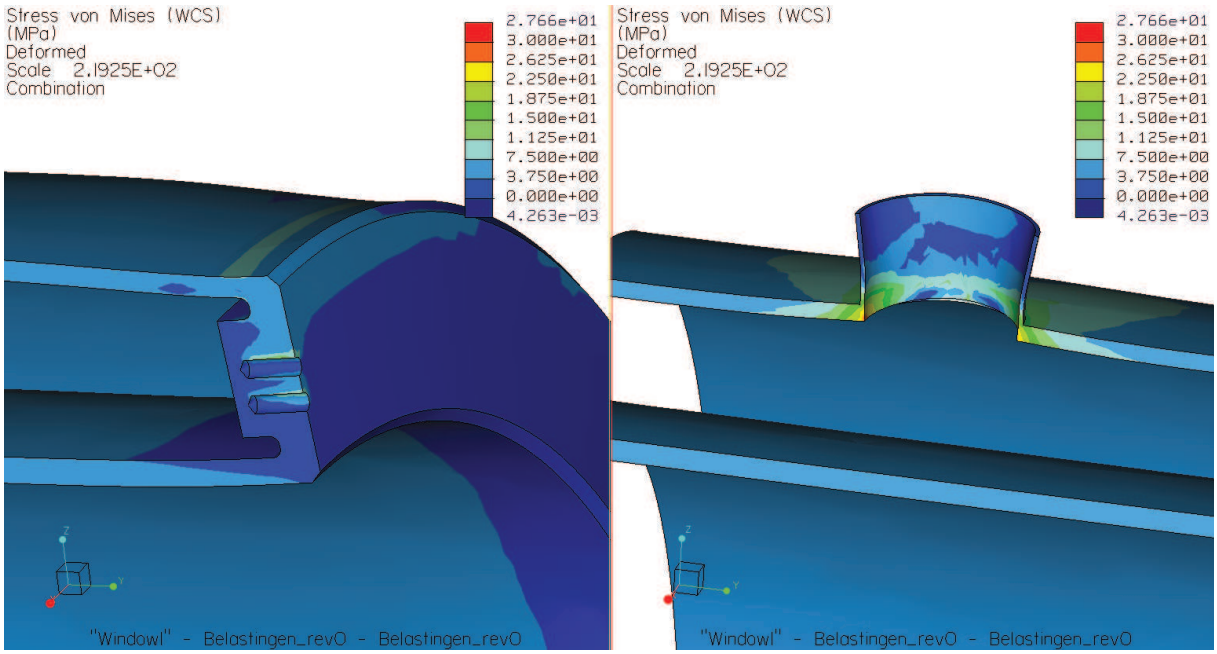


Figure 5: Primary loading (internal pressure only), detail of nozzle and pin holes
$\sigma_{v;pm,max}$ = 28 N/mm^2

3.2 Loadcase 2: Full Vacuum

Table 3: Summary and evaluation of stresses

Load	Maximum calculated stress	Check (T=20°C)	Result
$\sigma_{v;p}$	19 N/mm^2	53 N/mm^2 (0.2% yield/S)	acceptable

Conclusion: the shell complies with the requirements of AD 2000

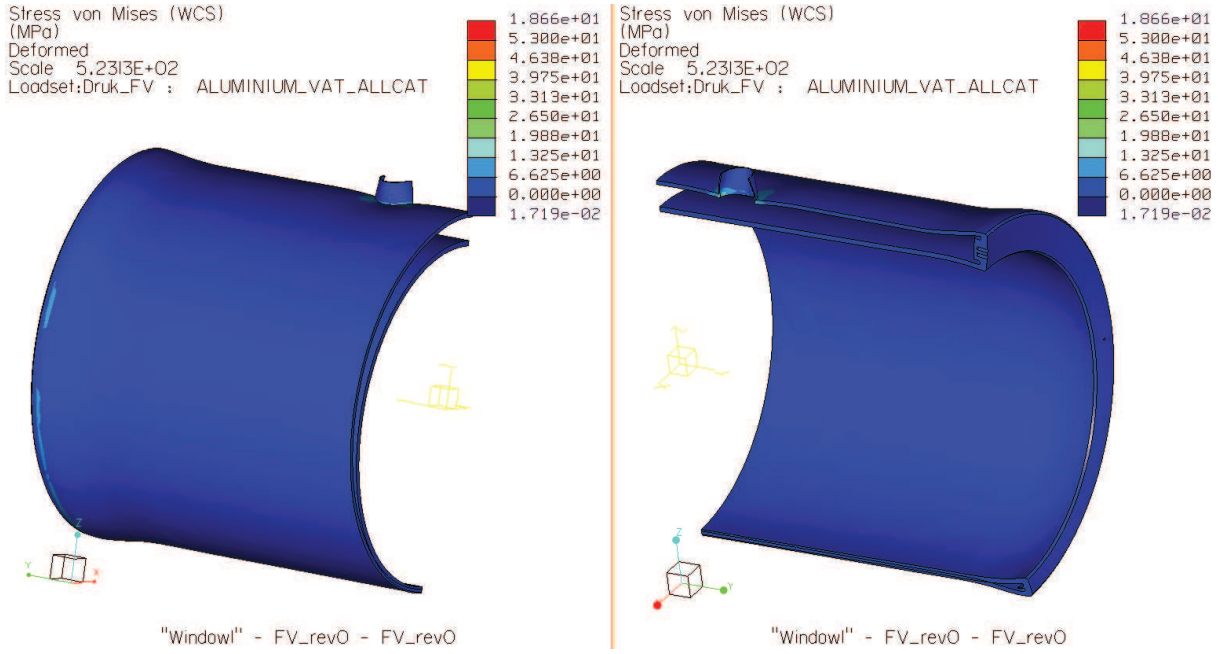


Figure 6: Primary loading (internal pressure only), von Mises stress. $\sigma_{v;pm,max}$ = 19 N/mm^2

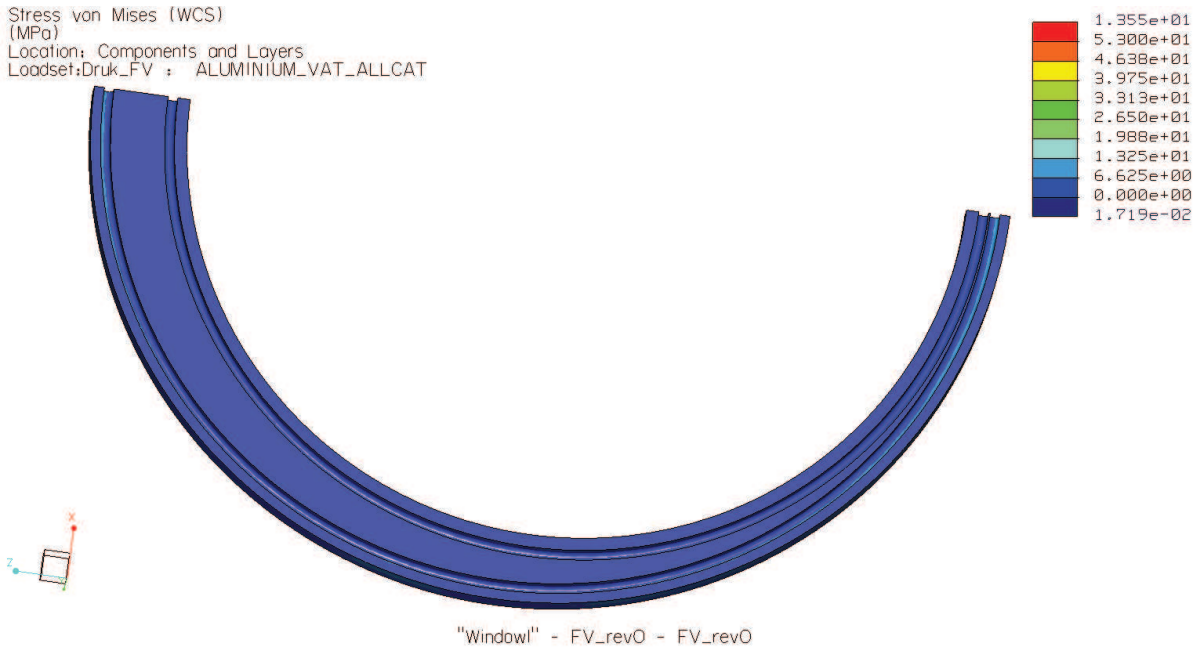


Figure 7: Primary loading (internal pressure only), detail of ring, $\sigma_{v;pm,max}$ = 13 N/mm^2

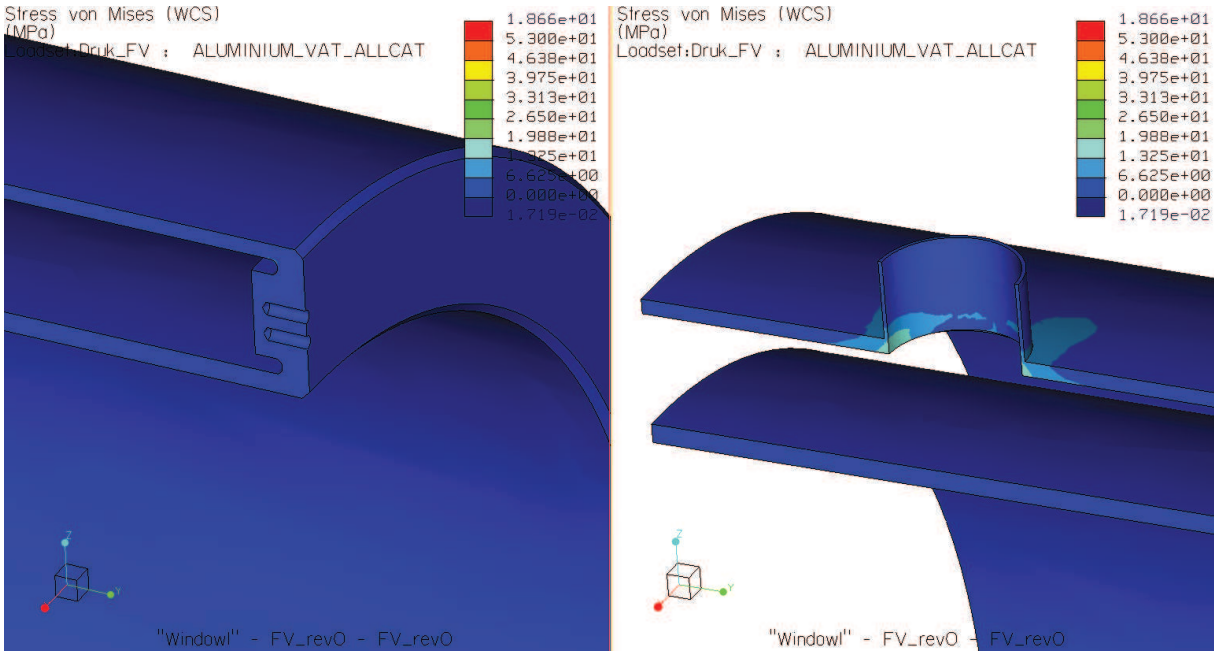


Figure 8: Primary loading (internal pressure only), detail of nozzle and pin holes

$\sigma_{v;pm,max}$ = 19 N/mm^2

3.3 Loadcase 3: Test

Table 4: Summary and evaluation of stresses

Load	Maximum calculated stress	Check (T=20°C)	Result
$\sigma_{v;p}$	62 N/mm^2	72.7 N/mm^2 (0.2% yield/S_{test})	acceptable

Conclusion: the shell complies with the requirements of AD 2000

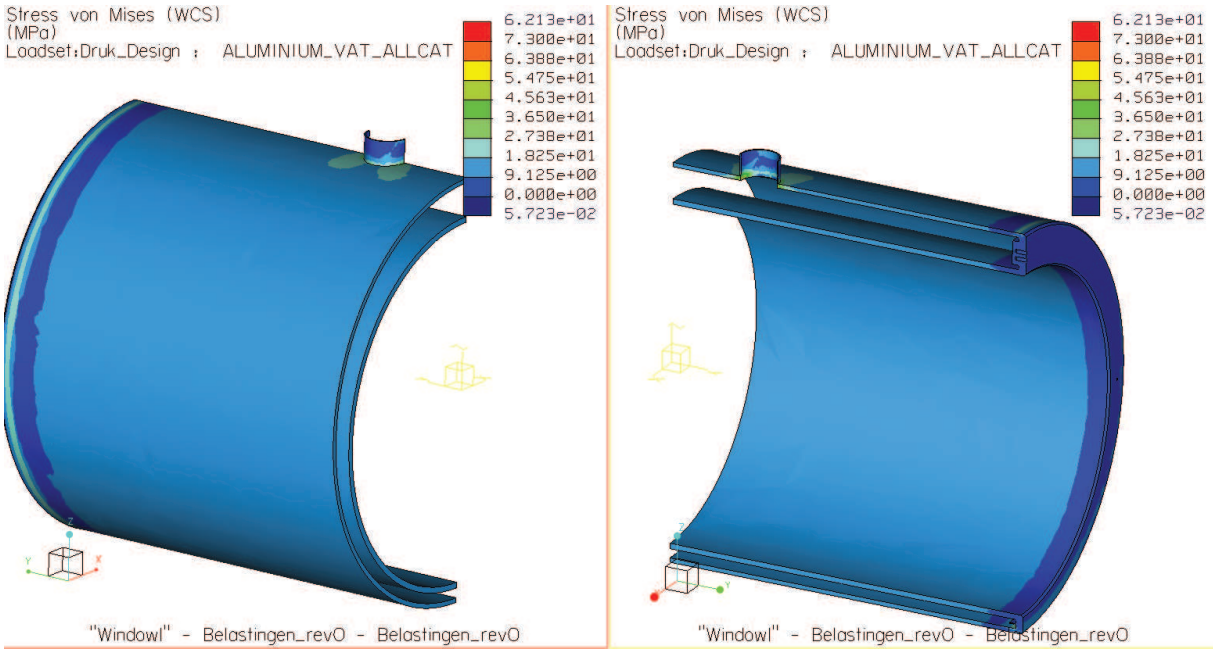


Figure 9: Primary loading (internal pressure only), von Mises stress. $\sigma_{v;pm,max}$ = 62 N/mm^2

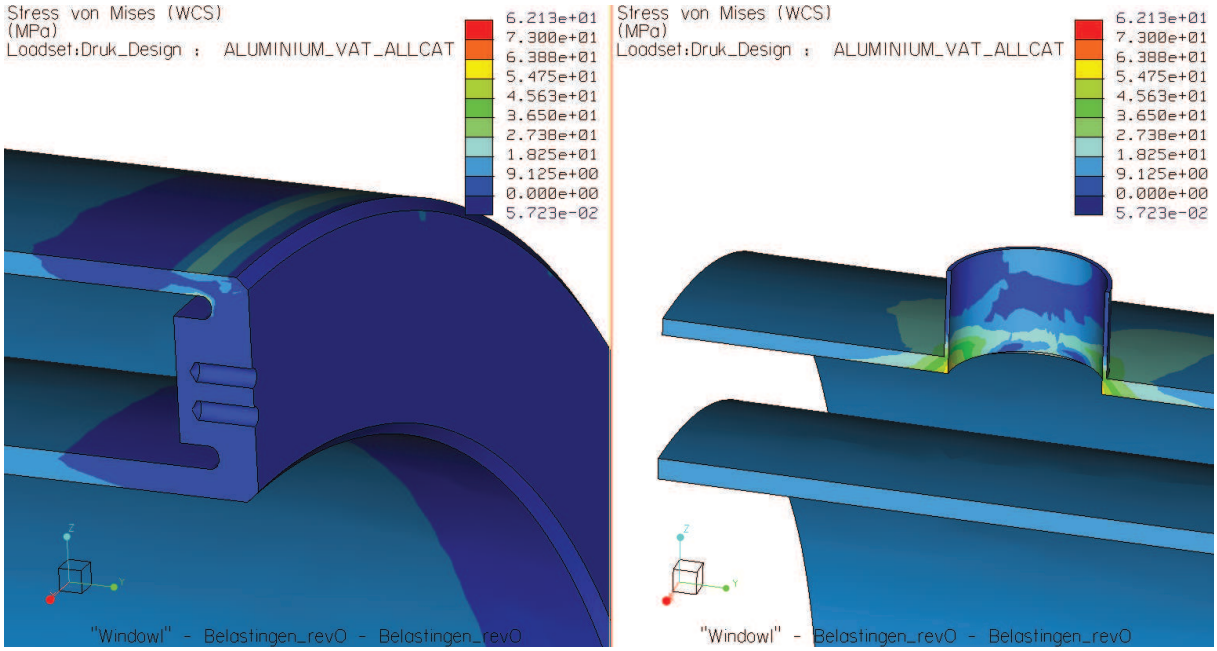


Figure 10: Primary loading (internal pressure only), detail of nozzle and baffle, $\sigma_{v;pm,max}$ = 62 N/mm^2

4 Results of external pressure check according AD2000 B6

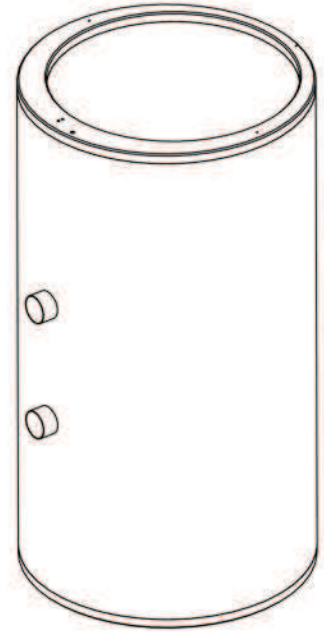
The results of the pressure vessel program BabsyWin in appendix 2 show that the outer vessel is able to withstand an external pressure of 5.4 barg, the inner shell 10 barg according to AD2000 B6 with a safety factor S=1.1 (test condition).

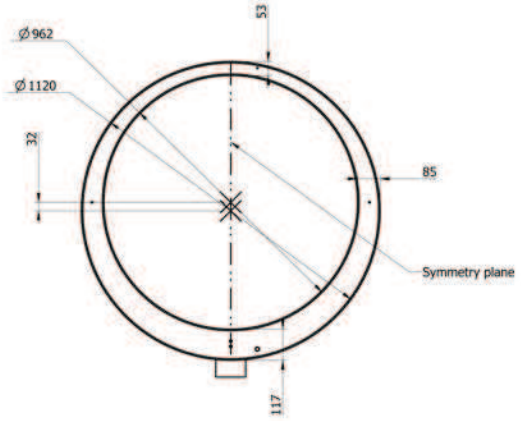
Appendix 1: Drawing

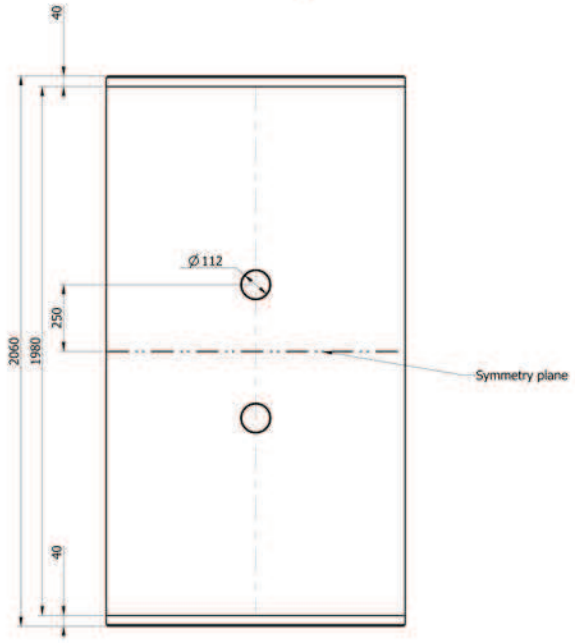
See document: 11-0082C Aluminum Inner Shell NIKHEF rev 0 Appendix 1.pdf

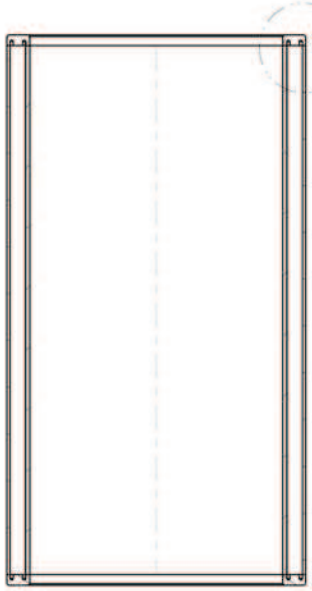
Appendix 2: AD2000 B6 external pressure check

See document: 11-0082C Aluminum Inner Shell NIKHEF rev 0 Appendix 2.pdf

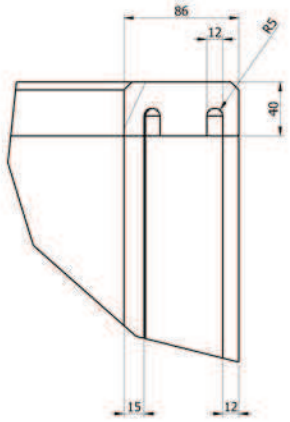








SECTION A-A



DETAIL A
SCALE 1:2

FIRST ISSUE		
APPROVED:	DATE:	INITIAL:

REV	DRW.	DATE	DESCRIPTION	CHKD.
D				
C				
B				
A				
0				

POS.	#	DESCRIPTION	DIMENSIONS	kg	MATERIAL	REMARKS

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PROJECT: Nikhef Aluminum shell allcat
CLIENT: DeMaCo
TITLE: FEA Model
DeMaCo project P100331

SCALE:	1:10	FORM:	A1
DRAWN:	RvR	DATE:	21-03-2011
CHECKED:		DATE:	

DRW. NO.: 11-0082-01 REV.: 0 PROJEC.: GEN. TOLERANCES:

Stress-analysis

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AD-2000-B6:Cylindrical shells subjected to external pressure, issue 10/2006

Loadcase	Testing		
Nominal diameter	DN	1100	
External test pressure	PT	1,00	bar
Temperature	T	20,00	°Celsius

Permitted range

Da/Di =1,0219 <= 1.2 satisfied

Material Data

Chosen material	AlMg3 W19		
Type	Plate		
References	AD W6.1 1.90		
Tensile stress	RmRT	190,00	N/mm²
0.2%-Yield-stress	Rp02,T	80,00	N/mm²
Safety factor	S	1,10	--
Permissible stress	K/S	72,73	N/mm²
Safety factor	Sk(')	2,20	--
Young's modulus	E	70000,00	N/mm²

Allowances

Shell tolerance	c1	0,00	mm
Corrosion allowance	c2	0,00	mm

Geometrical data

External diameter	Da	1120,00	mm
Actual shell thickness	se	12,00	mm
Buckling length	l	2000,00	mm
Number of ridges	n	4	--
Flattening	u	1,50	%
Parameter	Z	0,87965	--
Parameter	Da/l	0,56000	--

Pressure

Elastic buckl. pressure	p1	5,67	bar
Plastic buckl. pressure	p2	5,44	bar
Design pressure	p	1,00	bar

--> no buckling

Stress-analysis

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AD-2000-B6:Cylindrical shells subjected to external pressure, issue 10/2006

Loadcase	Testing		
Nominal diameter	DN	950	
External test pressure	PT	1,00	bar
Temperature	T	20,00	°Celsius

Permitted range

Da/Di =1,0326 <= 1.2 satisfied

Material Data

Chosen material	AlMg3 W19		
Type	Plate		
References	AD W6.1 1.90		
Tensile stress	RmRT	190,00	N/mm²
0.2%-Yield-stress	Rp02,T	80,00	N/mm²
Safety factor	S	1,10	--
Permissible stress	K/S	72,73	N/mm²
Safety factor	Sk(')	2,20	--
Young's modulus	E	70000,00	N/mm²

Allowances

Shell tolerance	c1	0,00	mm
Corrosion allowance	c2	0,00	mm

Geometrical data

External diameter	Da	950,00	mm
Actual shell thickness	se	15,00	mm
Buckling length	l	2000,00	mm
Number of ridges	n	3	--
Flattening	u	1,50	%
Parameter	Z	0,74613	--
Parameter	Da/l	0,47500	--

Pressure

Elastic buckl. pressure	p1	12,50	bar
Plastic buckl. pressure	p2	10,03	bar
Design pressure	p	1,00	bar

--> no buckling

Alca Technology srl
Via Lago di Garda 130 Schio (VI), ITALY 36015

Date Printed: 07/02/2012

VESSEL DESCRIPTION

Cryogenic Vacuum Vessel

Vessel designed with DesignCalcs, Version: 2012.2
Vessel is ASME Code Stamped

Job No: ALCA 20106-01
Vessel Number: 20106-01

NAMEPLATE INFORMATION

Vessel MAWP:	0,0500 MPa at -196 °C - FV
MDMT:	-196 °C at 0,0500 MPa - FV
Serial Number(s):	20106/01
National Board Number(s):	_____
Year Built:	2012
Radiography:	RT 3
Postweld Heat Treated:	NONE
Construction Type:	W
Special Type:	LT

Signatures

_____ Date: ____/____/____

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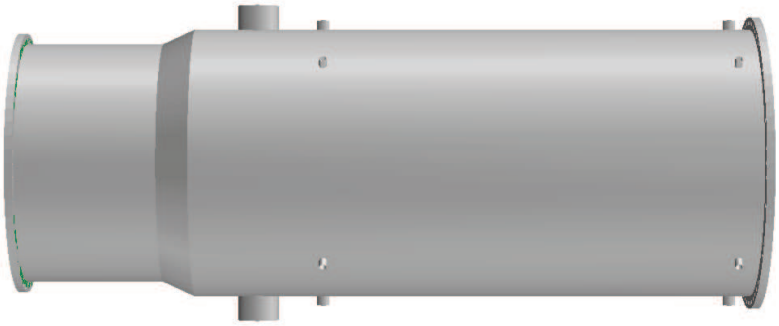
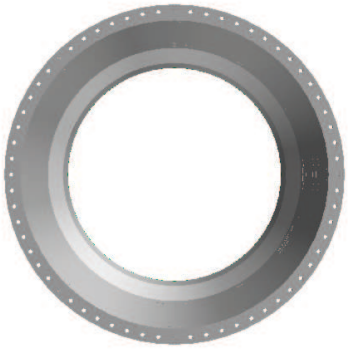
Via Lago di Garda 130 Schio (VI), ITALY 36015

Date Printed: 07/02/2012





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Shell 1

Job No: ALCA 20106-01 Vessel Number: 20106-01
Number: 1 Mark Number: S1

Date Printed: 07/02/2012

Cylindrical Shell Design Information

Design Pressure:	0.0500	MPa	Design Temperature:	-196	°C
Static Head:	0.0000	MPa	Long. Joint Efficiency:	85	%
Shell Material:	SA-240 Gr. 304, High		Factor B Chart:	HA-1	
			Material Stress (hot):	138.00	MPa
Shell Length:	2870.00	mm	Material Stress (cold):	138.00	MPa
			Compressive Stress:	72.12	MPa
Corrosion Allowance:	0.00	mm	Actual Circumferential Stress:	5.00	MPa
External Corrosion Allowance:	0.00	mm	Actual Longitudinal Stress:	2.47	MPa
Inside Diameter (new):	1350.00	mm	Extreme Fiber Elongation:	0.59	%
Inside Diameter (corroded):	1350.00	mm	Specific Gravity:	1.00	
Shell Surface Area:	12.32	sq. m	Weight of Fluid:	4108.08	kg
Shell Estimated Volume:	4.11	cu. m	Total Flooded Shell Weight:	4894.65	kg
Circ. Joint Efficiency:	85	%	Shell Weight:	786.57	kg

Minimum Design Metal Temperature Data

Minimum Design Metal Temperature: -196 °C
Material is exempt from impact testing per UHA-51(d)

External Pressure Data

Design Pressure (Pa):	0.1000	MPa	Design Temperature:	-196	°C
Dimension L:	2870.00	mm			
Ext. Minimum t:	5.87	mm	Ext. Nominal t:	8.00	mm
Minimum L/Do:	2.1010		Nominal L/Do:	2.1010	
Minimum Do/t:	232.7090		Nominal Do/t:	170.7500	
Minimum Factor A:	0.0001803		Nominal Factor A:	0.0002906	
Minimum Factor B:	17.45	MPa	Nominal Factor B:	28.12	MPa

Design Thickness Calculations

Longitudinal Stress Calculations per Paragraph UG-27(c)(2)

$$\mathbf{t} = \frac{PR}{2SE + 0.4P} = \frac{0.0500 * 675.00}{2 * 138.00 * 0.85 + 0.4 * 0.0500}$$

= Greater Of $(0.14_{(Calculated)}, 1.50_{(Minimum\ Allowed)}) + 0.00_{(corrosion)} + 0.00_{(ext.\ corrosion)}$ = minimum of **1.50** mm

Circumferential Stress Calculations per UG-27(c)(1)

$$\mathbf{t} = \frac{PR}{SE - 0.6P} = \frac{0.0500 * 675.00}{138.00 * 0.85 - 0.6 * 0.0500}$$

= Greater of $(0.29_{(Calculated)}, 1.50_{(Minimum\ Allowed)}) + 0.00_{(corrosion)} + 0.00_{(ext.\ corrosion)}$ = minimum of **1.50** mm

Maximum External Pressure Calculation per Paragraph UG-28

$$\mathbf{Pa}\ (\text{using } \textit{nominal}t) = \frac{4B}{3(D_o / t)} = \frac{4 * 28.12}{3 * (1366.00 / 8.00)}$$

= maximum external pressure of **0.2196** MPa

External loads do not control design.

Nominal Shell Thickness Selected = **8.00** mm

Alca Technology srl

A D63.5

Job No: ALCA 20106-01
Number: 1
ID Number: 1

Vessel Number: 20106-01
Mark Number: A

Date Printed: 07/02/2012

Nozzle Design Information

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Nozzle Efficiency (E):	100 %
Nozzle Material:	SA-312 TP304L, High	Joint Efficiency (E_1):	1.00
		Factor B Chart:	HA-3
External Projection:	45.00 mm	Allowable Stress at Design Temperature (S_n):	97.80 MPa
Internal Projection:	0.00 mm	Allowable Stress at Ambient Temperature:	97.80 MPa
Inside Corrosion Allowance:	0.00 mm	Correction Factor (F):	1.00
External Corrosion Allowance:	0.00 mm	Nozzle Path:	None
Nozzle ID (new):	59.50 mm	Nozzle Wall Thickness(new):	2.00 mm
Nozzle ID (corroded):	59.50 mm	Nozzle Wall Thickness(corroded):	2.00 mm
Outer "h" Limit:	5.00 mm	Upper Weld Leg Size(Weld 41):	2.00 mm
Internal "h" Limit:	5.00 mm	Internal Weld Leg Size(Weld 43):	0.00 mm
OD, Limit of Reinforcement:	119.00 mm	Outside Groove Weld Depth:	8.00 mm

Minimum Design Metal Temperature

Minimum Design Metal Temperature: -196 °C
Other Exemption

Host Component: Shell 1 - Shell 1

Material:	SA-240 Gr. 304, High	Shell wall thickness(new):	8.00 mm
Material Stress(S_V):	138.00 MPa	Shell wall thickness(corroded):	8.00 mm

Nozzle Detail Information

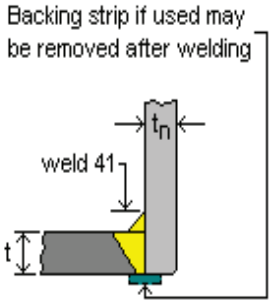

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 2.00 mm

Nozzle Wall Thickness(t_n): 2.00 mm

Outside Groove Weld Depth: 8.00 mm

Nozzle passes through the vessel, attached by a groove weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is adequately reinforced for External Pressure.
Reinforcement calculations are not required per UG-36(c)(3)(a)See Uw-14 for exceptions.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PR}{SE - 0.6P} = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} = \mathbf{0.24} \text{ mm}$$

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{0.0500 * 29.75}{97.80 * 1 - 0.6 * 0.0500} = \mathbf{0.02} \text{ mm}$$

Required Nozzle Thickness for External Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 63.50 * 0.1000}{4 * 29.48} = \mathbf{0.18} \text{ mm}$$

Strength Reduction Factors

$$\mathbf{fr1} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087 \quad \mathbf{fr2} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

$$\mathbf{fr3} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion)

$$t_a = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 29.75}{97.80 * 1.00 - 0.6 * 0.0500} + 0.00 + 0.00 = \mathbf{0.02} \text{ mm}$$

Nozzle Thickness for Internal Pressure (plus corrosion) Based on Host

$$t_{b1} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} + 0.00 + 0.00$$

$= \text{Greater Of } (0.24_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00 \text{ (corrosion)} + 0.00 \text{ (ext. corrosion)} = \mathbf{1.50}$ mm

Nozzle Thickness for External Pressure (plus corrosion) Based on Host

$$t_{b2} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.1000 * 675.00}{138.00 * 1 - 0.6 * 0.1000} + 0.00 + 0.00$$

$= \text{Greater Of } (0.49_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00 \text{ (corrosion)} + 0.00 \text{ (ext. corrosion)} = \mathbf{1.50}$ mm

Minimum Thickness (plus corrosion) per Table UG-45

t_{b3} = minimum thickness (Table UG-45) + Ca + ext. Ca = **4.52** mm

Nozzle Minimum Thickness Based on Host and Table UG-45

$t_b = \min[t_{b3}, \max(t_{b1}, t_{b2})]$ = **1.50** mm

$t_{UG\text{-}45} = \max(t_a, t_b)$ = **1.50** mm

Wall thickness = tn = **2.00** is greater than or equal to UG-45 value of **1.50**

Alca Technology srl

H D63.5

Job No: ALCA 20106-01
Number: 8
ID Number: 8

Vessel Number: 20106-01
Mark Number: H

Date Printed: 07/02/2012

Nozzle Design Information

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Nozzle Efficiency (E):	100 %
Nozzle Material:	SA-312 TP304L, High	Joint Efficiency (E_1):	1.00
		Factor B Chart:	HA-3
External Projection:	45.00 mm	Allowable Stress at Design Temperature (S_n):	97.80 MPa
Internal Projection:	0.00 mm	Allowable Stress at Ambient Temperature:	97.80 MPa
Inside Corrosion Allowance:	0.00 mm	Correction Factor (F):	1.00
External Corrosion Allowance:	0.00 mm	Nozzle Path:	None
Nozzle ID (new):	59.50 mm	Nozzle Wall Thickness(new):	2.00 mm
Nozzle ID (corroded):	59.50 mm	Nozzle Wall Thickness(corroded):	2.00 mm
Outer "h" Limit:	5.00 mm	Upper Weld Leg Size(Weld 41):	2.00 mm
Internal "h" Limit:	5.00 mm	Internal Weld Leg Size(Weld 43):	0.00 mm
OD, Limit of Reinforcement:	119.00 mm	Outside Groove Weld Depth:	8.00 mm

Minimum Design Metal Temperature

Minimum Design Metal Temperature: -196 °C
Other Exemption

Host Component: Shell 1 - Shell 1

Material:	SA-240 Gr. 304, High	Shell wall thickness(new):	8.00 mm
Material Stress(S_V):	138.00 MPa	Shell wall thickness(corroded):	8.00 mm

Nozzle Detail Information

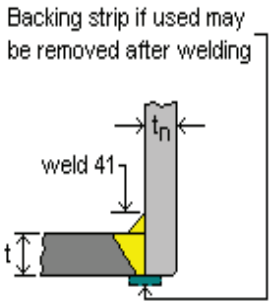

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 2.00 mm

Nozzle Wall Thickness(t_n): 2.00 mm

Outside Groove Weld Depth: 8.00 mm

Nozzle passes through the vessel, attached by a groove weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is adequately reinforced for External Pressure.
Reinforcement calculations are not required per UG-36(c)(3)(a)See Uw-14 for exceptions.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PR}{SE - 0.6P} = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} = \mathbf{0.24} \text{ mm}$$

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{0.0500 * 29.75}{97.80 * 1 - 0.6 * 0.0500} = \mathbf{0.02} \text{ mm}$$

Required Nozzle Thickness for External Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 63.50 * 0.1000}{4 * 29.48} = \mathbf{0.18} \text{ mm}$$

Strength Reduction Factors

$$\mathbf{fr1} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087 \quad \mathbf{fr2} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

$$\mathbf{fr3} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion)

$$t_a = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 29.75}{97.80 * 1.00 - 0.6 * 0.0500} + 0.00 + 0.00 = \mathbf{0.02} \text{ mm}$$

Nozzle Thickness for Internal Pressure (plus corrosion) Based on Host

$$t_{b1} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} + 0.00 + 0.00$$

$= \text{Greater Of } (0.24_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00 \text{ (corrosion)} + 0.00 \text{ (ext. corrosion)} = \mathbf{1.50}$ mm

Nozzle Thickness for External Pressure (plus corrosion) Based on Host

$$t_{b2} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.1000 * 675.00}{138.00 * 1 - 0.6 * 0.1000} + 0.00 + 0.00$$

$= \text{Greater Of } (0.49_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00 \text{ (corrosion)} + 0.00 \text{ (ext. corrosion)} = \mathbf{1.50}$ mm

Minimum Thickness (plus corrosion) per Table UG-45

t_{b3} = minimum thickness (Table UG-45) + Ca + ext. Ca = **4.52** mm

Nozzle Minimum Thickness Based on Host and Table UG-45

$t_b = \min[t_{b3}, \max(t_{b1}, t_{b2})]$ = **1.50** mm

$t_{UG\text{-}45} = \max(t_a, t_b)$ = **1.50** mm

Wall thickness = tn = **2.00** is greater than or equal to UG-45 value of **1.50**

Nozzle Design Information

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Nozzle Efficiency (E):	100 %
Nozzle Material:	SA-312 TP304L, High	Joint Efficiency (E_1):	1.00
		Factor B Chart:	HA-3
External Projection:	45.00 mm	Allowable Stress at Design Temperature (S_n):	97.80 MPa
Internal Projection:	0.00 mm	Allowable Stress at Ambient Temperature:	97.80 MPa
Inside Corrosion Allowance:	0.00 mm	Correction Factor (F):	1.00
External Corrosion Allowance:	0.00 mm	Nozzle Path:	None
Nozzle ID (new):	59.50 mm	Nozzle Wall Thickness(new):	2.00 mm
Nozzle ID (corroded):	59.50 mm	Nozzle Wall Thickness(corroded):	2.00 mm
Outer "h" Limit:	5.00 mm	Upper Weld Leg Size(Weld 41):	2.00 mm
Internal "h" Limit:	5.00 mm	Internal Weld Leg Size(Weld 43):	0.00 mm
OD, Limit of Reinforcement:	119.00 mm	Outside Groove Weld Depth:	8.00 mm

Minimum Design Metal Temperature

Minimum Design Metal Temperature: -196 °C
Other Exemption

Host Component: Shell 1 - Shell 1

Material:	SA-240 Gr. 304, High	Shell wall thickness(new):	8.00 mm
Material Stress(S_V):	138.00 MPa	Shell wall thickness(corroded):	8.00 mm

Nozzle Detail Information

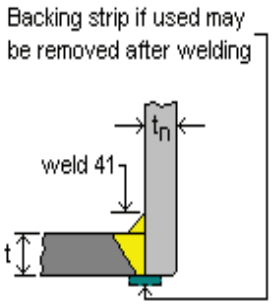

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 2.00 mm

Nozzle Wall Thickness(t_n): 2.00 mm

Outside Groove Weld Depth: 8.00 mm

Nozzle passes through the vessel, attached by a groove weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is adequately reinforced for External Pressure.
Reinforcement calculations are not required per UG-36(c)(3)(a)See Uw-14 for exceptions.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PR}{SE - 0.6P} = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} = \mathbf{0.24}\ \text{mm}$$

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{0.0500 * 29.75}{97.80 * 1 - 0.6 * 0.0500} = \mathbf{0.02}\ \text{mm}$$

Required Nozzle Thickness for External Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 63.50 * 0.1000}{4 * 29.48} = \mathbf{0.18}\ \text{mm}$$

Strength Reduction Factors

$$\mathbf{fr1} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087 \quad \mathbf{fr2} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

$$\mathbf{fr3} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion)

$$t_a = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 29.75}{97.80 * 1.00 - 0.6 * 0.0500} + 0.00 + 0.00 = \mathbf{0.02}\ \text{mm}$$

Nozzle Thickness for Internal Pressure (plus corrosion) Based on Host

$$t_{b1} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} + 0.00 + 0.00$$

$= \text{Greater Of } (0.24_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00\ (\text{corrosion}) + 0.00\ (\text{ext. corrosion}) = \mathbf{1.50}\ \text{mm}$

Nozzle Thickness for External Pressure (plus corrosion) Based on Host

$$t_{b2} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.1000 * 675.00}{138.00 * 1 - 0.6 * 0.1000} + 0.00 + 0.00$$

$= \text{Greater Of } (0.49_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00\ (\text{corrosion}) + 0.00\ (\text{ext. corrosion}) = \mathbf{1.50}\ \text{mm}$

Minimum Thickness (plus corrosion) per Table UG-45

t_{b3} = minimum thickness (Table UG-45) + Ca + ext. Ca = **4.52** mm

Nozzle Minimum Thickness Based on Host and Table UG-45

$t_b = \min[t_{b3}, \max(t_{b1}, t_{b2})]$ = **1.50** mm

$t_{UG\text{-}45} = \max(t_a, t_b)$ = **1.50** mm

Wall thickness = tn = **2.00** is greater than or equal to UG-45 value of **1.50**

Alca Technology srl

L D38

Job No: ALCA 20106-01
Number: 10
ID Number: 10

Vessel Number: 20106-01
Mark Number: L

Date Printed: 07/02/2012

Nozzle Design Information

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Nozzle Efficiency (E):	100 %
Nozzle Material:	SA-312 TP304L, High	Joint Efficiency (E_1):	1.00
		Factor B Chart:	HA-3
External Projection:	45.00 mm	Allowable Stress at Design Temperature (S_n):	97.80 MPa
Internal Projection:	0.00 mm	Allowable Stress at Ambient Temperature:	97.80 MPa
Inside Corrosion Allowance:	0.00 mm	Correction Factor (F):	1.00
External Corrosion Allowance:	0.00 mm	Nozzle Path:	None
Nozzle ID (new):	34.00 mm	Nozzle Wall Thickness(new):	2.00 mm
Nozzle ID (corroded):	34.00 mm	Nozzle Wall Thickness(corroded):	2.00 mm
Outer "h" Limit:	5.00 mm	Upper Weld Leg Size(Weld 41):	2.00 mm
Internal "h" Limit:	5.00 mm	Internal Weld Leg Size(Weld 43):	0.00 mm
OD, Limit of Reinforcement:	68.00 mm	Outside Groove Weld Depth:	8.00 mm

Minimum Design Metal Temperature

Minimum Design Metal Temperature: -196 °C
Other Exemption

Host Component: Shell 1 - Shell 1

Material:	SA-240 Gr. 304, High	Shell wall thickness(new):	8.00 mm
Material Stress(S_V):	138.00 MPa	Shell wall thickness(corroded):	8.00 mm

Nozzle Detail Information

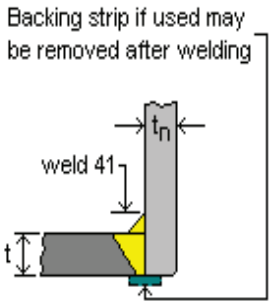

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 2.00 mm

Nozzle Wall Thickness(t_n): 2.00 mm

Outside Groove Weld Depth: 8.00 mm

Nozzle passes through the vessel, attached by a groove weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is adequately reinforced for External Pressure.
Reinforcement calculations are not required per UG-36(c)(3)(a)See Uw-14 for exceptions.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PR}{SE - 0.6P} = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500}$$ = **0.24** mm

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{0.0500 * 17.00}{97.80 * 1 - 0.6 * 0.0500}$$ = **0.01** mm

Required Nozzle Thickness for External Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 38.00 * 0.1000}{4 * 23.41}$$ = **0.13** mm

Strength Reduction Factors

$$\mathbf{fr1} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087 \quad \mathbf{fr2} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

$$\mathbf{fr3} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion)

$$t_a = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 17.00}{97.80 * 1.00 - 0.6 * 0.0500} + 0.00 + 0.00$$ = **0.01** mm

Nozzle Thickness for Internal Pressure (plus corrosion) Based on Host

$$t_{b1} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} + 0.00 + 0.00$$

= Greater Of $(0.24_{(Calculated)}, 1.50_{(Minimum\ Allowed)}) + 0.00$ (corrosion) $+ 0.00$ (ext. corrosion) = **1.50** mm

Nozzle Thickness for External Pressure (plus corrosion) Based on Host

$$t_{b2} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.1000 * 675.00}{138.00 * 1 - 0.6 * 0.1000} + 0.00 + 0.00$$

= Greater Of $(0.49_{(Calculated)}, 1.50_{(Minimum\ Allowed)}) + 0.00$ (corrosion) $+ 0.00$ (ext. corrosion) = **1.50** mm

Minimum Thickness (plus corrosion) per Table UG-45

t_{b3} = minimum thickness (Table UG-45) + Ca + ext. Ca = **3.12** mm

Nozzle Minimum Thickness Based on Host and Table UG-45

$t_b = \min[t_{b3}, \max(t_{b1}, t_{b2})]$ = **1.50** mm

$t_{UG-45} = \max(t_a, t_b)$ = **1.50** mm

Wall thickness = tn = **2.00** is greater than or equal to UG-45 value of **1.50**

Alca Technology srl

M D38

Job No: ALCA 20106-01
Number: 11
ID Number: 11

Vessel Number: 20106-01
Mark Number: M

Date Printed: 07/02/2012

Nozzle Design Information

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Nozzle Efficiency (E):	100 %
Nozzle Material:	SA-312 TP304L, High	Joint Efficiency (E_1):	1.00
		Factor B Chart:	HA-3
External Projection:	45.00 mm	Allowable Stress at Design Temperature (S_n):	97.80 MPa
Internal Projection:	0.00 mm	Allowable Stress at Ambient Temperature:	97.80 MPa
Inside Corrosion Allowance:	0.00 mm	Correction Factor (F):	1.00
External Corrosion Allowance:	0.00 mm	Nozzle Path:	None
Nozzle ID (new):	34.00 mm	Nozzle Wall Thickness(new):	2.00 mm
Nozzle ID (corroded):	34.00 mm	Nozzle Wall Thickness(corroded):	2.00 mm
Outer "h" Limit:	5.00 mm	Upper Weld Leg Size(Weld 41):	2.00 mm
Internal "h" Limit:	5.00 mm	Internal Weld Leg Size(Weld 43):	0.00 mm
OD, Limit of Reinforcement:	68.00 mm	Outside Groove Weld Depth:	8.00 mm

Minimum Design Metal Temperature

Minimum Design Metal Temperature: -196 °C
Other Exemption

Host Component: Shell 1 - Shell 1

Material:	SA-240 Gr. 304, High	Shell wall thickness(new):	8.00 mm
Material Stress(S_v):	138.00 MPa	Shell wall thickness(corroded):	8.00 mm

Nozzle Detail Information

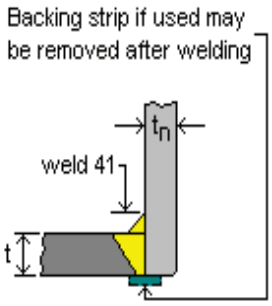

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 2.00 mm

Nozzle Wall Thickness(t_n): 2.00 mm

Outside Groove Weld Depth: 8.00 mm

Nozzle passes through the vessel, attached by a groove weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is adequately reinforced for External Pressure.
Reinforcement calculations are not required per UG-36(c)(3)(a)See Uw-14 for exceptions.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PR}{SE - 0.6P} = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} = \mathbf{0.24} \text{ mm}$$

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{0.0500 * 17.00}{97.80 * 1 - 0.6 * 0.0500} = \mathbf{0.01} \text{ mm}$$

Required Nozzle Thickness for External Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 38.00 * 0.1000}{4 * 23.41} = \mathbf{0.13} \text{ mm}$$

Strength Reduction Factors

$$\mathbf{fr1} = \min\left[\frac{Sn}{Sv}, 1.0000\right] = \min\left[\frac{97.80}{138.00}, 1.0000\right] = 0.7087 \quad \mathbf{fr2} = \min\left[\frac{Sn}{Sv}, 1.0000\right] = \min\left[\frac{97.80}{138.00}, 1.0000\right] = 0.7087$$

$$\mathbf{fr3} = \min\left[\frac{Sn}{Sv}, 1.0000\right] = \min\left[\frac{97.80}{138.00}, 1.0000\right] = 0.7087$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion)

$$t_a = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 17.00}{97.80 * 1.00 - 0.6 * 0.0500} + 0.00 + 0.00 = \mathbf{0.01} \text{ mm}$$

Nozzle Thickness for Internal Pressure (plus corrosion) Based on Host

$$t_{b1} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} + 0.00 + 0.00$$

$= \text{Greater Of } (0.24_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00 \text{ (corrosion)} + 0.00 \text{ (ext. corrosion)} = \mathbf{1.50}$ mm

Nozzle Thickness for External Pressure (plus corrosion) Based on Host

$$t_{b2} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.1000 * 675.00}{138.00 * 1 - 0.6 * 0.1000} + 0.00 + 0.00$$

$= \text{Greater Of } (0.49_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00 \text{ (corrosion)} + 0.00 \text{ (ext. corrosion)} = \mathbf{1.50}$ mm

Minimum Thickness (plus corrosion) per Table UG-45

t_{b3} = minimum thickness (Table UG-45) + Ca + ext. Ca = **3.12** mm

Nozzle Minimum Thickness Based on Host and Table UG-45

$t_b = \min[t_{b3}, \max(t_{b1}, t_{b2})]$ = **1.50** mm

$t_{UG\text{-}45} = \max(t_a, t_b)$ = **1.50** mm

Wall thickness = tn = **2.00** is greater than or equal to UG-45 value of **1.50**

Alca Technology srl

B D159

Job No: ALCA 20106-01
Number: 2
ID Number: 2

Vessel Number: 20106-01
Mark Number: B

Date Printed: 07/02/2012

Nozzle Design Information

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Nozzle Efficiency (E):	100 %
Nozzle Material:	SA-312 TP304L, High	Joint Efficiency (E_1):	1.00
		Factor B Chart:	HA-3
External Projection:	25.50 mm	Allowable Stress at Design Temperature (S_n):	97.80 MPa
Internal Projection:	0.00 mm	Allowable Stress at Ambient Temperature:	97.80 MPa
Inside Corrosion Allowance:	0.00 mm	Correction Factor (F):	1.00
External Corrosion Allowance:	0.00 mm	Nozzle Path:	None
Nozzle ID (new):	149.00 mm	Nozzle Wall Thickness(new):	5.00 mm
Nozzle ID (corroded):	149.00 mm	Nozzle Wall Thickness(corroded):	5.00 mm
Outer "h" Limit:	12.50 mm	Upper Weld Leg Size(Weld 41):	6.00 mm
Internal "h" Limit:	12.50 mm	Internal Weld Leg Size(Weld 43):	0.00 mm
OD, Limit of Reinforcement:	298.00 mm	Outside Groove Weld Depth:	8.00 mm

Minimum Design Metal Temperature

Minimum Design Metal Temperature: -196 °C
Other Exemption

Host Component: Shell 1 - Shell 1

Material:	SA-240 Gr. 304, High	Shell wall thickness(new):	8.00 mm
Material Stress(S_V):	138.00 MPa	Shell wall thickness(corroded):	8.00 mm

Nozzle Detail Information

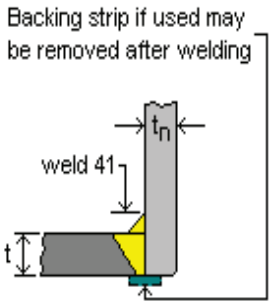

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 6.00 mm

Nozzle Wall Thickness(t_n): 5.00 mm

Outside Groove Weld Depth: 8.00 mm

Nozzle passes through the vessel, attached by a groove weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is **NOT** adequately reinforced for External Pressure.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PR}{SE - 0.6P} = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500}$$ = **0.24** mm

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{0.0500 * 74.50}{97.80 * 1 - 0.6 * 0.0500}$$ = **0.04** mm

Required Nozzle Thickness for External Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 159.00 * 0.1000}{4 * 52.31}$$ = **0.24** mm

Strength Reduction Factors

$$\mathbf{fr1} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$ $$\mathbf{fr2} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

$$\mathbf{fr3} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion)

$$t_a = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 74.50}{97.80 * 1.00 - 0.6 * 0.0500} + 0.00 + 0.00$$ = **0.04** mm

Nozzle Thickness for Internal Pressure (plus corrosion) Based on Host

$$t_{b1} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} + 0.00 + 0.00$$

= Greater Of $(0.24_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00$ (corrosion) $+ 0.00$ (ext. corrosion) = **1.50** mm

Nozzle Thickness for External Pressure (plus corrosion) Based on Host

$$t_{b2} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.1000 * 675.00}{138.00 * 1 - 0.6 * 0.1000} + 0.00 + 0.00$$

= Greater Of $(0.49_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00$ (corrosion) $+ 0.00$ (ext. corrosion) = **1.50** mm

Minimum Thickness (plus corrosion) per Table UG-45

t_{b3} = minimum thickness (Table UG-45) + Ca + ext. Ca = **6.22** mm

Nozzle Minimum Thickness Based on Host and Table UG-45

$t_b = \min[t_{b3}, \max(t_{b1}, t_{b2})]$ = **1.50** mm

$t_{UG-45} = \max(t_a, t_b)$ = **1.50** mm

Wall thickness = tn = **5.00** is greater than or equal to UG-45 value of **1.50**

Nozzle Reinforcement Calculations

Area Required for Internal Pressure

A = d tr F + 2 tn tr F (1 - fr1) = (149.00 * 0.24 * 1.00) + (2 * 5.00 * 0.24 * 1.00 * (1 - 0.7087)) = **36.46** sq. mm

Area Available - Internal Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
149.00 * (1.00 * 8.00 - 1.00 * 0.24) - 2 * 5.00 * (1.00 * 8.00 - 1.00 * 0.24) * (1 - 0.7087) = *1133.63* sq. mm

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (8.00 + 5.00)(1.00 * 8.00 - 1.00 * 0.24) - 2 * 5.00 * (1.00 * 8.00 - 1.00 * 0.24) * (1 - 0.7087) = *179.15* sq. mm

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **1133.63** sq. mm

A2 Formula 1 = 5(tn - trn) fr2 t = 5(5.00 - 0.04) * 0.7087 * 8.00 = *140.61* sq. mm
A2 Formula 2 = 5(tn - trn) fr2 tn = 5(5.00 - 0.04) * 0.7087 * 5.00 = *87.88* sq. mm
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **87.88** sq. mm

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 8.00 * 5.00 * 0.7087 = 141.74 sq. mm
$5 * t_i * t_i * f_{r2}$ = 5 * 5.00 * 5.00 * 0.7087 = 88.59 sq. mm
$2 * h * t_i * f_{r2}$ = 2 * 0.00 * 5.00 * 0.7087 = 0.00 sq. mm
= **0.00** sq. mm

A41 = $(leg)^2 * fr2$ = $(6.00)^2 * 0.7087$ = **25.51** sq. mm

A43 = $(leg)^2 * fr2$ = 0 * 0.7087 = **0.00** sq. mm

Area Available (Internal Pressure) = A1 + A2 + A3 + A41 + A43 = 1247.02 sq. mm, which is **greater** than A (36.46)

Nozzle Reinforcement Calculations

Area Required for External Pressure

A = ½ * (d tr F + 2 tn tr F (1 - fr1)) = ½ * ((149.00 * 5.87 * 1.0) + (2 * 5.00 * 5.87 * 1.0 * (1 - 0.7087))) = **445.86** sq. mm

Area Available - External Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
149.00 * (1.00 * 8.00 - 1.00 * 5.87) - 2 * 5.00 * (1.00 * 8.00 - 1.00 * 5.87) * (1 - 0.7087) = *311.17* sq. mm

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (8.00 + 5.00)(1.00 * 8.00 - 1.00 * 5.87) - 2 * 5.00 * (1.00 * 8.00 - 1.00 * 5.87) * (1 - 0.7087) = *49.18* sq. mm

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **311.17** sq. mm

A2 Formula 1 = 5(tn - trn) fr2 t = 5(5.00 - 0.24) * 0.7087 * 8.00 = *134.94* sq. mm
A2 Formula 2 = 5(tn - trn) fr2 tn = 5(5.00 - 0.24) * 0.7087 * 5.00 = *84.33* sq. mm
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **84.33** sq. mm

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 8.00 * 5.00 * 0.7087 = 141.74 sq. mm
$5 * t_i * t_i * f_{r2}$ = 5 * 5.00 * 5.00 * 0.7087 = 88.59 sq. mm
$2 * h * t_i * f_{r2}$ = 2 * 0.00 * 5.00 * 0.7087 = 0.00 sq. mm
= **0.00** sq. mm

A41 = $(leg)^2 * fr2$ = $(6.00)^2 * 0.7087$ = **25.51** sq. mm

A43 = $(leg)^2 * fr2$ = 0 * 0.7087 = **0.00** sq. mm

Area Available (External Pressure) = A1 + A2 + A3 + A41 + A43 = 421.01 sq. mm, which is **smaller** than A (445.86)

Nozzle Design Information

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Nozzle Efficiency (E):	100 %
Nozzle Material:	SA-312 TP304L, High	Joint Efficiency (E_1):	1.00
		Factor B Chart:	HA-3
External Projection:	45.00 mm	Allowable Stress at Design Temperature (S_n):	97.80 MPa
Internal Projection:	0.00 mm	Allowable Stress at Ambient Temperature:	97.80 MPa
Inside Corrosion Allowance:	0.00 mm	Correction Factor (F):	1.00
External Corrosion Allowance:	0.00 mm	Nozzle Path:	None
Nozzle ID (new):	59.50 mm	Nozzle Wall Thickness(new):	2.00 mm
Nozzle ID (corroded):	59.50 mm	Nozzle Wall Thickness(corroded):	2.00 mm
Outer "h" Limit:	5.00 mm	Upper Weld Leg Size(Weld 41):	6.00 mm
Internal "h" Limit:	5.00 mm	Internal Weld Leg Size(Weld 43):	0.00 mm
OD, Limit of Reinforcement:	119.00 mm	Outside Groove Weld Depth:	8.00 mm

Minimum Design Metal Temperature

Minimum Design Metal Temperature: -196 °C
Other Exemption

Host Component: Shell 1 - Shell 1

Material:	SA-240 Gr. 304, High	Shell wall thickness(new):	8.00 mm
Material Stress(S_V):	138.00 MPa	Shell wall thickness(corroded):	8.00 mm

Nozzle Detail Information

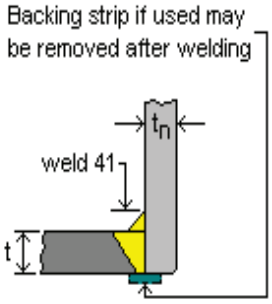

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 6.00 mm

Nozzle Wall Thickness(t_n): 2.00 mm

Outside Groove Weld Depth: 8.00 mm

Nozzle passes through the vessel, attached by a groove weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is adequately reinforced for External Pressure.
Reinforcement calculations are not required per UG-36(c)(3)(a)See Uw-14 for exceptions.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PR}{SE - 0.6P} = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500}$$ = **0.24** mm

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{0.0500 * 29.75}{97.80 * 1 - 0.6 * 0.0500}$$ = **0.02** mm

Required Nozzle Thickness for External Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 63.50 * 0.1000}{4 * 29.48}$$ = **0.18** mm

Strength Reduction Factors

$$\mathbf{fr1} = \min\left[\frac{Sn}{Sv}, 1.0000\right] = \min\left[\frac{97.80}{138.00}, 1.0000\right] = 0.7087 \quad \mathbf{fr2} = \min\left[\frac{Sn}{Sv}, 1.0000\right] = \min\left[\frac{97.80}{138.00}, 1.0000\right] = 0.7087$$

$$\mathbf{fr3} = \min\left[\frac{Sn}{Sv}, 1.0000\right] = \min\left[\frac{97.80}{138.00}, 1.0000\right] = 0.7087$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion)

$$t_a = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. Ca} = \frac{0.0500 * 29.75}{97.80 * 1.00 - 0.6 * 0.0500} + 0.00 + 0.00$$ = **0.02** mm

Nozzle Thickness for Internal Pressure (plus corrosion) Based on Host

$$t_{b1} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. Ca} = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} + 0.00 + 0.00$$

= Greater Of $(0.24_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00_{(\text{corrosion})} + 0.00_{(\text{ext. corrosion})}$ = **1.50** mm

Nozzle Thickness for External Pressure (plus corrosion) Based on Host

$$t_{b2} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. Ca} = \frac{0.1000 * 675.00}{138.00 * 1 - 0.6 * 0.1000} + 0.00 + 0.00$$

= Greater Of $(0.49_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00_{(\text{corrosion})} + 0.00_{(\text{ext. corrosion})}$ = **1.50** mm

Minimum Thickness (plus corrosion) per Table UG-45

t_{b3} = minimum thickness (Table UG-45) + Ca + ext. Ca = **4.52** mm

Nozzle Minimum Thickness Based on Host and Table UG-45

$t_b = \min[t_{b3}, \max(t_{b1}, t_{b2})]$ = **1.50** mm

$t_{UG\text{-}45} = \max(t_a, t_b)$ = **1.50** mm

Wall thickness = tn = **2.00** is greater than or equal to UG-45 value of **1.50**

Alca Technology srl

D D159

Job No: ALCA 20106-01
Number: 4
ID Number: 4

Vessel Number: 20106-01
Mark Number: D

Date Printed: 07/02/2012

Nozzle Design Information

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Nozzle Efficiency (E):	100 %
Nozzle Material:	SA-312 TP304L, High	Joint Efficiency (E_1):	1.00
		Factor B Chart:	HA-3
External Projection:	25.50 mm	Allowable Stress at Design Temperature (S_n):	97.80 MPa
Internal Projection:	0.00 mm	Allowable Stress at Ambient Temperature:	97.80 MPa
Inside Corrosion Allowance:	0.00 mm	Correction Factor (F):	1.00
External Corrosion Allowance:	0.00 mm	Nozzle Path:	None
Nozzle ID (new):	149.00 mm	Nozzle Wall Thickness(new):	5.00 mm
Nozzle ID (corroded):	149.00 mm	Nozzle Wall Thickness(corroded):	5.00 mm
Outer "h" Limit:	12.50 mm	Upper Weld Leg Size(Weld 41):	6.00 mm
Internal "h" Limit:	12.50 mm	Internal Weld Leg Size(Weld 43):	0.00 mm
OD, Limit of Reinforcement:	298.00 mm	Outside Groove Weld Depth:	8.00 mm

Minimum Design Metal Temperature

Minimum Design Metal Temperature: -196 °C
Other Exemption

Host Component: Shell 1 - Shell 1

Material:	SA-240 Gr. 304, High	Shell wall thickness(new):	8.00 mm
Material Stress(S_V):	138.00 MPa	Shell wall thickness(corroded):	8.00 mm

Nozzle Detail Information

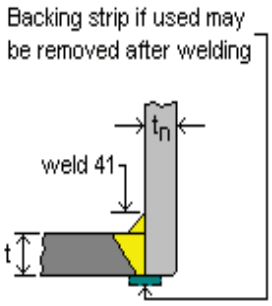

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 6.00 mm

Nozzle Wall Thickness(t_n): 5.00 mm

Outside Groove Weld Depth: 8.00 mm

Nozzle passes through the vessel, attached by a groove weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is **NOT** adequately reinforced for External Pressure.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PR}{SE - 0.6P} = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500}$$ = **0.24** mm

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{0.0500 * 74.50}{97.80 * 1 - 0.6 * 0.0500}$$ = **0.04** mm

Required Nozzle Thickness for External Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 159.00 * 0.1000}{4 * 52.31}$$ = **0.24** mm

Strength Reduction Factors

$$\mathbf{fr1} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$ $$\mathbf{fr2} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

$$\mathbf{fr3} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion)

$$t_a = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 74.50}{97.80 * 1.00 - 0.6 * 0.0500} + 0.00 + 0.00$$ = **0.04** mm

Nozzle Thickness for Internal Pressure (plus corrosion) Based on Host

$$t_{b1} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} + 0.00 + 0.00$$

= Greater Of $(0.24_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00$ (corrosion) $+ 0.00$ (ext. corrosion) = **1.50** mm

Nozzle Thickness for External Pressure (plus corrosion) Based on Host

$$t_{b2} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.1000 * 675.00}{138.00 * 1 - 0.6 * 0.1000} + 0.00 + 0.00$$

= Greater Of $(0.49_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00$ (corrosion) $+ 0.00$ (ext. corrosion) = **1.50** mm

Minimum Thickness (plus corrosion) per Table UG-45

t_{b3} = minimum thickness (Table UG-45) + Ca + ext. Ca = **6.22** mm

Nozzle Minimum Thickness Based on Host and Table UG-45

$t_b = \min[t_{b3}, \max(t_{b1}, t_{b2})]$ = **1.50** mm

$t_{UG\text{-}45} = \max(t_a, t_b)$ = **1.50** mm

Wall thickness = tn = **5.00** is greater than or equal to UG-45 value of **1.50**

Nozzle Reinforcement Calculations

Area Required for Internal Pressure

A = d tr F + 2 tn tr F (1 - fr1) = (149.00 * 0.24 * 1.00) + (2 * 5.00 * 0.24 * 1.00 * (1 - 0.7087)) = **36.46** sq. mm

Area Available - Internal Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
149.00 * (1.00 * 8.00 - 1.00 * 0.24) - 2 * 5.00 * (1.00 * 8.00 - 1.00 * 0.24) * (1 - 0.7087) = *1133.63* sq. mm

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (8.00 + 5.00)(1.00 * 8.00 - 1.00 * 0.24) - 2 * 5.00 * (1.00 * 8.00 - 1.00 * 0.24) * (1 - 0.7087) = *179.15* sq. mm

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **1133.63** sq. mm

A2 Formula 1 = 5(tn - trn) fr2 t = 5(5.00 - 0.04) * 0.7087 * 8.00 = *140.61* sq. mm
A2 Formula 2 = 5(tn - trn) fr2 tn = 5(5.00 - 0.04) * 0.7087 * 5.00 = *87.88* sq. mm
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **87.88** sq. mm

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 8.00 * 5.00 * 0.7087 = 141.74 sq. mm
$5 * t_i * t_i * f_{r2}$ = 5 * 5.00 * 5.00 * 0.7087 = 88.59 sq. mm
$2 * h * t_i * f_{r2}$ = 2 * 0.00 * 5.00 * 0.7087 = 0.00 sq. mm
= **0.00** sq. mm

A41 = $(leg)^2 * fr2$ = $(6.00)^2 * 0.7087$ = **25.51** sq. mm

A43 = $(leg)^2 * fr2$ = 0 * 0.7087 = **0.00** sq. mm

Area Available (Internal Pressure) = A1 + A2 + A3 + A41 + A43 = 1247.02 sq. mm, which is **greater** than A (36.46)

Nozzle Reinforcement Calculations

Area Required for External Pressure

A = ½ * (d tr F + 2 tn tr F (1 - fr1)) = ½ * ((149.00 * 5.87 * 1.0) + (2 * 5.00 * 5.87 * 1.0 * (1 - 0.7087))) = **445.86** sq. mm

Area Available - External Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
149.00 * (1.00 * 8.00 - 1.00 * 5.87) - 2 * 5.00 * (1.00 * 8.00 - 1.00 * 5.87) * (1 - 0.7087) = *311.17* sq. mm

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (8.00 + 5.00)(1.00 * 8.00 - 1.00 * 5.87) - 2 * 5.00 * (1.00 * 8.00 - 1.00 * 5.87) * (1 - 0.7087) = *49.18* sq. mm

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **311.17** sq. mm

A2 Formula 1 = 5(tn - trn) fr2 t = 5(5.00 - 0.24) * 0.7087 * 8.00 = *134.94* sq. mm
A2 Formula 2 = 5(tn - trn) fr2 tn = 5(5.00 - 0.24) * 0.7087 * 5.00 = *84.33* sq. mm
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **84.33** sq. mm

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 8.00 * 5.00 * 0.7087 = 141.74 sq. mm
$5 * t_i * t_i * f_{r2}$ = 5 * 5.00 * 5.00 * 0.7087 = 88.59 sq. mm
$2 * h * t_i * f_{r2}$ = 2 * 0.00 * 5.00 * 0.7087 = 0.00 sq. mm
= **0.00** sq. mm

A41 = $(leg)^2 * fr2$ = $(6.00)^2 * 0.7087$ = **25.51** sq. mm

A43 = $(leg)^2 * fr2$ = 0 * 0.7087 = **0.00** sq. mm

Area Available (External Pressure) = A1 + A2 + A3 + A41 + A43 = 421.01 sq. mm, which is **smaller** than A (445.86)

Alca Technology srl

E D63.5

Job No: ALCA 20106-01
Number: 5
ID Number: 5

Vessel Number: 20106-01
Mark Number: E

Date Printed: 07/02/2012

Nozzle Design Information

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Nozzle Efficiency (E):	100 %
Nozzle Material:	SA-312 TP304L, High	Joint Efficiency (E_1):	1.00
		Factor B Chart:	HA-3
External Projection:	45.00 mm	Allowable Stress at Design Temperature (S_n):	97.80 MPa
Internal Projection:	0.00 mm	Allowable Stress at Ambient Temperature:	97.80 MPa
Inside Corrosion Allowance:	0.00 mm	Correction Factor (F):	1.00
External Corrosion Allowance:	0.00 mm	Nozzle Path:	None
Nozzle ID (new):	59.50 mm	Nozzle Wall Thickness(new):	2.00 mm
Nozzle ID (corroded):	59.50 mm	Nozzle Wall Thickness(corroded):	2.00 mm
Outer "h" Limit:	5.00 mm	Upper Weld Leg Size(Weld 41):	6.00 mm
Internal "h" Limit:	5.00 mm	Internal Weld Leg Size(Weld 43):	0.00 mm
OD, Limit of Reinforcement:	119.00 mm	Outside Groove Weld Depth:	8.00 mm

Minimum Design Metal Temperature

Minimum Design Metal Temperature: -196 °C
Other Exemption

Host Component: Shell 1 - Shell 1

Material:	SA-240 Gr. 304, High	Shell wall thickness(new):	8.00 mm
Material Stress(S_V):	138.00 MPa	Shell wall thickness(corroded):	8.00 mm

Nozzle Detail Information

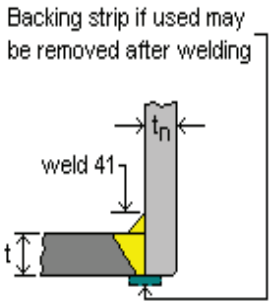

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 6.00 mm

Nozzle Wall Thickness(t_n): 2.00 mm

Outside Groove Weld Depth: 8.00 mm

Nozzle passes through the vessel, attached by a groove weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is adequately reinforced for External Pressure.
Reinforcement calculations are not required per UG-36(c)(3)(a)See Uw-14 for exceptions.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PR}{SE - 0.6P} = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} = \mathbf{0.24} \text{ mm}$$

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{0.0500 * 29.75}{97.80 * 1 - 0.6 * 0.0500} = \mathbf{0.02} \text{ mm}$$

Required Nozzle Thickness for External Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 63.50 * 0.1000}{4 * 29.48} = \mathbf{0.18} \text{ mm}$$

Strength Reduction Factors

$$\mathbf{fr1} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087 \quad \mathbf{fr2} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

$$\mathbf{fr3} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion)

$$t_a = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 29.75}{97.80 * 1.00 - 0.6 * 0.0500} + 0.00 + 0.00 = \mathbf{0.02} \text{ mm}$$

Nozzle Thickness for Internal Pressure (plus corrosion) Based on Host

$$t_{b1} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} + 0.00 + 0.00$$

$= \text{Greater Of } (0.24_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00_{(\text{corrosion})} + 0.00_{(\text{ext. corrosion})} = \mathbf{1.50}$ mm

Nozzle Thickness for External Pressure (plus corrosion) Based on Host

$$t_{b2} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.1000 * 675.00}{138.00 * 1 - 0.6 * 0.1000} + 0.00 + 0.00$$

$= \text{Greater Of } (0.49_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00_{(\text{corrosion})} + 0.00_{(\text{ext. corrosion})} = \mathbf{1.50}$ mm

Minimum Thickness (plus corrosion) per Table UG-45

t_{b3} = minimum thickness (Table UG-45) + Ca + ext. Ca = **4.52** mm

Nozzle Minimum Thickness Based on Host and Table UG-45

$t_b = \min[t_{b3}, \max(t_{b1}, t_{b2})]$ = **1.50** mm

$t_{UG\text{-}45} = \max(t_a, t_b)$ = **1.50** mm

Wall thickness = tn = **2.00** is greater than or equal to UG-45 value of **1.50**

Alca Technology srl

S D63.5

Job No: ALCA 20106-01
Number: 17
ID Number: 17

Vessel Number: 20106-01
Mark Number: S

Date Printed: 07/02/2012

Nozzle Design Information

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Nozzle Efficiency (E):	100 %
Nozzle Material:	SA-312 TP304L, High	Joint Efficiency (E_1):	1.00
		Factor B Chart:	HA-3
External Projection:	45.00 mm	Allowable Stress at Design Temperature (S_n):	97.80 MPa
Internal Projection:	0.00 mm	Allowable Stress at Ambient Temperature:	97.80 MPa
Inside Corrosion Allowance:	0.00 mm	Correction Factor (F):	1.00
External Corrosion Allowance:	0.00 mm	Nozzle Path:	None
Nozzle ID (new):	59.50 mm	Nozzle Wall Thickness(new):	2.00 mm
Nozzle ID (corroded):	59.50 mm	Nozzle Wall Thickness(corroded):	2.00 mm
Outer "h" Limit:	5.00 mm	Upper Weld Leg Size(Weld 41):	2.00 mm
Internal "h" Limit:	5.00 mm	Internal Weld Leg Size(Weld 43):	0.00 mm
OD, Limit of Reinforcement:	119.00 mm	Outside Groove Weld Depth:	8.00 mm

Minimum Design Metal Temperature

Minimum Design Metal Temperature: -196 °C
Other Exemption

Host Component: Shell 1 - Shell 1

Material:	SA-240 Gr. 304, High	Shell wall thickness(new):	8.00 mm
Material Stress(S_V):	138.00 MPa	Shell wall thickness(corroded):	8.00 mm

Nozzle Detail Information

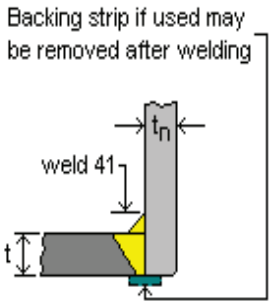

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 2.00 mm

Nozzle Wall Thickness(t_n): 2.00 mm

Outside Groove Weld Depth: 8.00 mm

Nozzle passes through the vessel, attached by a groove weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is adequately reinforced for External Pressure.
Reinforcement calculations are not required per UG-36(c)(3)(a)See Uw-14 for exceptions.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PR}{SE - 0.6P} = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} = \mathbf{0.24} \text{ mm}$$

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{0.0500 * 29.75}{97.80 * 1 - 0.6 * 0.0500} = \mathbf{0.02} \text{ mm}$$

Required Nozzle Thickness for External Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 63.50 * 0.1000}{4 * 29.48} = \mathbf{0.18} \text{ mm}$$

Strength Reduction Factors

$$\mathbf{fr1} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087 \quad \mathbf{fr2} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

$$\mathbf{fr3} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion)

$$t_a = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 29.75}{97.80 * 1.00 - 0.6 * 0.0500} + 0.00 + 0.00 = \mathbf{0.02} \text{ mm}$$

Nozzle Thickness for Internal Pressure (plus corrosion) Based on Host

$$t_{b1} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} + 0.00 + 0.00$$

$= \text{Greater Of } (0.24_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00_{(\text{corrosion})} + 0.00_{(\text{ext. corrosion})} = \mathbf{1.50}$ mm

Nozzle Thickness for External Pressure (plus corrosion) Based on Host

$$t_{b2} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.1000 * 675.00}{138.00 * 1 - 0.6 * 0.1000} + 0.00 + 0.00$$

$= \text{Greater Of } (0.49_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00_{(\text{corrosion})} + 0.00_{(\text{ext. corrosion})} = \mathbf{1.50}$ mm

Minimum Thickness (plus corrosion) per Table UG-45

t_{b3} = minimum thickness (Table UG-45) + Ca + ext. Ca = **4.52** mm

Nozzle Minimum Thickness Based on Host and Table UG-45

$t_b = \min[t_{b3}, \max(t_{b1}, t_{b2})]$ = **1.50** mm

$t_{UG\text{-}45} = \max(t_a, t_b)$ = **1.50** mm

Wall thickness = tn = **2.00** is greater than or equal to UG-45 value of **1.50**

Alca Technology srl

T D63.5

Job No: ALCA 20106-01
Number: 18
ID Number: 18

Vessel Number: 20106-01
Mark Number: T

Date Printed: 07/02/2012

Nozzle Design Information

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Nozzle Efficiency (E):	100 %
Nozzle Material:	SA-312 TP304L, High	Joint Efficiency (E_1):	1.00
		Factor B Chart:	HA-3
External Projection:	45.00 mm	Allowable Stress at Design Temperature (S_n):	97.80 MPa
Internal Projection:	0.00 mm	Allowable Stress at Ambient Temperature:	97.80 MPa
Inside Corrosion Allowance:	0.00 mm	Correction Factor (F):	1.00
External Corrosion Allowance:	0.00 mm	Nozzle Path:	None
Nozzle ID (new):	59.50 mm	Nozzle Wall Thickness(new):	2.00 mm
Nozzle ID (corroded):	59.50 mm	Nozzle Wall Thickness(corroded):	2.00 mm
Outer "h" Limit:	5.00 mm	Upper Weld Leg Size(Weld 41):	6.00 mm
Internal "h" Limit:	5.00 mm	Internal Weld Leg Size(Weld 43):	0.00 mm
OD, Limit of Reinforcement:	119.00 mm	Outside Groove Weld Depth:	8.00 mm

Minimum Design Metal Temperature

Minimum Design Metal Temperature: -196 °C
Other Exemption

Host Component: Shell 1 - Shell 1

Material:	SA-240 Gr. 304, High	Shell wall thickness(new):	8.00 mm
Material Stress(S_V):	138.00 MPa	Shell wall thickness(corroded):	8.00 mm

Nozzle Detail Information

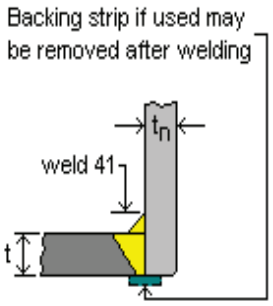

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 6.00 mm

Nozzle Wall Thickness(t_n): 2.00 mm

Outside Groove Weld Depth: 8.00 mm

Nozzle passes through the vessel, attached by a groove weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is adequately reinforced for External Pressure.
Reinforcement calculations are not required per UG-36(c)(3)(a)See Uw-14 for exceptions.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PR}{SE - 0.6P} = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} = \mathbf{0.24} \text{ mm}$$

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{0.0500 * 29.75}{97.80 * 1 - 0.6 * 0.0500} = \mathbf{0.02} \text{ mm}$$

Required Nozzle Thickness for External Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 63.50 * 0.1000}{4 * 29.48} = \mathbf{0.18} \text{ mm}$$

Strength Reduction Factors

$$\mathbf{fr1} = \min\left[\frac{Sn}{Sv}, 1.0000\right] = \min\left[\frac{97.80}{138.00}, 1.0000\right] = 0.7087 \quad \mathbf{fr2} = \min\left[\frac{Sn}{Sv}, 1.0000\right] = \min\left[\frac{97.80}{138.00}, 1.0000\right] = 0.7087$$

$$\mathbf{fr3} = \min\left[\frac{Sn}{Sv}, 1.0000\right] = \min\left[\frac{97.80}{138.00}, 1.0000\right] = 0.7087$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion)

$$t_a = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 29.75}{97.80 * 1.00 - 0.6 * 0.0500} + 0.00 + 0.00 = \mathbf{0.02} \text{ mm}$$

Nozzle Thickness for Internal Pressure (plus corrosion) Based on Host

$$t_{b1} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} + 0.00 + 0.00$$

$= \text{Greater Of } (0.24_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00_{(\text{corrosion})} + 0.00_{(\text{ext. corrosion})} = \mathbf{1.50}$ mm

Nozzle Thickness for External Pressure (plus corrosion) Based on Host

$$t_{b2} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.1000 * 675.00}{138.00 * 1 - 0.6 * 0.1000} + 0.00 + 0.00$$

$= \text{Greater Of } (0.49_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00_{(\text{corrosion})} + 0.00_{(\text{ext. corrosion})} = \mathbf{1.50}$ mm

Minimum Thickness (plus corrosion) per Table UG-45

t_{b3} = minimum thickness (Table UG-45) + Ca + ext. Ca = **4.52** mm

Nozzle Minimum Thickness Based on Host and Table UG-45

$t_b = \min[t_{b3}, \max(t_{b1}, t_{b2})]$ = **1.50** mm

$t_{UG\text{-}45} = \max(t_a, t_b)$ = **1.50** mm

Wall thickness = tn = **2.00** is greater than or equal to UG-45 value of **1.50**

Alca Technology srl

O D38

Job No: ALCA 20106-01
Number: 13
ID Number: 13

Vessel Number: 20106-01
Mark Number: N13

Date Printed: 07/02/2012

Nozzle Design Information

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Nozzle Efficiency (E):	100 %
Nozzle Material:	SA-312 TP304L, High	Joint Efficiency (E_1):	1.00
		Factor B Chart:	HA-3
External Projection:	45.00 mm	Allowable Stress at Design Temperature (S_n):	97.80 MPa
Internal Projection:	0.00 mm	Allowable Stress at Ambient Temperature:	97.80 MPa
Inside Corrosion Allowance:	0.00 mm	Correction Factor (F):	1.00
External Corrosion Allowance:	0.00 mm	Nozzle Path:	None
Nozzle ID (new):	34.00 mm	Nozzle Wall Thickness(new):	2.00 mm
Nozzle ID (corroded):	34.00 mm	Nozzle Wall Thickness(corroded):	2.00 mm
Outer "h" Limit:	5.00 mm	Upper Weld Leg Size(Weld 41):	2.00 mm
Internal "h" Limit:	5.00 mm	Internal Weld Leg Size(Weld 43):	0.00 mm
OD, Limit of Reinforcement:	68.00 mm	Outside Groove Weld Depth:	8.00 mm

Minimum Design Metal Temperature

Minimum Design Metal Temperature: -196 °C
Other Exemption

Host Component: Shell 1 - Shell 1

Material:	SA-240 Gr. 304, High	Shell wall thickness(new):	8.00 mm
Material Stress(S_V):	138.00 MPa	Shell wall thickness(corroded):	8.00 mm

Nozzle Detail Information

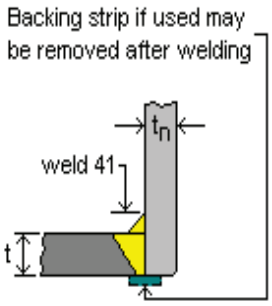

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 2.00 mm

Nozzle Wall Thickness(t_n): 2.00 mm

Outside Groove Weld Depth: 8.00 mm

Nozzle passes through the vessel, attached by a groove weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is adequately reinforced for External Pressure.
Reinforcement calculations are not required per UG-36(c)(3)(a)See Uw-14 for exceptions.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PR}{SE - 0.6P} = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500}$$ = **0.24** mm

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{0.0500 * 17.00}{97.80 * 1 - 0.6 * 0.0500}$$ = **0.01** mm

Required Nozzle Thickness for External Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 38.00 * 0.1000}{4 * 23.41}$$ = **0.13** mm

Strength Reduction Factors

$$\mathbf{fr1} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087 \quad \mathbf{fr2} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

$$\mathbf{fr3} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion)

$$t_a = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 17.00}{97.80 * 1.00 - 0.6 * 0.0500} + 0.00 + 0.00$$ = **0.01** mm

Nozzle Thickness for Internal Pressure (plus corrosion) Based on Host

$$t_{b1} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} + 0.00 + 0.00$$

= Greater Of $(0.24_{(Calculated)}, 1.50_{(Minimum\ Allowed)}) + 0.00$ (corrosion) $+ 0.00$ (ext. corrosion) = **1.50** mm

Nozzle Thickness for External Pressure (plus corrosion) Based on Host

$$t_{b2} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.1000 * 675.00}{138.00 * 1 - 0.6 * 0.1000} + 0.00 + 0.00$$

= Greater Of $(0.49_{(Calculated)}, 1.50_{(Minimum\ Allowed)}) + 0.00$ (corrosion) $+ 0.00$ (ext. corrosion) = **1.50** mm

Minimum Thickness (plus corrosion) per Table UG-45

t_{b3} = minimum thickness (Table UG-45) + Ca + ext. Ca = **3.12** mm

Nozzle Minimum Thickness Based on Host and Table UG-45

$t_b = \min[t_{b3}, \max(t_{b1}, t_{b2})]$ = **1.50** mm

$t_{UG-45} = \max(t_a, t_b)$ = **1.50** mm

Wall thickness = tn = **2.00** is greater than or equal to UG-45 value of **1.50**

Job No: ALCA 20106-01
Number: 14
ID Number: 14

Vessel Number: 20106-01
Mark Number: N14

Date Printed: 07/02/2012

Nozzle Design Information

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Nozzle Efficiency (E):	100 %
Nozzle Material:	SA-312 TP304L, High	Joint Efficiency (E_1):	1.00
		Factor B Chart:	HA-3
External Projection:	45.00 mm	Allowable Stress at Design Temperature (S_n):	97.80 MPa
Internal Projection:	0.00 mm	Allowable Stress at Ambient Temperature:	97.80 MPa
Inside Corrosion Allowance:	0.00 mm	Correction Factor (F):	1.00
External Corrosion Allowance:	0.00 mm	Nozzle Path:	None
Nozzle ID (new):	34.00 mm	Nozzle Wall Thickness(new):	2.00 mm
Nozzle ID (corroded):	34.00 mm	Nozzle Wall Thickness(corroded):	2.00 mm
Outer "h" Limit:	5.00 mm	Upper Weld Leg Size(Weld 41):	2.00 mm
Internal "h" Limit:	5.00 mm	Internal Weld Leg Size(Weld 43):	0.00 mm
OD, Limit of Reinforcement:	68.00 mm	Outside Groove Weld Depth:	8.00 mm

Minimum Design Metal Temperature

Minimum Design Metal Temperature: -196 °C
Other Exemption

Host Component: Shell 1 - Shell 1

Material:	SA-240 Gr. 304, High	Shell wall thickness(new):	8.00 mm
Material Stress(S_V):	138.00 MPa	Shell wall thickness(corroded):	8.00 mm

Nozzle Detail Information

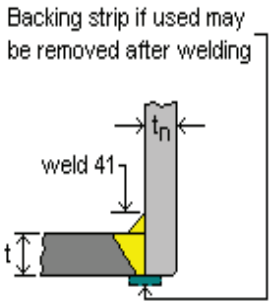

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 2.00 mm

Nozzle Wall Thickness(t_n): 2.00 mm

Outside Groove Weld Depth: 8.00 mm

Nozzle passes through the vessel, attached by a groove weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is adequately reinforced for External Pressure.
Reinforcement calculations are not required per UG-36(c)(3)(a)See Uw-14 for exceptions.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PR}{SE - 0.6P} = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500}$$ = **0.24** mm

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{0.0500 * 17.00}{97.80 * 1 - 0.6 * 0.0500}$$ = **0.01** mm

Required Nozzle Thickness for External Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 38.00 * 0.1000}{4 * 23.41}$$ = **0.13** mm

Strength Reduction Factors

$$\mathbf{fr1} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087 \quad \mathbf{fr2} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

$$\mathbf{fr3} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion)

$$t_a = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 17.00}{97.80 * 1.00 - 0.6 * 0.0500} + 0.00 + 0.00$$ = **0.01** mm

Nozzle Thickness for Internal Pressure (plus corrosion) Based on Host

$$t_{b1} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} + 0.00 + 0.00$$

= Greater Of $(0.24_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00$ (corrosion) $+ 0.00$ (ext. corrosion) = **1.50** mm

Nozzle Thickness for External Pressure (plus corrosion) Based on Host

$$t_{b2} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.1000 * 675.00}{138.00 * 1 - 0.6 * 0.1000} + 0.00 + 0.00$$

= Greater Of $(0.49_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00$ (corrosion) $+ 0.00$ (ext. corrosion) = **1.50** mm

Minimum Thickness (plus corrosion) per Table UG-45

t_{b3} = minimum thickness (Table UG-45) + Ca + ext. Ca = **3.12** mm

Nozzle Minimum Thickness Based on Host and Table UG-45

$t_b = \min[t_{b3}, \max(t_{b1}, t_{b2})]$ = **1.50** mm

$t_{UG\text{-}45} = \max(t_a, t_b)$ = **1.50** mm

Wall thickness = tn = **2.00** is greater than or equal to UG-45 value of **1.50**

Job No: ALCA 20106-01
Number: 19
ID Number: 19

Vessel Number: 20106-01
Mark Number: U

Date Printed: 07/02/2012

Nozzle Design Information

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Nozzle Efficiency (E):	100 %
Nozzle Material:	SA-312 TP304L, High	Joint Efficiency (E_1):	1.00
		Factor B Chart:	HA-3
External Projection:	85.00 mm	Allowable Stress at Design Temperature (S_n):	97.80 MPa
Internal Projection:	0.00 mm	Allowable Stress at Ambient Temperature:	97.80 MPa
Inside Corrosion Allowance:	0.00 mm	Correction Factor (F):	1.00
External Corrosion Allowance:	0.00 mm	Nozzle Path:	None
Nozzle ID (new):	26.00 mm	Nozzle Wall Thickness(new):	2.00 mm
Nozzle ID (corroded):	26.00 mm	Nozzle Wall Thickness(corroded):	2.00 mm
Outer "h" Limit:	5.00 mm	Upper Weld Leg Size(Weld 41):	6.00 mm
Internal "h" Limit:	5.00 mm	Internal Weld Leg Size(Weld 43):	0.00 mm
OD, Limit of Reinforcement:	52.00 mm	Outside Groove Weld Depth:	8.00 mm

Minimum Design Metal Temperature

Minimum Design Metal Temperature: -196 °C
Other Exemption

Host Component: Shell 1 - Shell 1

Material:	SA-240 Gr. 304, High	Shell wall thickness(new):	8.00 mm
Material Stress(S_V):	138.00 MPa	Shell wall thickness(corroded):	8.00 mm

Nozzle Detail Information

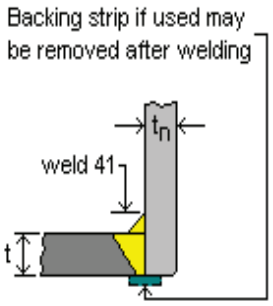

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 6.00 mm

Nozzle Wall Thickness(t_n): 2.00 mm

Outside Groove Weld Depth: 8.00 mm

Nozzle passes through the vessel, attached by a groove weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is adequately reinforced for External Pressure.
Reinforcement calculations are not required per UG-36(c)(3)(a)See Uw-14 for exceptions.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PR}{SE - 0.6P} = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} = \mathbf{0.24} \text{ mm}$$

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{0.0500 * 13.00}{97.80 * 1 - 0.6 * 0.0500} = \mathbf{0.01} \text{ mm}$$

Required Nozzle Thickness for External Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 30.00 * 0.1000}{4 * 17.38} = \mathbf{0.15} \text{ mm}$$

Strength Reduction Factors

$$\mathbf{fr1} = \min\left[\frac{Sn}{Sv}, 1.0000\right] = \min\left[\frac{97.80}{138.00}, 1.0000\right] = 0.7087 \quad \mathbf{fr2} = \min\left[\frac{Sn}{Sv}, 1.0000\right] = \min\left[\frac{97.80}{138.00}, 1.0000\right] = 0.7087$$

$$\mathbf{fr3} = \min\left[\frac{Sn}{Sv}, 1.0000\right] = \min\left[\frac{97.80}{138.00}, 1.0000\right] = 0.7087$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion)

$$t_a = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 13.00}{97.80 * 1.00 - 0.6 * 0.0500} + 0.00 + 0.00 = \mathbf{0.01} \text{ mm}$$

Nozzle Thickness for Internal Pressure (plus corrosion) Based on Host

$$t_{b1} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} + 0.00 + 0.00$$

$= \text{Greater Of } (0.24_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00 \text{ (corrosion)} + 0.00 \text{ (ext. corrosion)} = \mathbf{1.50}$ mm

Nozzle Thickness for External Pressure (plus corrosion) Based on Host

$$t_{b2} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.1000 * 675.00}{138.00 * 1 - 0.6 * 0.1000} + 0.00 + 0.00$$

$= \text{Greater Of } (0.49_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00 \text{ (corrosion)} + 0.00 \text{ (ext. corrosion)} = \mathbf{1.50}$ mm

Minimum Thickness (plus corrosion) per Table UG-45

t_{b3} = minimum thickness (Table UG-45) + Ca + ext. Ca = **2.96** mm

Nozzle Minimum Thickness Based on Host and Table UG-45

$t_b = \min[t_{b3}, \max(t_{b1}, t_{b2})]$ = **1.50** mm

$t_{UG\text{-}45} = \max(t_a, t_b)$ = **1.50** mm

Wall thickness = tn = **2.00** is greater than or equal to UG-45 value of **1.50**

Alca Technology srl

Z D63.5 tang

Job No: ALCA 20106-01
Number: 22
ID Number: 22

Vessel Number: 20106-01
Mark Number: Z

Date Printed: 07/02/2012

Nozzle Design Information

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Nozzle Efficiency (E):	100 %
Nozzle Material:	SA-312 TP304L, High	Joint Efficiency (E_1):	1.00
		Factor B Chart:	HA-3
External Projection:	160.00 mm	Allowable Stress at Design Temperature (S_n):	97.80 MPa
Internal Projection:	0.00 mm	Allowable Stress at Ambient Temperature:	97.80 MPa
Inside Corrosion Allowance:	0.00 mm	Correction Factor (F):	1.00
External Corrosion Allowance:	0.00 mm	Nozzle Path:	None
Nozzle ID (new):	55.50 mm	Nozzle Wall Thickness(new):	4.00 mm
Nozzle ID (corroded):	55.50 mm	Nozzle Wall Thickness(corroded):	4.00 mm
Developed Opening:	110.66 mm	Tangential Dimension L:	582.10 mm
Outer "h" Limit:	10.00 mm	Upper Weld Leg Size(Weld 41):	7.00 mm
Internal "h" Limit:	10.00 mm	Internal Weld Leg Size(Weld 43):	0.00 mm
OD, Limit of Reinforcement:	221.32 mm	Inside Groove Weld Depth:	4.00 mm

Minimum Design Metal Temperature

Minimum Design Metal Temperature: -196 °C
Other Exemption

Host Component: Shell 1 - Shell 1

Material:	SA-240 Gr. 304, High	Shell wall thickness(new):	8.00 mm
Material Stress(S_V):	138.00 MPa	Shell wall thickness(corroded):	8.00 mm

Nozzle Detail Information

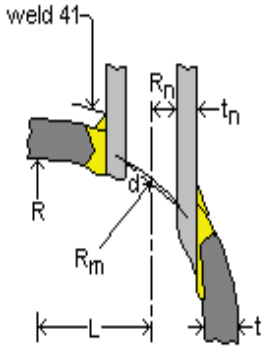

Fig. UW-16.1 (e)

Upper Weld Leg Size(Weld 41): 7.00 mm

Nozzle Wall Thickness(t_n): 4.00 mm

Inside Groove Weld Depth: 4.00 mm

tangential to the vessel wall, attached by a groove weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is **NOT** adequately reinforced for External Pressure.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PR}{SE - 0.6P} = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} = \mathbf{0.24} \text{ mm}$$

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{0.0500 * 27.75}{97.80 * 1 - 0.6 * 0.0500} = \mathbf{0.01} \text{ mm}$$

Required Nozzle Thickness for External Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 63.50 * 0.1000}{4 * 17.12} = \mathbf{0.29} \text{ mm}$$

Strength Reduction Factors

$$\mathbf{fr1} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087 \quad \mathbf{fr2} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

$$\mathbf{fr3} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion)

$$t_a = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 27.75}{97.80 * 1.00 - 0.6 * 0.0500} + 0.00 + 0.00 = \mathbf{0.01} \text{ mm}$$

Nozzle Thickness for Internal Pressure (plus corrosion) Based on Host

$$t_{b1} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} + 0.00 + 0.00$$

$= \text{Greater Of } (0.24_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00 \text{ (corrosion)} + 0.00 \text{ (ext. corrosion)} = \mathbf{1.50}$ mm

Nozzle Thickness for External Pressure (plus corrosion) Based on Host

$$t_{b2} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.1000 * 675.00}{138.00 * 1 - 0.6 * 0.1000} + 0.00 + 0.00$$

$= \text{Greater Of } (0.49_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00 \text{ (corrosion)} + 0.00 \text{ (ext. corrosion)} = \mathbf{1.50}$ mm

Minimum Thickness (plus corrosion) per Table UG-45

t_{b3} = minimum thickness (Table UG-45) + Ca + ext. Ca = **4.52** mm

Nozzle Minimum Thickness Based on Host and Table UG-45

$t_b = \min[t_{b3}, \max(t_{b1}, t_{b2})]$ = **1.50** mm

$t_{UG\text{-}45} = \max(t_a, t_b)$ = **1.50** mm

Wall thickness = tn = **4.00** is greater than or equal to UG-45 value of **1.50**

Nozzle Reinforcement Calculations

Area Required for Internal Pressure

A = d tr F + 2 tn tr F (1 - fr1) = (110.66 * 0.24 * 1.00) + (2 * 4.00 * 0.24 * 1.00 * (1 - 0.7087)) = **27.12** sq. mm

Area Available - Internal Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
110.66 * (1.00 * 8.00 - 1.00 * 0.24) - 2 * 4.00 * (1.00 * 8.00 - 1.00 * 0.24) * (1 - 0.7087) = *840.64* sq. mm

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (8.00 + 4.00)(1.00 * 8.00 - 1.00 * 0.24) - 2 * 4.00 * (1.00 * 8.00 - 1.00 * 0.24) * (1 - 0.7087) = *168.16* sq. mm

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **840.64** sq. mm

A2 Formula 1 = 5(tn - trn) fr2 t = 5(4.00 - 0.01) * 0.7087 * 8.00 = *113.11* sq. mm
A2 Formula 2 = 5(tn - trn) fr2 tn = 5(4.00 - 0.01) * 0.7087 * 4.00 = *56.55* sq. mm
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **56.55** sq. mm

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 8.00 * 4.00 * 0.7087 = 113.39 sq. mm
$5 * t_i * t_i * f_{r2}$ = 5 * 4.00 * 4.00 * 0.7087 = 56.70 sq. mm
$2 * h * t_i * f_{r2}$ = 2 * 0.00 * 4.00 * 0.7087 = 0.00 sq. mm
= **0.00** sq. mm

A41 = $(leg)^2 * fr2$ = $(7.00)^2 * 0.7087$ = **34.73** sq. mm

A43 = $(leg)^2 * fr2$ = 0 * 0.7087 = **0.00** sq. mm

Area Available (Internal Pressure) = A1 + A2 + A3 + A41 + A43 = 931.92 sq. mm, which is **greater** than A (27.12)

Nozzle Reinforcement Calculations

Area Required for External Pressure

A = ½ * (d tr F + 2 tn tr F (1 - fr1)) = ½ * ((110.66 * 5.87 * 1.0) + (2 * 4.00 * 5.87 * 1.0 * (1 - 0.7087))) = **331.63** sq. mm

Area Available - External Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
110.66 * (1.00 * 8.00 - 1.00 * 5.87) - 2 * 4.00 * (1.00 * 8.00 - 1.00 * 5.87) * (1 - 0.7087) = *230.74* sq. mm

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (8.00 + 4.00)(1.00 * 8.00 - 1.00 * 5.87) - 2 * 4.00 * (1.00 * 8.00 - 1.00 * 5.87) * (1 - 0.7087) = *46.16* sq. mm

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **230.74** sq. mm

A2 Formula 1 = 5(tn - trn) fr2 t = 5(4.00 - 0.29) * 0.7087 * 8.00 = *105.17* sq. mm
A2 Formula 2 = 5(tn - trn) fr2 tn = 5(4.00 - 0.29) * 0.7087 * 4.00 = *52.59* sq. mm
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **52.59** sq. mm

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 8.00 * 4.00 * 0.7087 = 113.39 sq. mm
$5 * t_i * t_i * f_{r2}$ = 5 * 4.00 * 4.00 * 0.7087 = 56.70 sq. mm
$2 * h * t_i * f_{r2}$ = 2 * 0.00 * 4.00 * 0.7087 = 0.00 sq. mm
= **0.00** sq. mm

A41 = $(leg)^2 * fr2$ = $(7.00)^2 * 0.7087$ = **34.73** sq. mm

A43 = $(leg)^2 * fr2$ = 0 * 0.7087 = **0.00** sq. mm

Area Available (External Pressure) = A1 + A2 + A3 + A41 + A43 = 318.06 sq. mm, which is **smaller** than A (331.63)

Nozzle Weld Strength Calculations

Attachment Weld Strength per Paragraph UW-16 (Corroded Condition)

Weld 41 tmin = smaller of 19.00, t, or tn = smaller of 19.00, 8.00, or 4.00 = **4.00** mm

Weld 41 Leg min. = $\frac{\text{(smaller of 6.00 or (tmin * 0.7)) + ext. CA}}{0.7} = \frac{2.80}{0.7}$ = **4.00** mm

Weld 41, actual weld leg = **7.00** mm

Unit Stresses per Paragraphs UG-45(c) and UW-15

Nozzle wall in shear = 0.70 * Sn = 0.70 * 97.80 = **68.46** MPa
Upper fillet, Weld 41, in shear = 0.49 * Material Stress = 0.49 * 97.80 = **47.92** MPa
Vessel groove weld, in tension = 0.74 * Material Stress = 0.74 * 97.80 = **72.37** MPa

Strength of Connection Elements

Nozzle wall in shear = ½ * • * mean nozzle diameter * tn * Nozzle wall in shear unit stress =
½ * • * 59.50 * 4.00 * 68.46 = **25600** N
Upper fillet in shear = ½ * • * Nozzle OD * weld leg * upper fillet in shear unit stress = ½ * • * 63.50 * 7.00 * 47.92 = **33400** N
Groove Weld in Tension = ½ * • * Nozzle OD * groove depth * groove weld tension unit stress =
½ * • * 63.50 * 4.00 * 72.37 = **28900** N

Load to be carried by welds, per UG-41(b)(1) and Fig. UG-41.1 sketch (a)

W = [A - A1 + 2 tn fr1(E1t - Ftr)] Sv = [27.12 - 840.64 + 2 * 4.00 * 0.7087 * (1.00 * 8.00 - 1.00 * 0.24)] * 138.00 = **-106194** N
W1-1 = (A2 + A5 + A41 + A42) * Sv = (56.55 + 0.00 + 34.73 + 0.00) * 138.00 = **12600** N
W2-2 = (A2 + A3 + A41 + A43 + 2 tn t fr1) Sv = (56.55 + 0.00 + 34.73 + 0.00 + 2 * 4.00 * 8.00 * 0.7087) * 138 = **18900** N
W3-3 = (A2 + A3 + A5 + A41 + A42 + A43 + 2 tn t fr1) * Sv =
(56.55 + 0.00 + 0.00 + 34.73 + 0.00 + 0.00 + 2 * 4.00 * 8.00 * 0.7087) * 138.00 = **18900** N

Check Strength Paths

Path 1-1 = Upper fillet in shear + Nozzle wall in shear = 33400 + 25600 = **59000** N
Path 2-2 = Upper fillet in shear + Groove weld in tension + Inner fillet in shear =
33400 + 28900 + 0 = **62300** N
Path 3-3 = Upper fillet in shear + Inner fillet in shear + Groove weld in tension = 33400 + 0 + 28900 = **62300** N

Nozzle Design Information

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Nozzle Efficiency (E):	100 %
Nozzle Material:	SA-312 TP304L, High	Joint Efficiency (E_1):	1.00
		Factor B Chart:	HA-3
External Projection:	120.00 mm	Allowable Stress at Design Temperature (S_n):	97.80 MPa
Internal Projection:	0.00 mm	Allowable Stress at Ambient Temperature:	97.80 MPa
Inside Corrosion Allowance:	0.00 mm	Correction Factor (F):	1.00
External Corrosion Allowance:	0.00 mm	Nozzle Path:	None
Nozzle ID (new):	193.00 mm	Nozzle Wall Thickness(new):	6.00 mm
Nozzle ID (corroded):	193.00 mm	Nozzle Wall Thickness(corroded):	6.00 mm
Outer "h" Limit:	15.00 mm	Upper Weld Leg Size(Weld 41):	6.00 mm
Internal "h" Limit:	15.00 mm	Internal Weld Leg Size(Weld 43):	0.00 mm
OD, Limit of Reinforcement:	386.00 mm	Outside Groove Weld Depth:	8.00 mm

Minimum Design Metal Temperature

Minimum Design Metal Temperature: -196 °C
Other Exemption

Host Component: Shell 1 - Shell 1

Material:	SA-240 Gr. 304, High	Shell wall thickness(new):	8.00 mm
Material Stress(S_V):	138.00 MPa	Shell wall thickness(corroded):	8.00 mm

Nozzle Detail Information

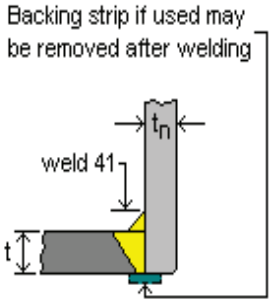

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 6.00 mm

Nozzle Wall Thickness(t_n): 6.00 mm

Outside Groove Weld Depth: 8.00 mm

Nozzle passes through the vessel, attached by a groove weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is **NOT** adequately reinforced for External Pressure.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PR}{SE - 0.6P} = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500}$$ = **0.24** mm

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{0.0500 * 96.50}{97.80 * 1 - 0.6 * 0.0500}$$ = **0.05** mm

Required Nozzle Thickness for External Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 205.00 * 0.1000}{4 * 30.39}$$ = **0.53** mm

Strength Reduction Factors

$$\mathbf{fr1} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087 \quad \mathbf{fr2} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

$$\mathbf{fr3} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion)

$$t_a = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 96.50}{97.80 * 1.00 - 0.6 * 0.0500} + 0.00 + 0.00$$ = **0.05** mm

Nozzle Thickness for Internal Pressure (plus corrosion) Based on Host

$$t_{b1} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} + 0.00 + 0.00$$

= Greater Of $(0.24_{(Calculated)}, 1.50_{(Minimum\ Allowed)}) + 0.00$ (corrosion) $+ 0.00$ (ext. corrosion) = **1.50** mm

Nozzle Thickness for External Pressure (plus corrosion) Based on Host

$$t_{b2} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.1000 * 675.00}{138.00 * 1 - 0.6 * 0.1000} + 0.00 + 0.00$$

= Greater Of $(0.49_{(Calculated)}, 1.50_{(Minimum\ Allowed)}) + 0.00$ (corrosion) $+ 0.00$ (ext. corrosion) = **1.50** mm

Minimum Thickness (plus corrosion) per Table UG-45

t_{b3} = minimum thickness (Table UG-45) + Ca + ext. Ca = **7.16** mm

Nozzle Minimum Thickness Based on Host and Table UG-45

$t_b = \min[t_{b3}, \max(t_{b1}, t_{b2})]$ = **1.50** mm

$t_{UG-45} = \max(t_a, t_b)$ = **1.50** mm

Wall thickness = tn = **6.00** is greater than or equal to UG-45 value of **1.50**

Nozzle Reinforcement Calculations

Area Required for Internal Pressure

A = d tr F + 2 tn tr F (1 - fr1) = (193.00 * 0.24 * 1.00) + (2 * 6.00 * 0.24 * 1.00 * (1 - 0.7087)) = **47.16** sq. mm

Area Available - Internal Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
193.00 * (1.00 * 8.00 - 1.00 * 0.24) - 2 * 6.00 * (1.00 * 8.00 - 1.00 * 0.24) * (1 - 0.7087) = *1470.55* sq. mm

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (8.00 + 6.00)(1.00 * 8.00 - 1.00 * 0.24) - 2 * 6.00 * (1.00 * 8.00 - 1.00 * 0.24) * (1 - 0.7087) = *190.15* sq. mm

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **1470.55** sq. mm

A2 Formula 1 = 5(tn - trn) fr2 t = 5(6.00 - 0.05) * 0.7087 * 8.00 = *168.67* sq. mm
A2 Formula 2 = 5(tn - trn) fr2 tn = 5(6.00 - 0.05) * 0.7087 * 6.00 = *126.50* sq. mm
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **126.50** sq. mm

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 8.00 * 6.00 * 0.7087 = 170.09 sq. mm
$5 * t_i * t_i * f_{r2}$ = 5 * 6.00 * 6.00 * 0.7087 = 127.57 sq. mm
$2 * h * t_i * f_{r2}$ = 2 * 0.00 * 6.00 * 0.7087 = 0.00 sq. mm
= **0.00** sq. mm

A41 = $(leg)^2 * fr2$ = $(6.00)^2 * 0.7087$ = **25.51** sq. mm

A43 = $(leg)^2 *$ fr2 = 0 * 0.7087 = **0.00** sq. mm

Area Available (Internal Pressure) = A1 + A2 + A3 + A41 + A43 = 1622.56 sq. mm, which is **greater** than A (47.16)

Nozzle Reinforcement Calculations

Area Required for External Pressure

A = ½ * (d tr F + 2 tn tr F (1 - fr1)) = ½ * ((193.00 * 5.87 * 1.0) + (2 * 6.00 * 5.87 * 1.0 * (1 - 0.7087))) = **576.71** sq. mm

Area Available - External Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
193.00 * (1.00 * 8.00 - 1.00 * 5.87) - 2 * 6.00 * (1.00 * 8.00 - 1.00 * 5.87) * (1 - 0.7087) = *403.64* sq. mm

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (8.00 + 6.00)(1.00 * 8.00 - 1.00 * 5.87) - 2 * 6.00 * (1.00 * 8.00 - 1.00 * 5.87) * (1 - 0.7087) = *52.19* sq. mm

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **403.64** sq. mm

A2 Formula 1 = 5(tn - trn) fr2 t = 5(6.00 - 0.53) * 0.7087 * 8.00 = *155.06* sq. mm
A2 Formula 2 = 5(tn - trn) fr2 tn = 5(6.00 - 0.53) * 0.7087 * 6.00 = *116.30* sq. mm
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **116.30** sq. mm

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 8.00 * 6.00 * 0.7087 = 170.09 sq. mm
$5 * t_i * t_i * f_{r2}$ = 5 * 6.00 * 6.00 * 0.7087 = 127.57 sq. mm
$2 * h * t_i * f_{r2}$ = 2 * 0.00 * 6.00 * 0.7087 = 0.00 sq. mm
= **0.00** sq. mm

A41 = $(leg)^2 * fr2$ = $(6.00)^2 * 0.7087$ = **25.51** sq. mm

A43 = $(leg)^2 *$ fr2 = 0 * 0.7087 = **0.00** sq. mm

Area Available (External Pressure) = A1 + A2 + A3 + A41 + A43 = 545.45 sq. mm, which is **smaller** than A (576.71)

Alca Technology srl

Q D63.5

Job No: ALCA 20106-01
Number: 15
ID Number: 15

Vessel Number: 20106-01
Mark Number: N15

Date Printed: 07/02/2012

Nozzle Design Information

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Nozzle Efficiency (E):	100 %
Nozzle Material:	SA-312 TP304L, High	Joint Efficiency (E_1):	1.00
		Factor B Chart:	HA-3
External Projection:	70.00 mm	Allowable Stress at Design Temperature (S_n):	97.80 MPa
Internal Projection:	0.00 mm	Allowable Stress at Ambient Temperature:	97.80 MPa
Inside Corrosion Allowance:	0.00 mm	Correction Factor (F):	1.00
External Corrosion Allowance:	0.00 mm	Nozzle Path:	None
Nozzle ID (new):	59.50 mm	Nozzle Wall Thickness(new):	2.00 mm
Nozzle ID (corroded):	59.50 mm	Nozzle Wall Thickness(corroded):	2.00 mm
Outer "h" Limit:	5.00 mm	Upper Weld Leg Size(Weld 41):	2.00 mm
Internal "h" Limit:	5.00 mm	Internal Weld Leg Size(Weld 43):	0.00 mm
OD, Limit of Reinforcement:	119.00 mm	Outside Groove Weld Depth:	8.00 mm

Minimum Design Metal Temperature

Minimum Design Metal Temperature: -196 °C
Other Exemption

Host Component: Shell 1 - Shell 1

Material:	SA-240 Gr. 304, High	Shell wall thickness(new):	8.00 mm
Material Stress(S_V):	138.00 MPa	Shell wall thickness(corroded):	8.00 mm

Nozzle Detail Information

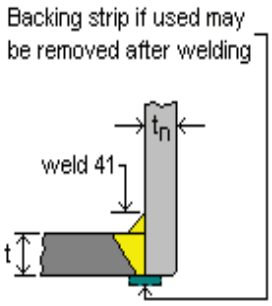

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 2.00 mm

Nozzle Wall Thickness(t_n): 2.00 mm

Outside Groove Weld Depth: 8.00 mm

Nozzle passes through the vessel, attached by a groove weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is adequately reinforced for External Pressure.
Reinforcement calculations are not required per UG-36(c)(3)(a)See Uw-14 for exceptions.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PR}{SE - 0.6P} = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} = \mathbf{0.24} \text{ mm}$$

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{0.0500 * 29.75}{97.80 * 1 - 0.6 * 0.0500} = \mathbf{0.02} \text{ mm}$$

Required Nozzle Thickness for External Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 63.50 * 0.1000}{4 * 23.26} = \mathbf{0.21} \text{ mm}$$

Strength Reduction Factors

$$\mathbf{fr1} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087 \quad \mathbf{fr2} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

$$\mathbf{fr3} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion)

$$t_a = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 29.75}{97.80 * 1.00 - 0.6 * 0.0500} + 0.00 + 0.00 = \mathbf{0.02} \text{ mm}$$

Nozzle Thickness for Internal Pressure (plus corrosion) Based on Host

$$t_{b1} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} + 0.00 + 0.00$$

$= \text{Greater Of } (0.24_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00_{(\text{corrosion})} + 0.00_{(\text{ext. corrosion})} = \mathbf{1.50}$ mm

Nozzle Thickness for External Pressure (plus corrosion) Based on Host

$$t_{b2} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.1000 * 675.00}{138.00 * 1 - 0.6 * 0.1000} + 0.00 + 0.00$$

$= \text{Greater Of } (0.49_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00_{(\text{corrosion})} + 0.00_{(\text{ext. corrosion})} = \mathbf{1.50}$ mm

Minimum Thickness (plus corrosion) per Table UG-45

t_{b3} = minimum thickness (Table UG-45) + Ca + ext. Ca = **4.52** mm

Nozzle Minimum Thickness Based on Host and Table UG-45

$t_b = \min[t_{b3}, \max(t_{b1}, t_{b2})]$ = **1.50** mm

$t_{UG\text{-}45} = \max(t_a, t_b)$ = **1.50** mm

Wall thickness = tn = **2.00** is greater than or equal to UG-45 value of **1.50**

Alca Technology srl

V D20

Job No: ALCA 20106-01
Number: 20
ID Number: V

Vessel Number: 20106-01
Mark Number: V

Date Printed: 07/02/2012

Nozzle Design Information

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Nozzle Efficiency (E):	100 %
Nozzle Material:	SA-312 TP304L, High	Joint Efficiency (E_1):	1.00
		Factor B Chart:	HA-3
External Projection:	85.00 mm	Allowable Stress at Design Temperature (S_n):	97.80 MPa
Internal Projection:	0.00 mm	Allowable Stress at Ambient Temperature:	97.80 MPa
Inside Corrosion Allowance:	0.00 mm	Correction Factor (F):	1.00
External Corrosion Allowance:	0.00 mm	Nozzle Path:	None
Nozzle ID (new):	16.00 mm	Nozzle Wall Thickness(new):	2.00 mm
Nozzle ID (corroded):	16.00 mm	Nozzle Wall Thickness(corroded):	2.00 mm
Outer "h" Limit:	5.00 mm	Upper Weld Leg Size(Weld 41):	6.00 mm
Internal "h" Limit:	5.00 mm	Internal Weld Leg Size(Weld 43):	0.00 mm
OD, Limit of Reinforcement:	36.00 mm	Outside Groove Weld Depth:	8.00 mm

Minimum Design Metal Temperature

Minimum Design Metal Temperature: -196 °C
Other Exemption

Host Component: Shell 1 - Shell 1

Material:	SA-240 Gr. 304, High	Shell wall thickness(new):	8.00 mm
Material Stress(S_V):	138.00 MPa	Shell wall thickness(corroded):	8.00 mm

Nozzle Detail Information

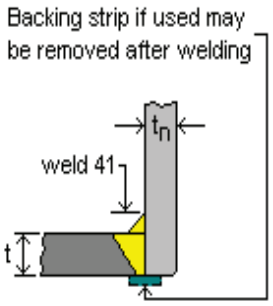

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 6.00 mm

Nozzle Wall Thickness(t_n): 2.00 mm

Outside Groove Weld Depth: 8.00 mm

Nozzle passes through the vessel, attached by a groove weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is adequately reinforced for External Pressure.
Reinforcement calculations are not required per UG-36(c)(3)(a)See Uw-14 for exceptions.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PR}{SE - 0.6P} = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500}$$ = **0.24** mm

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{0.0500 * 8.00}{97.80 * 1 - 0.6 * 0.0500}$$ = **0.00** mm

Required Nozzle Thickness for External Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 20.00 * 0.1000}{4 * 13.85}$$ = **0.12** mm

Strength Reduction Factors

$$\mathbf{fr1} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087 \quad \mathbf{fr2} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

$$\mathbf{fr3} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion)

$$t_a = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 8.00}{97.80 * 1.00 - 0.6 * 0.0500} + 0.00 + 0.00$$ = **0.00** mm

Nozzle Thickness for Internal Pressure (plus corrosion) Based on Host

$$t_{b1} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} + 0.00 + 0.00$$

= Greater Of $(0.24_{(Calculated)}, 1.50_{(Minimum\ Allowed)}) + 0.00$ (corrosion) $+ 0.00$ (ext. corrosion) = **1.50** mm

Nozzle Thickness for External Pressure (plus corrosion) Based on Host

$$t_{b2} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.1000 * 675.00}{138.00 * 1 - 0.6 * 0.1000} + 0.00 + 0.00$$

= Greater Of $(0.49_{(Calculated)}, 1.50_{(Minimum\ Allowed)}) + 0.00$ (corrosion) $+ 0.00$ (ext. corrosion) = **1.50** mm

Minimum Thickness (plus corrosion) per Table UG-45

t_{b3} = minimum thickness (Table UG-45) + Ca + ext. Ca = **2.42** mm

Nozzle Minimum Thickness Based on Host and Table UG-45

$t_b = \min[t_{b3}, \max(t_{b1}, t_{b2})]$ = **1.50** mm

$t_{UG-45} = \max(t_a, t_b)$ = **1.50** mm

Wall thickness = tn = **2.00** is greater than or equal to UG-45 value of **1.50**

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X D159

Job No: ALCA 20106-01
Number: 23
ID Number: X

Vessel Number: 20106-01
Mark Number: X

Date Printed: 07/02/2012

Nozzle Design Information

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Nozzle Efficiency (E):	100 %
Nozzle Material:	SA-312 TP304L, High	Joint Efficiency (E_1):	1.00
		Factor B Chart:	HA-3
External Projection:	120.00 mm	Allowable Stress at Design Temperature (S_n):	97.80 MPa
Internal Projection:	0.00 mm	Allowable Stress at Ambient Temperature:	97.80 MPa
Inside Corrosion Allowance:	0.00 mm	Correction Factor (F):	1.00
External Corrosion Allowance:	0.00 mm	Nozzle Path:	None
Nozzle ID (new):	149.00 mm	Nozzle Wall Thickness(new):	5.00 mm
Nozzle ID (corroded):	149.00 mm	Nozzle Wall Thickness(corroded):	5.00 mm
Outer "h" Limit:	12.50 mm	Upper Weld Leg Size(Weld 41):	6.00 mm
Internal "h" Limit:	12.50 mm	Internal Weld Leg Size(Weld 43):	0.00 mm
OD, Limit of Reinforcement:	298.00 mm	Outside Groove Weld Depth:	8.00 mm

Minimum Design Metal Temperature

Minimum Design Metal Temperature: -196 °C
Other Exemption

Host Component: Shell 1 - Shell 1

Material:	SA-240 Gr. 304, High	Shell wall thickness(new):	8.00 mm
Material Stress(S_V):	138.00 MPa	Shell wall thickness(corroded):	8.00 mm

Nozzle Detail Information

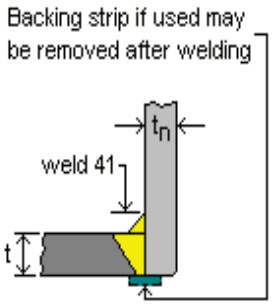

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 6.00 mm

Nozzle Wall Thickness(t_n): 5.00 mm

Outside Groove Weld Depth: 8.00 mm

Nozzle passes through the vessel, attached by a groove weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is **NOT** adequately reinforced for External Pressure.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PR}{SE - 0.6P} = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} = \mathbf{0.24} \text{ mm}$$

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{0.0500 * 74.50}{97.80 * 1 - 0.6 * 0.0500} = \mathbf{0.04} \text{ mm}$$

Required Nozzle Thickness for External Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 159.00 * 0.1000}{4 * 27.36} = \mathbf{0.45} \text{ mm}$$

Strength Reduction Factors

$$\mathbf{fr1} = \min\left[\frac{Sn}{Sv}, 1.0000\right] = \min\left[\frac{97.80}{138.00}, 1.0000\right] = 0.7087 \quad \mathbf{fr2} = \min\left[\frac{Sn}{Sv}, 1.0000\right] = \min\left[\frac{97.80}{138.00}, 1.0000\right] = 0.7087$$

$$\mathbf{fr3} = \min\left[\frac{Sn}{Sv}, 1.0000\right] = \min\left[\frac{97.80}{138.00}, 1.0000\right] = 0.7087$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion)

$$t_a = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 74.50}{97.80 * 1.00 - 0.6 * 0.0500} + 0.00 + 0.00 = \mathbf{0.04} \text{ mm}$$

Nozzle Thickness for Internal Pressure (plus corrosion) Based on Host

$$t_{b1} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} + 0.00 + 0.00$$

$= \text{Greater Of } (0.24_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00 \text{ (corrosion)} + 0.00 \text{ (ext. corrosion)} = \mathbf{1.50}$ mm

Nozzle Thickness for External Pressure (plus corrosion) Based on Host

$$t_{b2} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.1000 * 675.00}{138.00 * 1 - 0.6 * 0.1000} + 0.00 + 0.00$$

$= \text{Greater Of } (0.49_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00 \text{ (corrosion)} + 0.00 \text{ (ext. corrosion)} = \mathbf{1.50}$ mm

Minimum Thickness (plus corrosion) per Table UG-45

t_{b3} = minimum thickness (Table UG-45) + Ca + ext. Ca = **6.22** mm

Nozzle Minimum Thickness Based on Host and Table UG-45

$t_b = \min[t_{b3}, \max(t_{b1}, t_{b2})]$ = **1.50** mm

$t_{UG\text{-}45} = \max(t_a, t_b)$ = **1.50** mm

Wall thickness = tn = **5.00** is greater than or equal to UG-45 value of **1.50**

Nozzle Reinforcement Calculations

Area Required for Internal Pressure

A = d tr F + 2 tn tr F (1 - fr1) = (149.00 * 0.24 * 1.00) + (2 * 5.00 * 0.24 * 1.00 * (1 - 0.7087)) = **36.46** sq. mm

Area Available - Internal Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
149.00 * (1.00 * 8.00 - 1.00 * 0.24) - 2 * 5.00 * (1.00 * 8.00 - 1.00 * 0.24) * (1 - 0.7087) = *1133.63* sq. mm

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (8.00 + 5.00)(1.00 * 8.00 - 1.00 * 0.24) - 2 * 5.00 * (1.00 * 8.00 - 1.00 * 0.24) * (1 - 0.7087) = *179.15* sq. mm

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **1133.63** sq. mm

A2 Formula 1 = 5(tn - trn) fr2 t = 5(5.00 - 0.04) * 0.7087 * 8.00 = *140.61* sq. mm
A2 Formula 2 = 5(tn - trn) fr2 tn = 5(5.00 - 0.04) * 0.7087 * 5.00 = *87.88* sq. mm
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **87.88** sq. mm

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 8.00 * 5.00 * 0.7087 = 141.74 sq. mm
$5 * t_i * t_i * f_{r2}$ = 5 * 5.00 * 5.00 * 0.7087 = 88.59 sq. mm
$2 * h * t_i * f_{r2}$ = 2 * 0.00 * 5.00 * 0.7087 = 0.00 sq. mm
= **0.00** sq. mm

A41 = $(leg)^2 * fr2$ = $(6.00)^2 * 0.7087$ = **25.51** sq. mm

A43 = $(leg)^2 * fr2$ = 0 * 0.7087 = **0.00** sq. mm

Area Available (Internal Pressure) = A1 + A2 + A3 + A41 + A43 = 1247.02 sq. mm, which is **greater** than A (36.46)

Nozzle Reinforcement Calculations

Area Required for External Pressure

A = ½ * (d tr F + 2 tn tr F (1 - fr1)) = ½ * ((149.00 * 5.87 * 1.0) + (2 * 5.00 * 5.87 * 1.0 * (1 - 0.7087))) = **445.86** sq. mm

Area Available - External Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
149.00 * (1.00 * 8.00 - 1.00 * 5.87) - 2 * 5.00 * (1.00 * 8.00 - 1.00 * 5.87) * (1 - 0.7087) = *311.17* sq. mm

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (8.00 + 5.00)(1.00 * 8.00 - 1.00 * 5.87) - 2 * 5.00 * (1.00 * 8.00 - 1.00 * 5.87) * (1 - 0.7087) = *49.18* sq. mm

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **311.17** sq. mm

A2 Formula 1 = 5(tn - trn) fr2 t = 5(5.00 - 0.45) * 0.7087 * 8.00 = *128.98* sq. mm
A2 Formula 2 = 5(tn - trn) fr2 tn = 5(5.00 - 0.45) * 0.7087 * 5.00 = *80.61* sq. mm
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **80.61** sq. mm

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 8.00 * 5.00 * 0.7087 = 141.74 sq. mm
$5 * t_i * t_i * f_{r2}$ = 5 * 5.00 * 5.00 * 0.7087 = 88.59 sq. mm
$2 * h * t_i * f_{r2}$ = 2 * 0.00 * 5.00 * 0.7087 = 0.00 sq. mm
= **0.00** sq. mm

A41 = $(leg)^2 * fr2$ = $(6.00)^2 * 0.7087$ = **25.51** sq. mm

A43 = $(leg)^2 * fr2$ = 0 * 0.7087 = **0.00** sq. mm

Area Available (External Pressure) = A1 + A2 + A3 + A41 + A43 = 417.29 sq. mm, which is **smaller** than A (445.86)

Alca Technology srl

N D159

Job No: ALCA 20106-01
Number: 12
ID Number: 12

Vessel Number: 20106-01
Mark Number: N

Date Printed: 07/02/2012

Nozzle Design Information

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Nozzle Efficiency (E):	100 %
Nozzle Material:	SA-312 TP304L, High	Joint Efficiency (E_1):	1.00
		Factor B Chart:	HA-3
External Projection:	120.00 mm	Allowable Stress at Design Temperature (S_n):	97.80 MPa
Internal Projection:	0.00 mm	Allowable Stress at Ambient Temperature:	97.80 MPa
Inside Corrosion Allowance:	0.00 mm	Correction Factor (F):	1.00
External Corrosion Allowance:	0.00 mm	Nozzle Path:	None
Nozzle ID (new):	149.00 mm	Nozzle Wall Thickness(new):	5.00 mm
Nozzle ID (corroded):	149.00 mm	Nozzle Wall Thickness(corroded):	5.00 mm
Outer "h" Limit:	12.50 mm	Upper Weld Leg Size(Weld 41):	6.00 mm
Internal "h" Limit:	12.50 mm	Internal Weld Leg Size(Weld 43):	0.00 mm
OD, Limit of Reinforcement:	298.00 mm	Outside Groove Weld Depth:	8.00 mm

Minimum Design Metal Temperature

Minimum Design Metal Temperature: -196 °C
Other Exemption

Host Component: Shell 1 - Shell 1

Material:	SA-240 Gr. 304, High	Shell wall thickness(new):	8.00 mm
Material Stress(S_V):	138.00 MPa	Shell wall thickness(corroded):	8.00 mm

Nozzle Detail Information

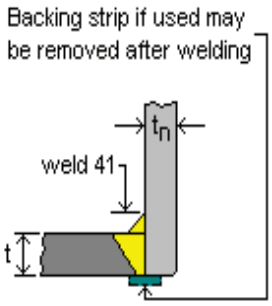

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 6.00 mm

Nozzle Wall Thickness(t_n): 5.00 mm

Outside Groove Weld Depth: 8.00 mm

Nozzle passes through the vessel, attached by a groove weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is **NOT** adequately reinforced for External Pressure.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PR}{SE - 0.6P} = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500}$$ = **0.24** mm

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{0.0500 * 74.50}{97.80 * 1 - 0.6 * 0.0500}$$ = **0.04** mm

Required Nozzle Thickness for External Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 159.00 * 0.1000}{4 * 27.36}$$ = **0.45** mm

Strength Reduction Factors

$$\mathbf{fr1} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087 \quad \mathbf{fr2} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

$$\mathbf{fr3} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion)

$$t_a = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 74.50}{97.80 * 1.00 - 0.6 * 0.0500} + 0.00 + 0.00$$ = **0.04** mm

Nozzle Thickness for Internal Pressure (plus corrosion) Based on Host

$$t_{b1} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} + 0.00 + 0.00$$

= Greater Of $(0.24_{(Calculated)}, 1.50_{(Minimum\ Allowed)}) + 0.00_{(corrosion)} + 0.00_{(ext.\ corrosion)}$ = **1.50** mm

Nozzle Thickness for External Pressure (plus corrosion) Based on Host

$$t_{b2} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.1000 * 675.00}{138.00 * 1 - 0.6 * 0.1000} + 0.00 + 0.00$$

= Greater Of $(0.49_{(Calculated)}, 1.50_{(Minimum\ Allowed)}) + 0.00_{(corrosion)} + 0.00_{(ext.\ corrosion)}$ = **1.50** mm

Minimum Thickness (plus corrosion) per Table UG-45

t_{b3} = minimum thickness (Table UG-45) + Ca + ext. Ca = **6.22** mm

Nozzle Minimum Thickness Based on Host and Table UG-45

$t_b = \min[t_{b3}, \max(t_{b1}, t_{b2})]$ = **1.50** mm

$t_{UG\text{-}45} = \max(t_a, t_b)$ = **1.50** mm

Wall thickness = tn = **5.00** is greater than or equal to UG-45 value of **1.50**

Nozzle Reinforcement Calculations

Area Required for Internal Pressure

A = d tr F + 2 tn tr F (1 - fr1) = (149.00 * 0.24 * 1.00) + (2 * 5.00 * 0.24 * 1.00 * (1 - 0.7087)) = **36.46** sq. mm

Area Available - Internal Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
149.00 * (1.00 * 8.00 - 1.00 * 0.24) - 2 * 5.00 * (1.00 * 8.00 - 1.00 * 0.24) * (1 - 0.7087) = *1133.63* sq. mm

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (8.00 + 5.00)(1.00 * 8.00 - 1.00 * 0.24) - 2 * 5.00 * (1.00 * 8.00 - 1.00 * 0.24) * (1 - 0.7087) = *179.15* sq. mm

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **1133.63** sq. mm

A2 Formula 1 = 5(tn - trn) fr2 t = 5(5.00 - 0.04) * 0.7087 * 8.00 = *140.61* sq. mm
A2 Formula 2 = 5(tn - trn) fr2 tn = 5(5.00 - 0.04) * 0.7087 * 5.00 = *87.88* sq. mm
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **87.88** sq. mm

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 8.00 * 5.00 * 0.7087 = 141.74 sq. mm
$5 * t_i * t_i * f_{r2}$ = 5 * 5.00 * 5.00 * 0.7087 = 88.59 sq. mm
$2 * h * t_i * f_{r2}$ = 2 * 0.00 * 5.00 * 0.7087 = 0.00 sq. mm
= **0.00** sq. mm

A41 = $(leg)^2 * fr2$ = $(6.00)^2 * 0.7087$ = **25.51** sq. mm

A43 = $(leg)^2 * fr2$ = 0 * 0.7087 = **0.00** sq. mm

Area Available (Internal Pressure) = A1 + A2 + A3 + A41 + A43 = 1247.02 sq. mm, which is **greater** than A (36.46)

Nozzle Reinforcement Calculations

Area Required for External Pressure

A = ½ * (d tr F + 2 tn tr F (1 - fr1)) = ½ * ((149.00 * 5.87 * 1.0) + (2 * 5.00 * 5.87 * 1.0 * (1 - 0.7087))) = **445.86** sq. mm

Area Available - External Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
149.00 * (1.00 * 8.00 - 1.00 * 5.87) - 2 * 5.00 * (1.00 * 8.00 - 1.00 * 5.87) * (1 - 0.7087) = *311.17* sq. mm

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (8.00 + 5.00)(1.00 * 8.00 - 1.00 * 5.87) - 2 * 5.00 * (1.00 * 8.00 - 1.00 * 5.87) * (1 - 0.7087) = *49.18* sq. mm

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **311.17** sq. mm

A2 Formula 1 = 5(tn - trn) fr2 t = 5(5.00 - 0.45) * 0.7087 * 8.00 = *128.98* sq. mm
A2 Formula 2 = 5(tn - trn) fr2 tn = 5(5.00 - 0.45) * 0.7087 * 5.00 = *80.61* sq. mm
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **80.61** sq. mm

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 8.00 * 5.00 * 0.7087 = 141.74 sq. mm
$5 * t_i * t_i * f_{r2}$ = 5 * 5.00 * 5.00 * 0.7087 = 88.59 sq. mm
$2 * h * t_i * f_{r2}$ = 2 * 0.00 * 5.00 * 0.7087 = 0.00 sq. mm
= **0.00** sq. mm

A41 = $(leg)^2 * fr2$ = $(6.00)^2 * 0.7087$ = **25.51** sq. mm

A43 = $(leg)^2 * fr2$ = 0 * 0.7087 = **0.00** sq. mm

Area Available (External Pressure) = A1 + A2 + A3 + A41 + A43 = 417.29 sq. mm, which is **smaller** than A (445.86)

Alca Technology srl

R D63.5

Job No: ALCA 20106-01
Number: 16
ID Number: 16

Vessel Number: 20106-01
Mark Number: R

Date Printed: 07/02/2012

Nozzle Design Information

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Nozzle Efficiency (E):	100 %
Nozzle Material:	SA-312 TP304L, High	Joint Efficiency (E_1):	1.00
		Factor B Chart:	HA-3
External Projection:	70.00 mm	Allowable Stress at Design Temperature (S_n):	97.80 MPa
Internal Projection:	0.00 mm	Allowable Stress at Ambient Temperature:	97.80 MPa
Inside Corrosion Allowance:	0.00 mm	Correction Factor (F):	1.00
External Corrosion Allowance:	0.00 mm	Nozzle Path:	None
Nozzle ID (new):	59.50 mm	Nozzle Wall Thickness(new):	2.00 mm
Nozzle ID (corroded):	59.50 mm	Nozzle Wall Thickness(corroded):	2.00 mm
Outer "h" Limit:	5.00 mm	Upper Weld Leg Size(Weld 41):	2.00 mm
Internal "h" Limit:	5.00 mm	Internal Weld Leg Size(Weld 43):	0.00 mm
OD, Limit of Reinforcement:	119.00 mm	Outside Groove Weld Depth:	8.00 mm

Minimum Design Metal Temperature

Minimum Design Metal Temperature: -196 °C
Other Exemption

Host Component: Shell 1 - Shell 1

Material:	SA-240 Gr. 304, High	Shell wall thickness(new):	8.00 mm
Material Stress(S_V):	138.00 MPa	Shell wall thickness(corroded):	8.00 mm

Nozzle Detail Information

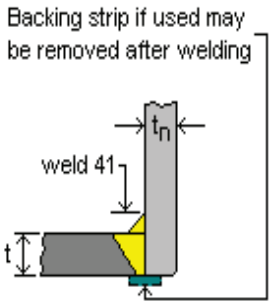

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 2.00 mm

Nozzle Wall Thickness(t_n): 2.00 mm

Outside Groove Weld Depth: 8.00 mm

Nozzle passes through the vessel, attached by a groove weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is adequately reinforced for External Pressure.
Reinforcement calculations are not required per UG-36(c)(3)(a)See Uw-14 for exceptions.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PR}{SE - 0.6P} = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} = \mathbf{0.24}\ \text{mm}$$

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{0.0500 * 29.75}{97.80 * 1 - 0.6 * 0.0500} = \mathbf{0.02}\ \text{mm}$$

Required Nozzle Thickness for External Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 63.50 * 0.1000}{4 * 23.26} = \mathbf{0.21}\ \text{mm}$$

Strength Reduction Factors

$$\mathbf{fr1} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087 \quad \mathbf{fr2} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

$$\mathbf{fr3} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion)

$$t_a = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 29.75}{97.80 * 1.00 - 0.6 * 0.0500} + 0.00 + 0.00 = \mathbf{0.02}\ \text{mm}$$

Nozzle Thickness for Internal Pressure (plus corrosion) Based on Host

$$t_{b1} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} + 0.00 + 0.00$$

$= \text{Greater Of } (0.24_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00\ (\text{corrosion}) + 0.00\ (\text{ext. corrosion}) = \mathbf{1.50}\ \text{mm}$

Nozzle Thickness for External Pressure (plus corrosion) Based on Host

$$t_{b2} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.1000 * 675.00}{138.00 * 1 - 0.6 * 0.1000} + 0.00 + 0.00$$

$= \text{Greater Of } (0.49_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00\ (\text{corrosion}) + 0.00\ (\text{ext. corrosion}) = \mathbf{1.50}\ \text{mm}$

Minimum Thickness (plus corrosion) per Table UG-45

t_{b3} = minimum thickness (Table UG-45) + Ca + ext. Ca $= \mathbf{4.52}\ \text{mm}$

Nozzle Minimum Thickness Based on Host and Table UG-45

$t_b = \min[t_{b3}, \max(t_{b1}, t_{b2})] = \mathbf{1.50}\ \text{mm}$

$t_{UG\text{-}45} = \max(t_a, t_b) = \mathbf{1.50}\ \text{mm}$

Wall thickness = tn = **2.00** is greater than or equal to UG-45 value of **1.50**

Alca Technology srl

G D205

Job No: ALCA 20106-01
Number: 7
ID Number: 7

Vessel Number: 20106-01
Mark Number: G

Date Printed: 07/02/2012

Nozzle Design Information

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Nozzle Efficiency (E):	100 %
Nozzle Material:	SA-312 TP304L, High	Joint Efficiency (E_1):	1.00
		Factor B Chart:	HA-3
External Projection:	120.00 mm	Allowable Stress at Design Temperature (S_n):	97.80 MPa
Internal Projection:	0.00 mm	Allowable Stress at Ambient Temperature:	97.80 MPa
Inside Corrosion Allowance:	0.00 mm	Correction Factor (F):	1.00
External Corrosion Allowance:	0.00 mm	Nozzle Path:	None
Nozzle ID (new):	193.00 mm	Nozzle Wall Thickness(new):	6.00 mm
Nozzle ID (corroded):	193.00 mm	Nozzle Wall Thickness(corroded):	6.00 mm
Outer "h" Limit:	15.00 mm	Upper Weld Leg Size(Weld 41):	6.00 mm
Internal "h" Limit:	15.00 mm	Internal Weld Leg Size(Weld 43):	0.00 mm
OD, Limit of Reinforcement:	386.00 mm	Outside Groove Weld Depth:	8.00 mm

Minimum Design Metal Temperature

Minimum Design Metal Temperature: -196 °C
Other Exemption

Host Component: Shell 1 - Shell 1

Material:	SA-240 Gr. 304, High	Shell wall thickness(new):	8.00 mm
Material Stress(S_V):	138.00 MPa	Shell wall thickness(corroded):	8.00 mm

Nozzle Detail Information

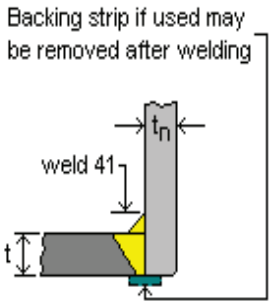

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 6.00 mm

Nozzle Wall Thickness(t_n): 6.00 mm

Outside Groove Weld Depth: 8.00 mm

Nozzle passes through the vessel, attached by a groove weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is **NOT** adequately reinforced for External Pressure.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PR}{SE - 0.6P} = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500}$$ = **0.24** mm

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{0.0500 * 96.50}{97.80 * 1 - 0.6 * 0.0500}$$ = **0.05** mm

Required Nozzle Thickness for External Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 205.00 * 0.1000}{4 * 30.39}$$ = **0.53** mm

Strength Reduction Factors

$$\mathbf{fr1} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$ $$\mathbf{fr2} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

$$\mathbf{fr3} = \min\left(\frac{Sn}{Sv}, 1.0000\right) = \min\left(\frac{97.80}{138.00}, 1.0000\right) = 0.7087$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion)

$$t_a = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 96.50}{97.80 * 1.00 - 0.6 * 0.0500} + 0.00 + 0.00$$ = **0.05** mm

Nozzle Thickness for Internal Pressure (plus corrosion) Based on Host

$$t_{b1} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.0500 * 675.00}{138.00 * 1 - 0.6 * 0.0500} + 0.00 + 0.00$$

= Greater Of $(0.24_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00$ (corrosion) $+ 0.00$ (ext. corrosion) = **1.50** mm

Nozzle Thickness for External Pressure (plus corrosion) Based on Host

$$t_{b2} = \frac{PR}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.1000 * 675.00}{138.00 * 1 - 0.6 * 0.1000} + 0.00 + 0.00$$

= Greater Of $(0.49_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00$ (corrosion) $+ 0.00$ (ext. corrosion) = **1.50** mm

Minimum Thickness (plus corrosion) per Table UG-45

t_{b3} = minimum thickness (Table UG-45) + Ca + ext. Ca = **7.16** mm

Nozzle Minimum Thickness Based on Host and Table UG-45

$t_b = \min[t_{b3}, \max(t_{b1}, t_{b2})]$ = **1.50** mm

$t_{UG-45} = \max(t_a, t_b)$ = **1.50** mm

Wall thickness = tn = **6.00** is greater than or equal to UG-45 value of **1.50**

Nozzle Reinforcement Calculations

Area Required for Internal Pressure

A = d tr F + 2 tn tr F (1 - fr1) = (193.00 * 0.24 * 1.00) + (2 * 6.00 * 0.24 * 1.00 * (1 - 0.7087)) = **47.16** sq. mm

Area Available - Internal Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
193.00 * (1.00 * 8.00 - 1.00 * 0.24) - 2 * 6.00 * (1.00 * 8.00 - 1.00 * 0.24) * (1 - 0.7087) = *1470.55* sq. mm

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (8.00 + 6.00)(1.00 * 8.00 - 1.00 * 0.24) - 2 * 6.00 * (1.00 * 8.00 - 1.00 * 0.24) * (1 - 0.7087) = *190.15* sq. mm

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **1470.55** sq. mm

A2 Formula 1 = 5(tn - trn) fr2 t = 5(6.00 - 0.05) * 0.7087 * 8.00 = *168.67* sq. mm
A2 Formula 2 = 5(tn - trn) fr2 tn = 5(6.00 - 0.05) * 0.7087 * 6.00 = *126.50* sq. mm
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **126.50** sq. mm

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 8.00 * 6.00 * 0.7087 = 170.09 sq. mm
$5 * t_i * t_i * f_{r2}$ = 5 * 6.00 * 6.00 * 0.7087 = 127.57 sq. mm
$2 * h * t_i * f_{r2}$ = 2 * 0.00 * 6.00 * 0.7087 = 0.00 sq. mm
= **0.00** sq. mm

A41 = $(leg)^2 * fr2$ = $(6.00)^2 * 0.7087$ = **25.51** sq. mm

A43 = $(leg)^2 * fr2$ = 0 * 0.7087 = **0.00** sq. mm

Area Available (Internal Pressure) = A1 + A2 + A3 + A41 + A43 = 1622.56 sq. mm, which is **greater** than A (47.16)

Nozzle Reinforcement Calculations

Area Required for External Pressure

A = ½ * (d tr F + 2 tn tr F (1 - fr1)) = ½ * ((193.00 * 5.87 * 1.0) + (2 * 6.00 * 5.87 * 1.0 * (1 - 0.7087))) = **576.71** sq. mm

Area Available - External Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
193.00 * (1.00 * 8.00 - 1.00 * 5.87) - 2 * 6.00 * (1.00 * 8.00 - 1.00 * 5.87) * (1 - 0.7087) = *403.64* sq. mm

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (8.00 + 6.00)(1.00 * 8.00 - 1.00 * 5.87) - 2 * 6.00 * (1.00 * 8.00 - 1.00 * 5.87) * (1 - 0.7087) = *52.19* sq. mm

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **403.64** sq. mm

A2 Formula 1 = 5(tn - trn) fr2 t = 5(6.00 - 0.53) * 0.7087 * 8.00 = *155.06* sq. mm
A2 Formula 2 = 5(tn - trn) fr2 tn = 5(6.00 - 0.53) * 0.7087 * 6.00 = *116.30* sq. mm
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **116.30** sq. mm

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 8.00 * 6.00 * 0.7087 = 170.09 sq. mm
$5 * t_i * t_i * f_{r2}$ = 5 * 6.00 * 6.00 * 0.7087 = 127.57 sq. mm
$2 * h * t_i * f_{r2}$ = 2 * 0.00 * 6.00 * 0.7087 = 0.00 sq. mm
= **0.00** sq. mm

A41 = $(leg)^2 * fr2$ = $(6.00)^2 * 0.7087$ = **25.51** sq. mm

A43 = $(leg)^2 * fr2$ = 0 * 0.7087 = **0.00** sq. mm

Area Available (External Pressure) = A1 + A2 + A3 + A41 + A43 = 545.45 sq. mm, which is **smaller** than A (576.71)

Conical Reducer Design Information

Design Pressure:	0.0500	MPa	Design Temperature:	-196	°C
Static Head:	0.0000	MPa	Joint Efficiency:	85	%
Conical Reducer Material:	SA-240 Gr. 304, High		Factor B Chart:	HA-1	
			Material Stress (hot):	138.00	MPa
Corrosion Allowance:	0.00	mm	Material Stress (cold):	138.00	MPa
External Corrosion Allowance:	0.00	mm	Actual Conical Reducer Stress:	5.50	MPa
Small End of Cone Located at:	Top		Inside Ds :	1200.00	mm
Inside Diameter (new) :	1350.00	mm	Cone Height (h) :	162.00	mm
Inside Diameter (corroded) :	1350.00	mm	angle a (•):	24.84	°
Extreme Fiber Elongation:	0.66	%			
Conical Reducer Surface Area:	0.73	sq. m	Specific Gravity:	1.00	
Conical Reducer Estimated Volume:	0.21	cu. m	Weight of Fluid:	207.10	kg
Conical Reducer Weight:	46.26	kg	Total Flooded Conical Reducer Weight:	253.36	kg

Minimum Design Metal Temperature Data

Minimum Design Metal Temperature: -196 °C
Material is exempt from impact testing per UHA-51(d)

External Pressure Data

Design Pressure (Pa):	0.1000	MPa	Design Temperature:	-196	°C
Ext. Minimum t:	2.14	mm	Ext. Nominal t:	8.00	mm
Minimum te:	1.94	mm	Nominal te:	7.26	mm
Minimum Factor A:	0.0007698		Nominal Factor A:	0.0066790	
Minimum Factor B:	53.17	MPa	Nominal Factor B:	91.61	MPa

Design Thickness Calculations

Design Thickness Calculations per Appendix 1-4(e)

$$\mathbf{t} = \frac{PD}{2\cos\bullet\,(SE - 0.6P)} = \frac{0.0500 * 1350.00}{2 * 0.9075 * (138.00 * 0.85 - 0.6 * 0.0500\ )}$$

= Greater of (0.32(Calc.), 1.50(Min. t)) + $0.00_{(corrosion)}$ + $0.00_{(ext.\ corrosion)}$ = minimum of **1.50** mm

Maximum External Pressure Calculation per Paragraph UG-33

$$\mathbf{Pa}\ (\text{using } \textit{nominal}\text{t}) = \frac{4B}{3\bullet\frac{D_l}{t_e}\bullet} = \frac{4 * 91.61}{3\bullet\frac{1367.63}{7.26}\bullet} =$$

= maximum external pressure of **0.6484** MPa

Nominal Conical Reducer Thickness Selected = **8.00** mm

Cone-to-Cylinder Reinforcement
Design Calculations for Small End Juncture
Juncture is not a line of support

Description:	Cone to Cylinder 1	Design Temperature:	-196 °C
Design Pressure:	0.0500 MPa	Static Head:	0.0000 MPa
External Pressure:	0.1000 MPa	Axial Load in Tension (f_2):	0 N/mm

Shell Design Information

Shell 2

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Corrosion Allowance:	0.00 mm
Shell Material:	SA-240 Gr. 304L, High	Shell B Factor Table:	HA-3
		Material Stress (hot) (S_s):	115.00 MPa
Modulus of Elasticity (E_s):	208.7 10^3 MPa	Material Stress (cold):	138.00 MPa
Shell Length (L_S):	738.00 mm	Longitudinal Efficiency (E_1):	85.00 %
Inside Radius:	600.00 mm	Nominal Thickness (t_s):	8.00 mm
Minimum Thickness (t):	0.31 mm	External Minimum Thickness (t):	3.15 mm

Conical Reducer Design Information

Conical Reducer 1

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Corrosion Allowance:	0.00 mm
Cone Material:	SA-240 Gr. 304, High	Cone B Factor Table:	HA-1
		Material Stress (hot) (S_c):	138.00 MPa
Modulus of Elasticity (E_c):	208.7 10^3 MPa	Material Stress (cold):	138.00 MPa
Cone Surface Length (L_c):	178.52 mm		
Cone Small End Diameter:	1200.00 mm	Cone Large End Diameter:	1350.00 mm
Nominal Thickness (t_c):	8.00 mm	Minimum Thickness (t_r):	0.29 mm
External Minimum Thickness (t_r):	2.14 mm	Cone Angle (•):	24.84 °

Internal Pressure per Appendix 1-5

For $\frac{P}{S_s E_1} = \frac{0.0500}{115.00 * 0.85}$ = 0.000512, maximum cone angle (•) = **1.0°**

Actual Cone Angle of 25° > maximum cone angle of 1.0°, reinforcement area requirements must be checked.

$$Q_S = f_2 + \left[\frac{PR_S}{2} \right] = 0.00 + \left[\frac{0.0500 * 600.00}{2} \right]$$ = **15.00** N/mm

$Y = S_s E_s$ = 115.00 * 208.7x10• = **24004** 10^3 MPa²

k = 1, No ring stiffener.

$$A_{rS} = \left[\frac{kQ_S R_S}{S_s E_1} \right] \left[1 - \left[\frac{\ }{\ } \right] \right] \tan(\bullet) = \left[\frac{1.0000 * 15.00 * 600.00}{138.00 * 0.85} \right] \left[1 - \frac{1.0}{24.8} \right] 0.4629$$ = **40.91** sq. mm

$$A_{eS} = \frac{Pi}{4} \sqrt{R_s t_s} \left[(t_s - t) + \left[\frac{t_c - t_r}{\cos \bullet} \right] \right] = \frac{3.14159}{4} \sqrt{600.00 * 8.00} \left[(8.00 - 0.31) + \left[\frac{8.00 - 0.29}{0.9075} \right] \right]$$ = **880.75** sq. mm

$A_{eS} + A_s$ = 880.75 + 0.00 = **880.75** sq. mm

External Pressure Calculations per Appendix 1-8

For $\frac{P}{S_s E_1} = \frac{0.1000}{115.00 * 0.85}$ = 0.00102, maximum cone angle (•) = **0.0°**

Actual Cone Angle of 24.84° > maximum cone angle of 0.0°, reinforcement area requirements must be checked.

$Q_s = f_2 + \frac{PR_s}{2} = 0.0000 + \frac{0.1000 * 608.00}{2}$ = **30.40** N/mm

$A_{rs} = \frac{kQ_s R_s \tan \bullet}{S_s E_1} = \frac{1.0000 * 30.40 * 608.00 * 0.4629}{115.00 * 0.85}$ = **87.53** sq. mm

$A_{es} = 0.55 \sqrt{D_s t_s} \left(t_s - t \right) + \frac{t_c - t_r}{\cos \bullet} = 0.55 \sqrt{1216.00 * 8.00} \left(8.00 - 3.15 \right) + \frac{8.00 - 2.14}{0.9075}$ = **613.39** sq. mm

$A_{es} + A_s = 613.39 + 0.00$ = **613.39** sq. mm

Cone area + shell area >= required area for internal reinforcement
Cone area + shell area >= required area for external reinforcement
JUNCTURE PASSES

Cone-to-Cylinder Reinforcement
Design Calculations for Small End Juncture
Juncture is not a line of support

Description:	Cone to Cylinder 2	Design Temperature:	-196 °C
Design Pressure:	0.0500 MPa	Static Head:	0.0000 MPa
External Pressure:	0.1000 MPa	Axial Load in Compression (f_2):	0 N/mm

Shell Design Information

Shell 2

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Corrosion Allowance:	0.00 mm
Shell Material:	SA-240 Gr. 304L, High	Shell B Factor Table:	HA-3
		Material Stress (hot) (S_s):	115.00 MPa
Modulus of Elasticity (E_s):	208.7 10^3 MPa	Material Stress (cold):	138.00 MPa
Shell Length (L_S):	738.00 mm	Longitudinal Efficiency (E_1):	85.00 %
Inside Radius:	600.00 mm	Nominal Thickness (t_s):	8.00 mm
Minimum Thickness (t):	0.31 mm	External Minimum Thickness (t):	3.15 mm

Conical Reducer Design Information

Conical Reducer 1

Design Pressure:	0.0500 MPa	Design Temperature:	-196 °C
Static Head:	0.0000 MPa	Corrosion Allowance:	0.00 mm
Cone Material:	SA-240 Gr. 304, High	Cone B Factor Table:	HA-1
		Material Stress (hot) (S_c):	138.00 MPa
Modulus of Elasticity (E_c):	208.7 10^3 MPa	Material Stress (cold):	138.00 MPa
Cone Surface Length (L_c):	178.52 mm		
Cone Small End Diameter:	1200.00 mm	Cone Large End Diameter:	1350.00 mm
Nominal Thickness (t_c):	8.00 mm	Minimum Thickness (t_r):	0.29 mm
External Minimum Thickness (t_r):	2.14 mm	Cone Angle (•):	24.84 °

Internal Pressure per Appendix 1-5

For $\frac{P}{S_s E_1} = \frac{0.0500}{115.00 * 0.85}$ = 0.000512, maximum cone angle (•) = **1.0°**

Actual Cone Angle of 25° > maximum cone angle of 1.0°, reinforcement area requirements must be checked.

$$Q_S = f_2 + \left[\frac{PR_S}{2} \right] = 0.0000 + \left[\frac{0.0500 * 600.00}{2} \right]$$ = **15.00** N/mm

$Y = S_s E_s$ = 115.00 * 208.7x10• = **24004** 10^3 MPa²

k = 1, No ring stiffener.

$$A_{rS} = \left[\frac{kQ_S R_S}{S_s E_1} \right] \left[1 - \left[\frac{}{} \right] \right] \tan(\bullet) = \frac{1.0000 * 15.00 * 600.00}{138.00 * 0.85} \left[1 - \frac{1.0}{24.8} \right] 0.4629$$ = **40.91** sq. mm

$$A_{eS} = \frac{Pi}{4} \sqrt{R_s t_s} \left[(t_s - t) + \left[\frac{t_c - t_r}{\cos \bullet} \right] \right] = \frac{3.14159}{4} \sqrt{600.00 * 8.00} \left[(8.00 - 0.31) + \left[\frac{8.00 - 0.29}{0.9075} \right] \right]$$ = **880.75** sq. mm

$A_{eS} + A_s$ = 880.75 + 0.00 = **880.75** sq. mm

External Pressure Calculations per Appendix 1-8

For $\frac{P}{S_s E_1} = \frac{0.1000}{115.00 * 0.85}$ = 0.00102, maximum cone angle (•) = **0.0°**

Actual Cone Angle of 24.84° > maximum cone angle of 0.0°, reinforcement area requirements must be checked.

$Q_s = f_2 + \frac{PR_s}{2} = 0.0000 + \frac{0.1000 * 608.00}{2}$ = **30.40** N/mm

$A_{rs} = \frac{kQ_s R_s \tan \bullet}{S_s E_1} = \frac{1.0000 * 30.40 * 608.00 * 0.4629}{115.00 * 0.85}$ = **87.53** sq. mm

$A_{es} = 0.55 \sqrt{D_s t_s} \left((t_s - t) + \frac{t_c - t_r}{\cos \bullet} \right) = 0.55 \sqrt{1216.00 * 8.00} \left((8.00 - 3.15) + \frac{8.00 - 2.14}{0.9075} \right)$ = **613.39** sq. mm

$A_{es} + A_s = 613.39 + 0.00$ = **613.39** sq. mm

Cone area + shell area >= required area for internal reinforcement
Cone area + shell area >= required area for external reinforcement
JUNCTURE PASSES

Cylindrical Shell Design Information

Design Pressure:	0.0500	MPa	Design Temperature:	-196	°C
Static Head:	0.0000	MPa	Long. Joint Efficiency:	85	%
Shell Material:	SA-240 Gr. 304, High		Factor B Chart:	HA-1	
			Material Stress (hot):	138.00	MPa
Shell Length:	738.00	mm	Material Stress (cold):	138.00	MPa
			Compressive Stress:	74.89	MPa
Corrosion Allowance:	0.00	mm	Actual Circumferential Stress:	4.45	MPa
External Corrosion Allowance:	0.00	mm	Actual Longitudinal Stress:	2.19	MPa
Inside Diameter (new):	1200.00	mm	Extreme Fiber Elongation:	0.66	%
Inside Diameter (corroded):	1200.00	mm	Specific Gravity:	1.00	
Shell Surface Area:	2.82	sq. m	Weight of Fluid:	834.66	kg
Shell Estimated Volume:	0.83	cu. m	Total Flooded Shell Weight:	1014.58	kg
Circ. Joint Efficiency:	85	%	Shell Weight:	179.92	kg

Minimum Design Metal Temperature Data

Minimum Design Metal Temperature: -196 °C
Material is exempt from impact testing per UHA-51(d)

External Pressure Data

Design Pressure (Pa):	0.1000	MPa	Design Temperature:	-196	°C
Dimension L:	738.00	mm			
Ext. Minimum t:	3.16	mm	Ext. Nominal t:	8.00	mm
Minimum L/Do:	0.6069		Nominal L/Do:	0.6069	
Minimum Do/t:	384.8100		Nominal Do/t:	152.0000	
Minimum Factor A:	0.0003005		Nominal Factor A:	0.0012249	
Minimum Factor B:	29.08	MPa	Nominal Factor B:	65.59	MPa

Design Thickness Calculations

Longitudinal Stress Calculations per Paragraph UG-27(c)(2)

$$\mathbf{t} = \frac{PR}{2SE + 0.4P} = \frac{0.0500 * 600.00}{2 * 138.00 * 0.85 + 0.4 * 0.0500}$$

= Greater Of $(0.13_{(Calculated)}, 1.50_{(Minimum\ Allowed)}) + 0.00_{(corrosion)} + 0.00_{(ext.\ corrosion)}$ = minimum of **1.50** mm

Circumferential Stress Calculations per UG-27(c)(1)

$$\mathbf{t} = \frac{PR}{SE - 0.6P} = \frac{0.0500 * 600.00}{138.00 * 0.85 - 0.6 * 0.0500}$$

= Greater of $(0.26_{(Calculated)}, 1.50_{(Minimum\ Allowed)}) + 0.00_{(corrosion)} + 0.00_{(ext.\ corrosion)}$ = minimum of **1.50** mm

Maximum External Pressure Calculation per Paragraph UG-28

$$\mathbf{Pa}\ (\text{using } \textit{nominal}\ t) = \frac{4B}{3(D_o / t)} = \frac{4 * 65.59}{3 * (1216.00 / 8.00)}$$

= maximum external pressure of **0.5754** MPa

External loads do not control design.

Nominal Shell Thickness Selected = **8.00** mm

Optional Integral Flange Design Information

Design Pressure:	0.0500	MPa	Design Temperature:	-196	°C
Static Head:	0.0000	MPa	Corrosion Allowance:	0.00	mm
Material:	SA-240 Gr. 304, High		Factor B Chart:	HA-1	
			Material Stress Hot(S_{fo}):	138.00	MPa
Outside Diameter (A):	1490.00	mm	Material Stress Cold(S_{fa}):	138.00	MPa
Bolt Circle (C):	1433.00	mm	Inside Diameter (B):	1350.00	mm
Flange Weight:	69.46	kg	Flange MAWP (at design):	0.3299	MPa
Corroded Inside Diameter:	1350.00	mm			
Basic Weld Dimension (c):	8.00	mm	Neck Weld Size:	12.00	mm
Hub Length (h):	12.00	mm	Hub Thickness at Large End(g_1):	20.00	mm
Hub Thickness at Small End(g_0):	8.00	mm			

External Pressure Information

External Design Pressure:	0.1000	MPa	External Design Temperature:	-196	°C
External Static Head:	0.0000	MPa	Material Stress Hot($S_{fo,ext}$):	138.00	MPa
			Material Stress Cold($S_{fa,ext}$):	138.00	MPa

Minimum Design Metal Temperature

Material is exempt from impact testing per UHA-51(d)

Bolting Information

Material:	SA-193 Gr. B8, High		Material Stress Hot (S_b):	130.00	MPa
Material Condition:	1		Material Stress Cold (S_a):	130.00	MPa
Bolt Size:	16 mm		Threads Per Inch:	13	
Nominal Bolt Diameter (a):	16.00	mm	Number of Bolts:	64	
Bolt Hole Diameter:	18.00	mm	Bolt Root Area:	138.32	sq. mm

Gasket & Facing Information

Material:	Self energizing		Configuration:	Ring	
Type:	HNV 200 (Delta)		Seating Stress (y):	150.00	MPa
O.D. Contact Face:	1394.00	mm	Gasket Width (N):	1.00	mm
Factor m:	0.00				

Host Component: Shell 1 - Shell 1

Material:	SA-240 Gr. 304, High		Material Stress Hot (S_{no}):	138.00	MPa
			Material Stress Cold (S_{na}):	138.00	MPa
Inside Diameter:	1350.00	mm	Wall Thickness (t_n):	8.00	mm

ASME Flange Calculations per Appendix 2

Gasket Seating Calculations(Table 2-5.2)

$\mathbf{b_0} = \frac{N}{2} = \frac{1.00}{2}$ = **0.50** mm

Since b_0 <= 6 mm, **b** = b_0 = **0.50** mm

G = O.D. contact face - N = 1394.00 - 1.00 = **1393.00** mm

Bolt Spacing is Adequate for Flange Design

Bolting is Adequate for Flange Design

Nominal Thickness is Adequate for Seating Conditions

Nominal Thickness is Adequate for Operating Conditions

Flange Thickness is Adequate for Flange Design

Nominal Thickness Selected = **30.00** mm

Load and Bolting Calculations - Internal Pressure

The absolute value of effective pressure "P" is used for calculations.

$$\mathbf{P} = \frac{16\,M}{\bullet\ G^3} + \frac{4\,F_A}{\bullet\ G^2} + P_{int} + \text{Static Head} = \frac{16 * 0}{3.14159 * 1393.00^3} + \frac{4 * 0}{3.14159 * 1393.00^2} + 0.0500 + 0.0000 = \mathbf{0.0500}\ \text{MPa}$$

Minimum $\mathbf{W}_{m2}$ = • bGy = 3.14159 * 0.50 * 1393.00 * 150.00 = **328218** N

$$\mathbf{H} = \frac{\bullet}{4} G^2P = \frac{3.14159}{4} * 1393.00^2 * 0.0500 = \mathbf{76201}\ \text{N}$$

$\mathbf{H}_p$ = 2b• GmP = 2 * 0.50 * 3.14159 * 1393.00 * 0.00 * 0.0500 = **0** N

Minimum $\mathbf{W}_{m1}$ = H + H_p = 76201 + 0 = **76201** N

$$\mathbf{A}_{m1} = \frac{W_{m1}}{S_b} = \frac{76201}{130.00} = \mathbf{586.16}\ \text{sq. mm}$$

$$\mathbf{A}_{m2} = \frac{W_{m2}}{S_a} = \frac{328218}{130.00} = \mathbf{2524.75}\ \text{sq. mm}$$

$\mathbf{A}_m$ = Greater of A_{m1} or A_{m2} = greater of 586.16 or 2524.75 = **2524.75** sq. mm

$\mathbf{A}_b$ = Number of Bolts * Bolt Root Area = 64 * 138.32 = **8852.74** sq. mm

$$\mathbf{W} = \frac{(A_m + A_b)S_a}{2} = \frac{(2524.75 + 8852.74) * 130.00}{2} = \mathbf{739537}\ \text{N}$$

Ab >= Am, Bolting is Adequate for Flange Design

Internal Pressure Moment Calculations - Operating Conditions

$\mathbf{H_D} = \frac{\pi}{4} B^2P = \frac{3.1416}{4} * 1350.00^2 * 0.0500$ = **71569** N

$\mathbf{H_G} = W_{m1} - H = 76201 - 76201$ = **0** N

$\mathbf{H_T} = H - H_D = 76201 - 71569$ = **4632** N

$\mathbf{R} = \frac{C - B}{2} - g_1 = \frac{1433.00 - 1350.00}{2} - 20.00$ = **21.50** mm

$\mathbf{h_D} = R + \frac{g_1}{2} = 21.50 + \frac{20.00}{2}$ = **31.50** mm

$\mathbf{h_G} = \frac{C - G}{2} = \frac{1433.00 - 1393.00}{2}$ = **20.00** mm

$\mathbf{h_T} = \frac{R + g_1 + h_G}{2} = \frac{21.50 + 20.00 + 20.00}{2}$ = **30.75** mm

$\mathbf{M_D} = H_D h_D = 71569 * 31.50$ = **2254424** N-mm

$\mathbf{M_G} = H_G h_G = 0 * 20.00$ = **0** N-mm

$\mathbf{M_T} = H_T h_T = 4632 * 30.75$ = **142434** N-mm

$\mathbf{M_o} = M_D + M_G + M_T = 2254424 + 0 + 142434$ = **2396858** N-mm

Internal Pressure Moment Calculations - Gasket Seating

$\mathbf{M_s} = W h_G = 739537 * 20.00$ = **14790740** N-mm

Shape Constants
Calculated from Figure 2-7.1

$\mathbf{K} = \frac{A}{B} = \frac{1490.00}{1350.00}$ = **1.1037**

$\mathbf{Y} = \frac{1}{K - 1}\left\{0.66845 + 5.71690\frac{K^2 \log_{10} K}{K^2 - 1}\right\} = \frac{1}{1.1037 - 1}\left\{0.66845 + 5.7169 * \frac{1.1037^2 * \log_{10} 1.1037}{1.1037^2 - 1}\right\}$ = **19.6372**

$\mathbf{T} = \frac{K^2(1 + 8.55246 \log_{10} K) - 1}{(1.04720 + 1.9448K^2)(K - 1)} = \frac{1.1037^2(1 + 8.55246 \log_{10} 1.1037) - 1}{[1.04720 + (1.9448 * 1.1037^2)](1.1037 - 1)}$ = **1.8759**

$\mathbf{U} = \frac{K^2(1 + 8.55246 \log_{10} K) - 1}{1.36136(K^2 - 1)(K - 1)} = \frac{1.1037^2[1 + (8.55246 * \log_{10} 1.1037)] - 1}{1.36136(1.1037^2 - 1)(1.1037 - 1)}$ = **21.5792**

$\mathbf{Z} = \frac{K^2 + 1}{K^2 - 1} = \frac{1.1037^2 + 1}{1.1037^2 - 1}$ = **10.1678**

$\mathbf{h_0} = \sqrt{Bg_0} = \sqrt{1350.00 * 8.00}$ = **103.92** mm

$\frac{\mathbf{h}}{\mathbf{h_0}} = \frac{12.00}{103.92}$ = **0.1155**

$\frac{\mathbf{g_1}}{\mathbf{g_0}} = \frac{20.00}{8.00}$ = **2.5000**

Calculated from equations from TABLE 2-7.1

F = 0.9030 **V** = 0.4089 **f** = 4.9714

$\mathbf{d} = \left\{\frac{U}{V}\right\} h_0 g_0^2 = \frac{21.5792}{0.4089} * 103.92 * 8.00^2$ = **350992.10** mm³

$\mathbf{e} = \frac{F}{h_0} = \frac{0.9030}{103.92}$ = **0.008689** mm^{-1}

$\mathbf{L} = \frac{te + 1}{T} + \frac{t^3}{d} = \frac{(30.00 * 0.008689) + 1}{1.8759} + \frac{30.00^3}{350992.10}$ = **0.7490**

Bolt Spacing Calculations

$\mathbf{B_s}$ = Bolt Spacing = **70.31** mm

$\mathbf{B_{smax}} = 2a + \frac{6t}{m + 0.5} = (2 * 16.00) + \left\{\frac{6 * 30.00}{0.00 + 0.5}\right\}$ = **392.00** mm

$\mathbf{B_{spenalty}} = 2a + t = (2 * 16.00) + 30.00$ = **62.00** mm

$\mathbf{B_s} <= \mathbf{B_{smax}}$ **: Acceptable per App. 2-5(d)**

$\mathbf{B_s} > \mathbf{B_{penalty}}$: $B_{sc} = \sqrt{\frac{B_s}{2a + t}}$ = **1.0649**

Internal Pressure Stress Calculations - Operating Conditions

$$S_H = \frac{fB_{sc}M_o}{Lg_1^2B} = \frac{4.9714 * 1.0649 * 2396858}{0.7490 * 20.00^2 * 1350.00} = \mathbf{31.37}\ \text{MPa}$$

$$S_R = \frac{\left(\frac{4}{3}\right) te + 1\right) B_{sc}M_o}{Lt^2B} = \frac{\left(\frac{4}{3}\right) * 30.00 * 0.008689 + 1\right) * 1.0649 * 2396858}{0.7490 * 30.00^2 * 1350.00} = \mathbf{3.78}\ \text{MPa}$$

$$S_T = \frac{Y B_{sc} M_o}{t^2B} - (Z S_R) = \frac{19.6372 * 1.0649 * 2396858}{30.00^2 * 1350.00} - (10.1678 * 3.78) = \mathbf{2.82}\ \text{MPa}$$

$$\frac{S_H + S_R}{2} = \frac{(31.37 + 3.78)}{2} = \mathbf{17.58}\ \text{MPa} \qquad \frac{S_H + S_T}{2} = \frac{(31.37 + 2.82)}{2} = \mathbf{17.10}\ \text{MPa}$$

$$S_c = \text{Max}\left(\frac{S_H + S_R}{2}, \frac{S_H + S_T}{2}\right) = \mathbf{17.58}\ \text{MPa} \qquad S_{Hmax} = \text{smaller of } 1.5\ S_{fo} \text{ or } 1.5\ S_{no} = \mathbf{207.00}\ \text{MPa}$$

Since (S_H <= S_{Hmax}), (S_T <= S_{fo}), (S_R <= S_{fo}), (S_c <= S_{fo}), nominal thickness is **ADEQUATE** for operating conditions

Internal Pressure Stress Calculations - Gasket Seating

$$S_H = \frac{fB_{sc}M_s}{Lg_1^2B} = \frac{4.9714 * 1.0649 * 14790740}{0.7490 * 20.00^2 * 1350.00} = \mathbf{193.60}\ \text{MPa}$$

$$S_R = \frac{\left(\frac{4}{3}\right) te + 1\right) B_{sc}M_s}{L\,t^2\,B} = \frac{\left(\frac{4}{3}\right) * 30.00 * 0.008689\right) + 1 * 1.0649 * 14790740}{0.7490 * 30.00^2 * 1350.00} = \mathbf{23.32}\ \text{MPa}$$

$$S_T = \frac{Y B_{sc} M_s}{t^2\,B} - (Z S_R) = \frac{19.6372 * 1.0649 * 14790740}{30.00^2 * 1350.00} - (10.1678 * 23.32) = \mathbf{17.45}\ \text{MPa}$$

$$\frac{S_H + S_R}{2} = \frac{193.60 + 23.32}{2} = \mathbf{108.46}\ \text{MPa} \qquad \frac{S_H + S_T}{2} = \frac{193.60 + 17.45}{2} = \mathbf{105.52}\ \text{MPa}$$

$$S_c = \text{Max}\left(\frac{S_H + S_R}{2}, \frac{S_H + S_T}{2}\right) = \mathbf{108.46}\ \text{MPa} \qquad S_{Hmax} = \text{smaller of } 1.5\ S_{fa} \text{ or } 1.5\ S_{na} = \mathbf{207.00}\ \text{MPa}$$

Since (S_H <= S_{Hmax}), (S_R <= S_{fa}), (S_T <= S_{fa}), (S_c <= S_{fa}), nominal thickness is **ADEQUATE** for seating conditions

Internal Pressure Minimum Thickness = **27.24** mm

ASME Flange Calculations per Appendix 2

Gasket Seating Calculations(Table 2-5.2)

$\mathbf{b_0} = \frac{N}{2} = \frac{1.00}{2}$ = **0.50** mm

Since b_0 <= 6 mm, **b** = b_0 = **0.50** mm

G = O.D. contact face - N = 1394.00 - 1.00 = **1393.00** mm

External Pressure Summary

Bolt Spacing is Adequate for Flange Design

Bolting is Adequate for Flange Design

Nominal Thickness is Adequate for Seating Conditions

Nominal Thickness is Adequate for Operating Conditions

Flange Thickness is Adequate for Flange Design

Nominal Thickness Selected = **30.00** mm

External Pressure Load and Bolting Calculations

The absolute value of effective pressure “P” is used for calculations.

$\mathbf{P} = \frac{16\,M}{\bullet\, G^3} - \frac{4\,F_A}{\bullet\, G^2} + P - \text{Static Head} = \frac{16 * 0}{3.14159 * 1393.00^3} - \frac{4 * 0}{3.14159 * 1393.00^2} + 0.1000 - 0.0000$ = **0.1000** MPa

Minimum $\mathbf{W_{m2}} = \bullet\, bGy = 3.14159 * 0.50 * 1393.00 * 150.00$ = **328218** N

$\mathbf{H} = \frac{\bullet}{4} G^2P = \frac{3.14159}{4} * 1393.00^2 * 0.1000$ = **152403** N

$\mathbf{H_p}$ = = **0** N

Minimum $\mathbf{W_{m1}}$ = = **0** N

$\mathbf{A_{m1}} = \frac{W_{m1}}{S_b} = \frac{0}{130.00}$ = **0.00** sq. mm

$\mathbf{A_{m2}} = \frac{W_{m2}}{S_a} = \frac{328218}{130.00}$ = **2524.75** sq. mm

$\mathbf{A_m}$ = Greater of A_{m1} or A_{m2} = greater of 0.00 or 2524.75 = **2524.75** sq. mm

$\mathbf{A_b}$ = Number of Bolts * Bolt Root Area = 64 * 138.32 = **8852.74** sq. mm

$\mathbf{W} = \frac{(A_m + A_b)S_a}{2} = \frac{(2524.75 + 8852.74) * 130.00}{2}$ = **739537** N

Ab >= Am, Bolting is Adequate for Flange Design

External Pressure Moment Calculations - Operating Conditions

$\mathbf{H_D} = \frac{\pi}{4} B^2 P = \frac{3.1416}{4} * 1350.00^2 * 0.1000$ = **143139** N

$\mathbf{H_G} = W_{m1} - H = 0 - 152403$ = **-152403** N

$\mathbf{H_T} = H - H_D = 152403 - 143139$ = **9264** N

$\mathbf{R} = \frac{C - B}{2} - g_1 = \frac{1433.00 - 1350.00}{2} - 20.00$ = **21.50** mm

$\mathbf{h_D} = R + \frac{g_1}{2} = 21.50 + \frac{20.00}{2}$ = **31.50** mm

$\mathbf{h_G} = \frac{C - G}{2} = \frac{1433.00 - 1393.00}{2}$ = **20.00** mm

$\mathbf{h_T} = \frac{R + g_1 + h_G}{2} = \frac{21.50 + 20.00 + 20.00}{2}$ = **30.75** mm

$\mathbf{M_D} = H_D h_D = 143139 * 31.50$ = **4508879** N-mm

$\mathbf{M_G} = H_G h_G = -152403 * 20.00$ = **-3048060** N-mm

$\mathbf{M_T} = H_T h_T = 9264 * 30.75$ = **284868** N-mm

$\mathbf{M_o} = M_D + M_G + M_T = 4508879 + -3048060 + 284868$ = **1745687** N-mm

External Pressure Moment Calculations - Gasket Seating

$\mathbf{M_s} = W h_G = 739537 * 20.00$ = **14790740** N-mm

Shape Constants
Calculated from Figure 2-7.1

$\mathbf{K} = \frac{A}{B} = \frac{1490.00}{1350.00}$ = **1.1037**

$\mathbf{Y} = \frac{1}{K - 1}\left\{0.66845 + 5.71690\frac{K^2 \log_{10} K}{K^2 - 1}\right\} = \frac{1}{1.1037 - 1}\left\{0.66845 + 5.7169 * \frac{1.1037^2 * \log_{10} 1.1037}{1.1037^2 - 1}\right\}$ = **19.6372**

$\mathbf{T} = \frac{K^2(1 + 8.55246 \log_{10} K) - 1}{(1.04720 + 1.9448K^2)(K - 1)} = \frac{1.1037^2(1 + 8.55246 \log_{10} 1.1037) - 1}{[1.04720 + (1.9448 * 1.1037^2)](1.1037 - 1)}$ = **1.8759**

$\mathbf{U} = \frac{K^2(1 + 8.55246 \log_{10} K) - 1}{1.36136(K^2 - 1)(K - 1)} = \frac{1.1037^2[1 + (8.55246 * \log_{10} 1.1037)] - 1}{1.36136(1.1037^2 - 1)(1.1037 - 1)}$ = **21.5792**

$\mathbf{Z} = \frac{K^2 + 1}{K^2 - 1} = \frac{1.1037^2 + 1}{1.1037^2 - 1}$ = **10.1678**

$\mathbf{h_0} = \sqrt{Bg_0} = \sqrt{1350.00 * 8.00}$ = **103.92** mm

$\frac{\mathbf{h}}{\mathbf{h_0}} = \frac{12.00}{103.92}$ = **0.1155**

$\frac{\mathbf{g_1}}{\mathbf{g_0}} = \frac{20.00}{8.00}$ = **2.5000**

Calculated from equations from TABLE 2-7.1

F = 0.9030 **V** = 0.4089 **f** = 4.9714

$\mathbf{d} = \left\{\frac{U}{V}\right\} h_0 g_0^2 = \frac{21.5792}{0.4089} * 103.92 * 8.00^2$ = **350992.10** mm³

$\mathbf{e} = \frac{F}{h_0} = \frac{0.9030}{103.92}$ = **0.008689** mm^{-1}

$\mathbf{L} = \frac{te + 1}{T} + \frac{t^3}{d} = \frac{(30.00 * 0.008689) + 1}{1.8759} + \frac{30.00^3}{350992.10}$ = **0.7490**

Bolt Spacing Calculations

$\mathbf{B_s}$ = Bolt Spacing = **70.31** mm

$\mathbf{B_{smax}} = 2a + \frac{6t}{m + 0.5} = (2 * 16.00) + \left\{\frac{6 * 30.00}{0.00 + 0.5}\right\}$ = **392.00** mm

$\mathbf{B_{spenalty}} = 2a + t = (2 * 16.00) + 30.00$ = **62.00** mm

$\mathbf{B_s} <= \mathbf{B_{smax}}$ **: Acceptable per App. 2-5(d)**

$\mathbf{B_s} > \mathbf{B_{penalty}}$: $B_{sc} = \sqrt{\frac{B_s}{2a + t}}$ = **1.0649**

External Pressure Stress Calculations - Operating Conditions

$$S_H = \frac{fB_{sc}M_o}{Lg_1^2B} = \frac{4.9714 * 1.0649 * 1745687}{0.7490 * 20.00^2 * 1350.00} = \mathbf{22.85}\ \text{MPa}$$

$$S_R = \frac{\left[\frac{4}{3}\ te + 1\right] B_{sc}M_o}{Lt^2B} = \frac{\left[\frac{4}{3} * 30.00 * 0.008689 + 1\right] * 1.0649 * 1745687}{0.7490 * 30.00^2 * 1350.00} = \mathbf{2.75}\ \text{MPa}$$

$$S_T = \frac{Y B_{sc} M_o}{t^2B} - (Z S_R) = \frac{19.6372 * 1.0649 * 1745687}{30.00^2 * 1350.00} - (10.1678 * 2.75) = \mathbf{2.08}\ \text{MPa}$$

$$\frac{S_H + S_R}{2} = \frac{(22.85 + 2.75)}{2} = \mathbf{12.80}\ \text{MPa} \qquad \frac{S_H + S_T}{2} = \frac{(22.85 + 2.08)}{2} = \mathbf{12.47}\ \text{MPa}$$

$$S_c = \text{Max}\left[\frac{S_H + S_R}{2}, \frac{S_H + S_T}{2}\right] = \mathbf{12.80}\ \text{MPa} \qquad S_{Hmax} = \text{smaller of } 1.5\ S_{fo} \text{ or } 1.5\ S_{no} = \mathbf{207.00}\ \text{MPa}$$

Since (S_H <= S_{Hmax}), (S_T <= S_{fo}), (S_R <= S_{fo}), (S_c <= S_{fo}), nominal thickness is **ADEQUATE** for operating conditions

External Pressure Stress Calculations - Gasket Seating

$$S_H = \frac{fB_{sc}M_s}{Lg_1^2B} = \frac{4.9714 * 1.0649 * 14790740}{0.7490 * 20.00^2 * 1350.00} = \mathbf{193.60}\ \text{MPa}$$

$$S_R = \frac{\left[\frac{4}{3}\ te + 1\right] B_{sc}M_s}{L\ t^2\ B} = \frac{\left[\frac{4}{3} * 30.00 * 0.008689\right] + 1 * 1.0649 * 14790740}{0.7490 * 30.00^2 * 1350.00} = \mathbf{23.32}\ \text{MPa}$$

$$S_T = \frac{Y B_{sc} M_s}{t^2\ B} - (Z S_R) = \frac{19.6372 * 1.0649 * 14790740}{30.00^2 * 1350.00} - (10.1678 * 23.32) = \mathbf{17.45}\ \text{MPa}$$

$$\frac{S_H + S_R}{2} = \frac{193.60 + 23.32}{2} = \mathbf{108.46}\ \text{MPa} \qquad \frac{S_H + S_T}{2} = \frac{193.60 + 17.45}{2} = \mathbf{105.52}\ \text{MPa}$$

$$S_c = \text{Max}\left[\frac{S_H + S_R}{2}, \frac{S_H + S_T}{2}\right] = \mathbf{108.46}\ \text{MPa} \qquad S_{Hmax} = \text{smaller of } 1.5\ S_{fa} \text{ or } 1.5\ S_{na} = \mathbf{207.00}\ \text{MPa}$$

Since (S_H <= S_{Hmax}), (S_R <= S_{fa}), (S_T <= S_{fa}), (S_c <= S_{fa}), nominal thickness is **ADEQUATE** for seating conditions

External Pressure Minimum Thickness = **27.24** mm

Optional Integral Flange Design Information

Design Pressure:	0.0500	MPa	Design Temperature:	-196	°C
Static Head:	0.0000	MPa	Corrosion Allowance:	0.00	mm
Material:	SA-240 Gr. 304, High		Factor B Chart:	HA-1	
			Material Stress Hot(S_{fo}):	138.00	MPa
Outside Diameter (A):	1320.00	mm	Material Stress Cold(S_{fa}):	138.00	MPa
Bolt Circle (C):	1283.00	mm	Inside Diameter (B):	1200.00	mm
Flange Weight:	68.71	kg	Flange MAWP (at design):	0.4811	MPa
Corroded Inside Diameter:	1200.00	mm			
Basic Weld Dimension (c):	8.00	mm	Neck Weld Size:	12.00	mm
Hub Length (h):	12.00	mm	Hub Thickness at Large End(g_1):	20.00	mm
Hub Thickness at Small End(g_0):	8.00	mm			

External Pressure Information

External Design Pressure:	0.1000	MPa	External Design Temperature:	-196	°C
External Static Head:	0.0000	MPa	Material Stress Hot($S_{fo,ext}$):	138.00	MPa
			Material Stress Cold($S_{fa,ext}$):	138.00	MPa

Minimum Design Metal Temperature

Material is exempt from impact testing per UHA-51(d)

Bolting Information

Material:	SA-193 Gr. B8, High		Material Stress Hot (S_b):	130.00	MPa
Material Condition:	1		Material Stress Cold (S_a):	130.00	MPa
Bolt Size:	16 mm		Threads Per Inch:	13	
Nominal Bolt Diameter (a):	16.00	mm	Number of Bolts:	64	
Bolt Hole Diameter:	18.00	mm	Bolt Root Area:	138.32	sq. mm

Gasket & Facing Information

Material:	Self energizing		Configuration:	Ring	
Type:	HNV 200		Seating Stress (y):	150.00	MPa
O.D. Contact Face:	1253.00	mm	Gasket Width (N):	1.00	mm
Factor m:	0.00				

Host Component: Shell 2 - Shell 2

Material:	SA-240 Gr. 304, High		Material Stress Hot (S_{no}):	138.00	MPa
			Material Stress Cold (S_{na}):	138.00	MPa
Inside Diameter:	1200.00	mm	Wall Thickness (t_n):	8.00	mm

ASME Flange Calculations per Appendix 2

Gasket Seating Calculations(Table 2-5.2)

$\mathbf{b_0} = \frac{N}{2} = \frac{1.00}{2}$ = **0.50** mm

Since b_0 <= 6 mm, **b** = b_0 = **0.50** mm

G = O.D. contact face - N = 1253.00 - 1.00 = **1252.00** mm

Bolt Spacing is Adequate for Flange Design

Bolting is Adequate for Flange Design

Nominal Thickness is Adequate for Seating Conditions

Nominal Thickness is Adequate for Operating Conditions

Flange Thickness is Adequate for Flange Design

Flange Rigidity is Adequate.

Nominal Thickness Selected = **40.00** mm

Load and Bolting Calculations - Internal Pressure

The absolute value of effective pressure "P" is used for calculations.

$$\mathbf{P} = \frac{16\,M}{\pi\,G^3} + \frac{4\,F_A}{\pi\,G^2} + P_{int} + \text{Static Head} = \frac{16 * 0}{3.14159 * 1252.00^3} + \frac{4 * 0}{3.14159 * 1252.00^2} + 0.0500 + 0.0000 = \mathbf{0.0500}\ \text{MPa}$$

Minimum W $_{m2} = \pi\, bGy = 3.14159 * 0.50 * 1252.00 * 150.00$ = **294996** N

$$\mathbf{H} = \frac{\pi}{4} G^2 P = \frac{3.14159}{4} * 1252.00^2 * 0.0500 = \mathbf{61556}\ \text{N}$$

$\mathbf{H_p} = 2b\pi GmP = 2 * 0.50 * 3.14159 * 1252.00 * 0.00 * 0.0500$ = **0** N

Minimum W $_{m1} = H + H_p = 61556 + 0$ = **61556** N

$$\mathbf{A}_{m1} = \frac{W_{m1}}{S_b} = \frac{61556}{130.00} = \mathbf{473.51}\ \text{sq. mm}$$

$$\mathbf{A}_{m2} = \frac{W_{m2}}{S_a} = \frac{294996}{130.00} = \mathbf{2269.20}\ \text{sq. mm}$$

$\mathbf{A_m}$ = Greater of A_{m1} or A_{m2} = greater of 473.51 or 2269.20 = **2269.20** sq. mm

$\mathbf{A_b}$ = Number of Bolts * Bolt Root Area = 64 * 138.32 = **8852.74** sq. mm

$$\mathbf{W} = \frac{(A_m + A_b)S_a}{2} = \frac{(2269.20 + 8852.74) * 130.00}{2} = \mathbf{722926}\ \text{N}$$

Ab >= Am, Bolting is Adequate for Flange Design

Internal Pressure Moment Calculations - Operating Conditions

$\mathbf{H_D} = \frac{\pi}{4} B^2P = \frac{3.1416}{4} * 1200.00^2 * 0.0500$ = **56549** N

$\mathbf{H_G} = W_{m1} - H = 61556 - 61556$ = **0** N

$\mathbf{H_T} = H - H_D = 61556 - 56549$ = **5007** N

$\mathbf{R} = \frac{C - B}{2} - g_1 = \frac{1283.00 - 1200.00}{2} - 20.00$ = **21.50** mm

$\mathbf{h_D} = R + \frac{g_1}{2} = 21.50 + \frac{20.00}{2}$ = **31.50** mm

$\mathbf{h_G} = \frac{C - G}{2} = \frac{1283.00 - 1252.00}{2}$ = **15.50** mm

$\mathbf{h_T} = \frac{R + g_1 + h_G}{2} = \frac{21.50 + 20.00 + 15.50}{2}$ = **28.50** mm

$\mathbf{M_D} = H_D h_D = 56549 * 31.50$ = **1781294** N-mm

$\mathbf{M_G} = H_G h_G = 0 * 15.50$ = **0** N-mm

$\mathbf{M_T} = H_T h_T = 5007 * 28.50$ = **142700** N-mm

$\mathbf{M_o} = M_D + M_G + M_T = 1781294 + 0 + 142700$ = **1923993** N-mm

Internal Pressure Moment Calculations - Gasket Seating

$\mathbf{M_s} = W h_G = 722926 * 15.50$ = **11205353** N-mm

Shape Constants
Calculated from Figure 2-7.1

$$\mathbf{K} = \frac{A}{B} = \frac{1320.00}{1200.00} = \mathbf{1.1000}$$

$$\mathbf{Y} = \frac{1}{K - 1}\left\{0.66845 + 5.71690\frac{K^2 \log_{10} K}{K^2 - 1}\right\} = \frac{1}{1.1000 - 1}\left\{0.66845 + 5.7169 * \frac{1.1000^2 * \log_{10} 1.1000}{1.1000^2 - 1}\right\} = \mathbf{20.3193}$$

$$\mathbf{T} = \frac{K^2(1 + 8.55246 \log_{10} K) - 1}{(1.04720 + 1.9448K^2)(K - 1)} = \frac{1.1000^2(1 + 8.55246 \log_{10} 1.1000) - 1}{[1.04720 + (1.9448 * 1.1000^2)](1.1000 - 1)} = \mathbf{1.8773}$$

$$\mathbf{U} = \frac{K^2(1 + 8.55246 \log_{10} K) - 1}{1.36136(K^2 - 1)(K - 1)} = \frac{1.1000^2[1 + (8.55246 * \log_{10} 1.1000)] - 1}{1.36136(1.1000^2 - 1)(1.1000 - 1)} = \mathbf{22.3289}$$

$$\mathbf{Z} = \frac{K^2 + 1}{K^2 - 1} = \frac{1.1000^2 + 1}{1.1000^2 - 1} = \mathbf{10.5238}$$

$$\mathbf{h_0} = \sqrt{Bg_0} = \sqrt{1200.00 * 8.00} = \mathbf{97.98}\ \text{mm}$$

$$\frac{\mathbf{h}}{\mathbf{h_0}} = \frac{12.00}{97.98} = \mathbf{0.1225}$$

$$\frac{\mathbf{g_1}}{\mathbf{g_0}} = \frac{20.00}{8.00} = \mathbf{2.5000}$$

Calculated from equations from TABLE 2-7.1

F = 0.9022 **V** = 0.4019 **f** = 4.8978

$$\mathbf{d} = \left\{\frac{U}{V}\right\} h_0 g_0^2 = \frac{22.3289}{0.4019} * 97.98 * 8.00^2 = \mathbf{348390.84}\ \text{mm}^3$$

$$\mathbf{e} = \frac{F}{h_0} = \frac{0.9022}{97.98} = \mathbf{0.009208}\ \text{mm}^{-1}$$

$$\mathbf{L} = \frac{te + 1}{T} + \frac{t^3}{d} = \frac{(40.00 * 0.009208) + 1}{1.8773} + \frac{40.00^3}{348390.84} = \mathbf{0.9126}$$

Bolt Spacing Calculations

$\mathbf{B_s}$ = Bolt Spacing = **62.95** mm

$$\mathbf{B_{smax}} = 2a + \frac{6t}{m + 0.5} = (2 * 16.00) + \left\{\frac{6 * 40.00}{0.00 + 0.5}\right\} = \mathbf{512.00}\ \text{mm}$$

$$\mathbf{B_{spenalty}} = 2a + t = (2 * 16.00) + 40.00 = \mathbf{72.00}\ \text{mm}$$

B_s <= B_{smax} : Acceptable per App. 2-5(d)
B_s < $B_{penalty}$: B_{sc} = 1.0

Internal Pressure Stress Calculations - Operating Conditions

$$S_H = \frac{fB_{sc}M_o}{Lg_1^2B} = \frac{4.8978 * 1.0000 * 1923993}{0.9126 * 20.00^2 * 1200.00} = \mathbf{21.51}\ \text{MPa}$$

$$S_R = \frac{\left(\frac{4}{3}\right) te + 1\ B_{sc}M_o}{Lt^2B} = \frac{\left(\frac{4}{3}\right) * 40.00 * 0.009208 + 1 * 1.0000 * 1923993}{0.9126 * 40.00^2 * 1200.00} = \mathbf{1.64}\ \text{MPa}$$

$$S_T = \frac{Y B_{sc} M_o}{t^2B} - (Z S_R) = \frac{20.3193 * 1.0000 * 1923993}{40.00^2 * 1200.00} - (10.5238 * 1.64) = \mathbf{3.10}\ \text{MPa}$$

$$\frac{S_H + S_R}{2} = \frac{(21.51 + 1.64)}{2} = \mathbf{11.58}\ \text{MPa} \qquad \frac{S_H + S_T}{2} = \frac{(21.51 + 3.10)}{2} = \mathbf{12.31}\ \text{MPa}$$

$S_c = \text{Max}\left(\frac{S_H + S_R}{2}, \frac{S_H + S_T}{2}\right) = \mathbf{12.31}$ MPa S_{Hmax} = smaller of 1.5 S_{fo} or 1.5 S_{no} = **207.00** MPa

Since (S_H <= S_{Hmax}), (S_T <= S_{fo}), (S_R <= S_{fo}), (S_c <= S_{fo}), nominal thickness is **ADEQUATE** for operating conditions

Internal Pressure Stress Calculations - Gasket Seating

$$S_H = \frac{fB_{sc}M_s}{Lg_1^2B} = \frac{4.8978 * 1.0000 * 11205353}{0.9126 * 20.00^2 * 1200.00} = \mathbf{125.29}\ \text{MPa}$$

$$S_R = \frac{\left(\frac{4}{3}\right) te + 1\ B_{sc}M_s}{L\,t^2\,B} = \frac{\left(\frac{4}{3}\right) * 40.00 * 0.009208 + 1 * 1.0000 * 11205353}{0.9126 * 40.00^2 * 1200.00} = \mathbf{9.54}\ \text{MPa}$$

$$S_T = \frac{Y B_{sc} M_s}{t^2\,B} - (Z S_R) = \frac{20.3193 * 1.0000 * 11205353}{40.00^2 * 1200.00} - (10.5238 * 9.54) = \mathbf{18.19}\ \text{MPa}$$

$$\frac{S_H + S_R}{2} = \frac{125.29 + 9.54}{2} = \mathbf{67.42}\ \text{MPa} \qquad \frac{S_H + S_T}{2} = \frac{125.29 + 18.19}{2} = \mathbf{71.74}\ \text{MPa}$$

$S_c = \text{Max}\left(\frac{S_H + S_R}{2}, \frac{S_H + S_T}{2}\right) = \mathbf{71.74}$ MPa S_{Hmax} = smaller of 1.5 S_{fa} or 1.5 S_{na} = **207.00** MPa

Since (S_H <= S_{Hmax}), (S_R <= S_{fa}), (S_T <= S_{fa}), (S_c <= S_{fa}), nominal thickness is **ADEQUATE** for seating conditions

Internal Pressure Rigidity Index per Appendix 2-14 - Operating Conditions

$$J = \frac{52.14\ M_O V}{L E g_0^2 h_0 K_I} = \frac{52.14 * 1923993 * 0.4019}{0.9126 * 208.7x10^3 * 8.00^2 * 97.98 * 0.3}$$ **= 0.11**

J <= 1, design meets Flange Rigidity requirements for Operating Conditions

Internal Pressure Rigidity Index per Appendix 2-14 - Seating Conditions

$$J = \frac{52.14\ M_S V}{L E g_0^2 h_0 K_I} = \frac{52.14 * 11205353 * 0.4019}{0.9126 * 195.0x10^3 * 8.00^2 * 97.98 * 0.3}$$ **= 0.70**

J <= 1, design meets Flange Rigidity requirements for Seating Conditions

Internal Pressure Minimum Thickness **= 17.90** mm

ASME Flange Calculations per Appendix 2

Gasket Seating Calculations(Table 2-5.2)

$\mathbf{b_0} = \frac{N}{2} = \frac{1.00}{2}$ = **0.50** mm

Since b_0 <= 6 mm, **b** = b_0 = **0.50** mm

G = O.D. contact face - N = 1253.00 - 1.00 = **1252.00** mm

External Pressure Summary

Bolt Spacing is Adequate for Flange Design

Bolting is Adequate for Flange Design

Nominal Thickness is Adequate for Seating Conditions

Nominal Thickness is Adequate for Operating Conditions

Flange Thickness is Adequate for Flange Design

Flange Rigidity is Adequate.

Nominal Thickness Selected = **40.00** mm

External Pressure Load and Bolting Calculations

The absolute value of effective pressure "P" is used for calculations.

$\mathbf{P} = \frac{16\,M}{\pi \cdot G^3} - \frac{4\,F_A}{\pi \cdot G^2} + P - \text{Static Head} = \frac{16 * 0}{3.14159 * 1252.00^3} - \frac{4 * 0}{3.14159 * 1252.00^2} + 0.1000 - 0.0000$ = **0.1000** MPa

Minimum $\mathbf{W_{m2}} = \pi \cdot bGy = 3.14159 * 0.50 * 1252.00 * 150.00$ = **294996** N

$\mathbf{H} = \frac{\pi}{4} G^2P = \frac{3.14159}{4} * 1252.00^2 * 0.1000$ = **123111** N

$\mathbf{H_p}$ = = **0** N

Minimum $\mathbf{W_{m1}}$ = = **0** N

$\mathbf{A_{m1}} = \frac{W_{m1}}{S_b} = \frac{0}{130.00}$ = **0.00** sq. mm

$\mathbf{A_{m2}} = \frac{W_{m2}}{S_a} = \frac{294996}{130.00}$ = **2269.20** sq. mm

$\mathbf{A_m}$ = Greater of A_{m1} or A_{m2} = greater of 0.00 or 2269.20 = **2269.20** sq. mm

$\mathbf{A_b}$ = Number of Bolts * Bolt Root Area = 64 * 138.32 = **8852.74** sq. mm

$\mathbf{W} = \frac{(A_m + A_b)S_a}{2} = \frac{(2269.20 + 8852.74) * 130.00}{2}$ = **722926** N

Ab >= Am, Bolting is Adequate for Flange Design

External Pressure Moment Calculations - Operating Conditions

$\mathbf{H_D} = \frac{\pi}{4} B^2P = \frac{3.1416}{4} * 1200.00^2 * 0.1000$ = **113097** N

$\mathbf{H_G} = W_{m1} - H = 0 - 123111$ = **-123111** N

$\mathbf{H_T} = H - H_D = 123111 - 113097$ = **10014** N

$\mathbf{R} = \frac{C - B}{2} - g_1 = \frac{1283.00 - 1200.00}{2} - 20.00$ = **21.50** mm

$\mathbf{h_D} = R + \frac{g_1}{2} = 21.50 + \frac{20.00}{2}$ = **31.50** mm

$\mathbf{h_G} = \frac{C - G}{2} = \frac{1283.00 - 1252.00}{2}$ = **15.50** mm

$\mathbf{h_T} = \frac{R + g_1 + h_G}{2} = \frac{21.50 + 20.00 + 15.50}{2}$ = **28.50** mm

$\mathbf{M_D} = H_D h_D = 113097 * 31.50$ = **3562556** N-mm

$\mathbf{M_G} = H_G h_G = -123111 * 15.50$ = **-1908221** N-mm

$\mathbf{M_T} = H_T h_T = 10014 * 28.50$ = **285399** N-mm

$\mathbf{M_o} = M_D + M_G + M_T = 3562556 + -1908221 + 285399$ = **1939734** N-mm

External Pressure Moment Calculations - Gasket Seating

$\mathbf{M_s} = Wh_G = 722926 * 15.50$ = **11205353** N-mm

Shape Constants
Calculated from Figure 2-7.1

$$\mathbf{K} = \frac{A}{B} = \frac{1320.00}{1200.00} = \mathbf{1.1000}$$

$$\mathbf{Y} = \frac{1}{K - 1}\left\{0.66845 + 5.71690\frac{K^2 \log_{10} K}{K^2 - 1}\right\} = \frac{1}{1.1000 - 1}\left\{0.66845 + 5.7169 * \frac{1.1000^2 * \log_{10} 1.1000}{1.1000^2 - 1}\right\} = \mathbf{20.3193}$$

$$\mathbf{T} = \frac{K^2(1 + 8.55246 \log_{10} K) - 1}{(1.04720 + 1.9448K^2)(K - 1)} = \frac{1.1000^2(1 + 8.55246 \log_{10} 1.1000) - 1}{[1.04720 + (1.9448 * 1.1000^2)](1.1000 - 1)} = \mathbf{1.8773}$$

$$\mathbf{U} = \frac{K^2(1 + 8.55246 \log_{10} K) - 1}{1.36136(K^2 - 1)(K - 1)} = \frac{1.1000^2[1 + (8.55246 * \log_{10} 1.1000)] - 1}{1.36136(1.1000^2 - 1)(1.1000 - 1)} = \mathbf{22.3289}$$

$$\mathbf{Z} = \frac{K^2 + 1}{K^2 - 1} = \frac{1.1000^2 + 1}{1.1000^2 - 1} = \mathbf{10.5238}$$

$$\mathbf{h_0} = \sqrt{Bg_0} = \sqrt{1200.00 * 8.00} = \mathbf{97.98}\ \text{mm}$$

$$\frac{\mathbf{h}}{\mathbf{h_0}} = \frac{12.00}{97.98} = \mathbf{0.1225}$$

$$\frac{\mathbf{g_1}}{\mathbf{g_0}} = \frac{20.00}{8.00} = \mathbf{2.5000}$$

Calculated from equations from TABLE 2-7.1

F = 0.9022 **V** = 0.4019 **f** = 4.8978

$$\mathbf{d} = \left\{\frac{U}{V}\right\} h_0 g_0^2 = \frac{22.3289}{0.4019} * 97.98 * 8.00^2 = \mathbf{348390.84}\ \text{mm}^3$$

$$\mathbf{e} = \frac{F}{h_0} = \frac{0.9022}{97.98} = \mathbf{0.009208}\ \text{mm}^{-1}$$

$$\mathbf{L} = \frac{te + 1}{T} + \frac{t^3}{d} = \frac{(40.00 * 0.009208) + 1}{1.8773} + \frac{40.00^3}{348390.84} = \mathbf{0.9126}$$

Bolt Spacing Calculations

$\mathbf{B_s}$ = Bolt Spacing = **62.95** mm

$$\mathbf{B_{smax}} = 2a + \frac{6t}{m + 0.5} = (2 * 16.00) + \left\{\frac{6 * 40.00}{0.00 + 0.5}\right\} = \mathbf{512.00}\ \text{mm}$$

$$\mathbf{B_{spenalty}} = 2a + t = (2 * 16.00) + 40.00 = \mathbf{72.00}\ \text{mm}$$

B_s <= B_{smax} : Acceptable per App. 2-5(d)
B_s < $B_{penalty}$: B_{sc} = 1.0

External Pressure Stress Calculations - Operating Conditions

$$S_H = \frac{fB_{sc}M_o}{Lg_1^2B} = \frac{4.8978 * 1.0000 * 1939734}{0.9126 * 20.00^2 * 1200.00} = \mathbf{21.69}\ \text{MPa}$$

$$S_R = \frac{\left(\frac{4}{3}\right) te + 1\right) B_{sc}M_o}{Lt^2B} = \frac{\left(\frac{4}{3}\right) * 40.00 * 0.009208 + 1\right) * 1.0000 * 1939734}{0.9126 * 40.00^2 * 1200.00} = \mathbf{1.65}\ \text{MPa}$$

$$S_T = \frac{Y B_{sc} M_o}{t^2B} - (Z S_R) = \frac{20.3193 * 1.0000 * 1939734}{40.00^2 * 1200.00} - (10.5238 * 1.65) = \mathbf{3.16}\ \text{MPa}$$

$$\frac{S_H + S_R}{2} = \frac{(21.69 + 1.65)}{2} = \mathbf{11.67}\ \text{MPa} \qquad \frac{S_H + S_T}{2} = \frac{(21.69 + 3.16)}{2} = \mathbf{12.43}\ \text{MPa}$$

$$S_c = \text{Max}\left(\frac{S_H + S_R}{2}, \frac{S_H + S_T}{2}\right) = \mathbf{12.43}\ \text{MPa} \qquad S_{Hmax} = \text{smaller of } 1.5\ S_{fo} \text{ or } 1.5\ S_{no} = \mathbf{207.00}\ \text{MPa}$$

Since (S_H <= S_{Hmax}), (S_T <= S_{fo}), (S_R <= S_{fo}), (S_c <= S_{fo}), nominal thickness is **ADEQUATE** for operating conditions

External Pressure Stress Calculations - Gasket Seating

$$S_H = \frac{fB_{sc}M_s}{Lg_1^2B} = \frac{4.8978 * 1.0000 * 11205353}{0.9126 * 20.00^2 * 1200.00} = \mathbf{125.29}\ \text{MPa}$$

$$S_R = \frac{\left(\frac{4}{3}\right) te + 1\right) B_{sc}M_s}{L\,t^2\,B} = \frac{\left(\frac{4}{3}\right) * 40.00 * 0.009208\right) + 1 * 1.0000 * 11205353}{0.9126 * 40.00^2 * 1200.00} = \mathbf{9.54}\ \text{MPa}$$

$$S_T = \frac{Y B_{sc} M_s}{t^2\,B} - (Z S_R) = \frac{20.3193 * 1.0000 * 11205353}{40.00^2 * 1200.00} - (10.5238 * 9.54) = \mathbf{18.19}\ \text{MPa}$$

$$\frac{S_H + S_R}{2} = \frac{125.29 + 9.54}{2} = \mathbf{67.42}\ \text{MPa} \qquad \frac{S_H + S_T}{2} = \frac{125.29 + 18.19}{2} = \mathbf{71.74}\ \text{MPa}$$

$$S_c = \text{Max}\left(\frac{S_H + S_R}{2}, \frac{S_H + S_T}{2}\right) = \mathbf{71.74}\ \text{MPa} \qquad S_{Hmax} = \text{smaller of } 1.5\ S_{fa} \text{ or } 1.5\ S_{na} = \mathbf{207.00}\ \text{MPa}$$

Since (S_H <= S_{Hmax}), (S_R <= S_{fa}), (S_T <= S_{fa}), (S_c <= S_{fa}), nominal thickness is **ADEQUATE** for seating conditions

External Pressure Rigidity Index per Appendix 2-14 - Operating Conditions

$$J = \frac{52.14\ M_O V}{L E g_0^2 h_0 K_I} = \frac{52.14 * 1939734 * 0.4019}{0.9126 * 208.7x10^3 * 8.00^2 * 97.98 * 0.3}$$ **= 0.11**

J <= 1, design meets Flange Rigidity requirements for Operating Conditions

External Pressure Rigidity Index per Appendix 2-14 - Seating Conditions

$$J = \frac{52.14\ M_S V}{L E g_0^2 h_0 K_I} = \frac{52.14 * 11205353 * 0.4019}{0.9126 * 195.0x10^3 * 8.00^2 * 97.98 * 0.3}$$ **= 0.70**

J <= 1, design meets Flange Rigidity requirements for Seating Conditions

External Pressure Minimum Thickness **= 17.90** mm

MDMT Report by Components

Design MDMT is -196 °C

Component	Material	Curve	Pressure	MDMT
Shell 1	SA-240 Gr. 304, High			Exempt per UHA-51(d)
Flange 1	SA-240 Gr. 304, High			Exempt per UHA-51(d)
Flange 2	SA-240 Gr. 304, High			Exempt per UHA-51(d)
A D63.5	SA-312 TP304L, High			Other Exemption
B D159	SA-312 TP304L, High			Other Exemption
C D63.5	SA-312 TP304L, High			Other Exemption
D D159	SA-312 TP304L, High			Other Exemption
E D63.5	SA-312 TP304L, High			Other Exemption
F D205	SA-312 TP304L, High			Other Exemption
G D205	SA-312 TP304L, High			Other Exemption
H D63.5	SA-312 TP304L, High			Other Exemption
I D63.5	SA-312 TP304L, High			Other Exemption
L D38	SA-312 TP304L, High			Other Exemption
M D38	SA-312 TP304L, High			Other Exemption
N D159	SA-312 TP304L, High			Other Exemption
O D38	SA-312 TP304L, High			Other Exemption
P D38	SA-312 TP304L, High			Other Exemption
Q D63.5	SA-312 TP304L, High			Other Exemption
R D63.5	SA-312 TP304L, High			Other Exemption
S D63.5	SA-312 TP304L, High			Other Exemption
T D63.5	SA-312 TP304L, High			Other Exemption
U D30	SA-312 TP304L, High			Other Exemption
V D20	SA-312 TP304L, High			Other Exemption
Z D63.5 tang	SA-312 TP304L, High			Other Exemption
X D159	SA-312 TP304L, High			Other Exemption
Shell 2	SA-240 Gr. 304, High			Exempt per UHA-51(d)
Flange 3 DN 1200 Dis. 1.01.001	SA-240 Gr. 304, High			Exempt per UHA-51(d)
Flange 4 DN 1200 Loose Type	SA-240 Gr. 304, High			Exempt per UHA-51(d)
Conical Reducer 1	SA-240 Gr. 304, High			Exempt per UHA-51(d)

The required design MDMT of -196 °C has been met or exceeded for the calculated MDMT values.

ASME Flanges Are Not Included in MDMT Calculations.

Alca Technology srl
Via Lago di Garda, 130 SCHIO (VI), ITALY

Date Printed: 07/02/2012

Vessel designed with DesignCalcs, Version: 2012.2
Vessel is ASME Code Stamped

Job No: 20106-02
Vessel Number: 20106-02

NAMEPLATE INFORMATION

Vessel MAWP:	0.1500 MPa at -196 °C
MDMT:	-196 °C at 0.0500 MPa
Serial Number(s):	20106/02
National Board Number(s):	_____
Year Built:	2012
Radiography:	RT 3
Postweld Heat Treated:	NONE
Construction Type:	W
Special Type:	LT

Signatures

_____ Date: ____/____/____

Alca Technology srl

De 1120 Pe FV Pi 1,5 bar

Job No: 20106-02
Number: 1

Vessel Number: 20106-02
Mark Number: S1

Date Printed: 07/02/2012

Cylindrical Shell Design Information

Design Pressure:	0.1500	MPa	Design Temperature:	-196	°C
Static Head:	0.0000	MPa	Long. Joint Efficiency:	85	%
Shell Material:	SB-209		Factor B Chart:	NFA-12	
Material Condition:	T6 wld.		Material Stress (hot):	41.40	MPa
Shell Length:	2020.00	mm	Material Stress (cold):	41.40	MPa
			Compressive Stress:	62.82	MPa
Corrosion Allowance:	0.00	mm	Actual Circumferential Stress:	8.16	MPa
External Corrosion Allowance:	0.00	mm	Actual Longitudinal Stress:	3.99	MPa
Outside Diameter (new):	1120.00	mm			
Outside Diameter (corroded):	1120.00	mm	Specific Gravity:	1.00	
Shell Surface Area:	7.11	sq. m	Weight of Fluid:	1905.73	kg
Shell Estimated Volume:	1.91	cu. m	Total Flooded Shell Weight:	2133.55	kg
Circ. Joint Efficiency:	85	%	Shell Weight:	227.82	kg

Minimum Design Metal Temperature Data

Minimum Design Metal Temperature: -196 °C
Other Exemption

External Pressure Data

Design Pressure (Pa):	0.1000	MPa	Design Temperature:	-196	°C
Dimension L:	2020.00	mm			
Ext. Minimum t:	6.55	mm	Ext. Nominal t:	12.00	mm
Minimum L/Do:	1.8036		Nominal L/Do:	1.8036	
Minimum Do/t:	170.9920		Nominal Do/t:	93.3333	
Minimum Factor A:	0.0003607		Nominal Factor A:	0.0008817	
Minimum Factor B:	12.82	MPa	Nominal Factor B:	31.34	MPa

Design Thickness Calculations

Longitudinal Stress Calculations per Paragraph UG-27(c)(2)

$$t = \frac{PR}{2SE + 0.4P} = \frac{0.1500 * 548.00}{2 * 41.40 * 0.85 + 0.4 * 0.1500}$$

= Greater Of $(1.17_{(Calculated)}, 1.50_{(Minimum\ Allowed)}) + 0.00_{(corrosion)} + 0.00_{(ext.\ corrosion)}$ = minimum of **1.50** mm

Circumferential Stress Calculations per Appendix 1-1(a)(1)

$$t = \frac{PR_o}{SE + 0.4P} = \frac{0.1500 * 560.00}{41.40 * 0.85 + 0.4 * 0.1500} = 2.39 + 0.00_{(corrosion)} + 0.00_{(ext.\ corrosion)}$$ = minimum of **2.39** mm

Maximum External Pressure Calculation per Paragraph UG-28

$$\mathbf{Pa}\ (\text{using } \textit{nominal} t) = \frac{4B}{3(D_o / t)} = \frac{4 * 31.34}{3 * (\ 1120.00 / 12.00\ )}$$ = maximum external pressure of **0.4477** MPa

External loads do not control design.

Nominal Shell Thickness Selected = **12.00** mm

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D112

Job No: 20106-02
Number: 1
ID Number: 1

Vessel Number: 20106-02
Mark Number: N1

Date Printed: 07/02/2012

Nozzle Design Information

Design Pressure:	0.1500	MPa	Design Temperature:	-196	°C
Static Head:	0.0000	MPa	Nozzle Efficiency (E):	100	%
Nozzle Material:	SB-209		Joint Efficiency (E_1):	1.00	
Condition:	T6		Factor B Chart:	NFA-12	
External Projection:	68.00	mm	Allowable Stress at Design Temperature (S_n):	41.40	MPa
Internal Projection:	0.00	mm	Allowable Stress at Ambient Temperature:	41.40	MPa
Inside Corrosion Allowance:	0.00	mm	Correction Factor (F):	1.00	
External Corrosion Allowance:	0.00	mm	Nozzle Path:	None	
Nozzle ID (new):	106.00	mm	Nozzle Wall Thickness(new):	3.00	mm
Nozzle ID (corroded):	106.00	mm	Nozzle Wall Thickness(corroded):	3.00	mm
Outer "h" Limit:	7.50	mm	Upper Weld Leg Size(Weld 41):	3.00	mm
Internal "h" Limit:	7.50	mm	Internal Weld Leg Size(Weld 43):	0.00	mm
OD, Limit of Reinforcement:	212.00	mm	Outside Groove Weld Depth:	12.00	mm

Minimum Design Metal Temperature

Minimum Design Metal Temperature: -196 °C
Other Exemption

Host Component: Shell 1 - De 1120 Pe FV Pi 1,5 bar

Material:	SB-209		Shell wall thickness(new):	12.00	mm
Material Stress(S_V):	41.40	MPa	Shell wall thickness(corroded):	12.00	mm

Nozzle Detail Information

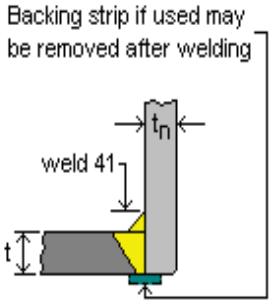

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 3.00 mm

Nozzle Wall Thickness(t_n): 3.00 mm

Outside Groove Weld Depth: 12.00 mm

Nozzle passes through the vessel, attached by a groove weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is adequately reinforced for External Pressure.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PRo}{SE + 0.4P} = \frac{0.1500 * 560.00}{41.40 * 1 + 0.4 * 0.1500} = \mathbf{2.03} \text{ mm}$$

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{0.1500 * 53.00}{41.40 * 1 - 0.6 * 0.1500} = \mathbf{0.19} \text{ mm}$$

Required Nozzle Thickness for External Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 112.00 * 0.1000}{4 * 19.69} = \mathbf{0.44} \text{ mm}$$

Strength Reduction Factors

$$\mathbf{fr1} = \min\left[\frac{Sn}{Sv}, 1.0000\right] = \min\left[\frac{41.40}{41.40}, 1.0000\right] = 1.0000 \qquad \mathbf{fr2} = \min\left[\frac{Sn}{Sv}, 1.0000\right] = \min\left[\frac{41.40}{41.40}, 1.0000\right] = 1.0000$$

$$\mathbf{fr3} = \min\left[\frac{Sn}{Sv}, 1.0000\right] = \min\left[\frac{41.40}{41.40}, 1.0000\right] = 1.0000$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion)

$$t_a = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.1500 * 53.00}{41.40 * 1.00 - 0.6 * 0.1500} + 0.00 + 0.00 = \mathbf{0.19} \text{ mm}$$

Nozzle Thickness for Internal Pressure (plus corrosion) Based on Host

$$t_{b1} = \frac{PRo}{SE + 0.4P} + Ca + \text{ext. } Ca = \frac{0.1500 * 560.00}{41.40 * 1 + 0.4 * 0.1500} + 0.00 + 0.00 = \mathbf{2.03} \text{ mm}$$

Nozzle Thickness for External Pressure (plus corrosion) Based on Host

$$t_{b2} = \frac{PRo}{SE + 0.4P} + Ca + \text{ext. } Ca = \frac{0.1000 * 560.00}{41.40 * 1 + 0.4 * 0.1000} + 0.00 + 0.00$$

$= \text{Greater Of } (1.35_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00 \text{ (corrosion)} + 0.00 \text{ (ext. corrosion)} = \mathbf{1.50}$ mm

Minimum Thickness (plus corrosion) per Table UG-45

t_{b3} = minimum thickness (Table UG-45) + Ca + ext. Ca = **5.27** mm

Nozzle Minimum Thickness Based on Host and Table UG-45

$t_b = \min[t_{b3}, \max(t_{b1}, t_{b2})]$ = **2.03** mm

$t_{UG-45} = \max(t_a, t_b)$ = **2.03** mm

Wall thickness = tn = **3.00** is greater than or equal to UG-45 value of **2.03**

Nozzle Reinforcement Calculations

Area Required for Internal Pressure

A = d tr F + 2 tn tr F (1 - fr1) = (106.00 * 2.03 * 1.00) + (2 * 3.00 * 2.03 * 1.00 * (1 - 1.0000)) = **215.18** sq. mm

Area Available - Internal Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
106.00 * (1.00 * 12.00 - 1.00 * 2.03) - 2 * 3.00 * (1.00 * 12.00 - 1.00 * 2.03) * (1 - 1.0000) = *1056.82* sq. mm

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (12.00 + 3.00)(1.00 * 12.00 - 1.00 * 2.03) - 2 * 3.00 * (1.00 * 12.00 - 1.00 * 2.03) * (1 - 1.0000) = *299.10* sq. mm

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **1056.82** sq. mm

A2 Formula 1 = 5(tn - trn) fr2 t = 5(3.00 - 0.19) * 1.0000 * 12.00 = *168.60* sq. mm
A2 Formula 2 = 5(tn - trn) fr2 tn = 5(3.00 - 0.19) * 1.0000 * 3.00 = *42.15* sq. mm
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **42.15** sq. mm

A3 = Smaller value of the following :
5 * t * t_i * f_{r2} = 5 * 12.00 * 3.00 * 1.0000 = 180.00 sq. mm
5 * t_i * t_i * f_{r2} = 5 * 3.00 * 3.00 * 1.0000 = 45.00 sq. mm
2 * h * t_i * f_{r2} = 2 * 0.00 * 3.00 * 1.0000 = 0.00 sq. mm
= **0.00** sq. mm

A41 = (leg)² * fr2 = (3.00)² * 1.0000 = **9.00** sq. mm

A43 = (leg)² * fr2 = 0 * 1.0000 = **0.00** sq. mm

Area Available (Internal Pressure) = A1 + A2 + A3 + A41 + A43 = 1107.97 sq. mm, which is **greater** than A (215.18)

Nozzle Reinforcement Calculations

Area Required for External Pressure

A = ½ * (d tr F + 2 tn tr F (1 - fr1)) = ½ * ((106.00 * 6.55 * 1.0) + (2 * 3.00 * 6.55 * 1.0 * (1 - 1.0000))) = **347.15** sq. mm

Area Available - External Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
106.00 * (1.00 * 12.00 - 1.00 * 6.55) - 2 * 3.00 * (1.00 * 12.00 - 1.00 * 6.55) * (1 - 1.0000) = *577.70* sq. mm

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (12.00 + 3.00)(1.00 * 12.00 - 1.00 * 6.55) - 2 * 3.00 * (1.00 * 12.00 - 1.00 * 6.55) * (1 - 1.0000) = *163.50* sq. mm

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **577.70** sq. mm

A2 Formula 1 = 5(tn - trn) fr2 t = 5(3.00 - 0.44) * 1.0000 * 12.00 = *153.60* sq. mm
A2 Formula 2 = 5(tn - trn) fr2 tn = 5(3.00 - 0.44) * 1.0000 * 3.00 = *38.40* sq. mm
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **38.40** sq. mm

A3 = Smaller value of the following :
5 * t * t_i * f_{r2} = 5 * 12.00 * 3.00 * 1.0000 = 180.00 sq. mm
5 * t_i * t_i * f_{r2} = 5 * 3.00 * 3.00 * 1.0000 = 45.00 sq. mm
2 * h * t_i * f_{r2} = 2 * 0.00 * 3.00 * 1.0000 = 0.00 sq. mm
= **0.00** sq. mm

A41 = (leg)² * fr2 = (3.00)² * 1.0000 = **9.00** sq. mm

A43 = (leg)² * fr2 = 0 * 1.0000 = **0.00** sq. mm

Area Available (External Pressure) = A1 + A2 + A3 + A41 + A43 = 625.10 sq. mm, which is **greater** than A (347.15)

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D112

Job No: 20106-02
Number: 2
ID Number: 2

Vessel Number: 20106-02
Mark Number: N2

Date Printed: 07/02/2012

Nozzle Design Information

Design Pressure:	0.1500	MPa	Design Temperature:	-196	°C
Static Head:	0.0000	MPa	Nozzle Efficiency (E):	100	%
Nozzle Material:	SB-209		Joint Efficiency (E_1):	1.00	
Condition:	T6 wld.		Factor B Chart:	NFA-12	
External Projection:	68.00	mm	Allowable Stress at Design Temperature (S_n):	41.40	MPa
Internal Projection:	0.00	mm	Allowable Stress at Ambient Temperature:	41.40	MPa
Inside Corrosion Allowance:	0.00	mm	Correction Factor (F):	1.00	
External Corrosion Allowance:	0.00	mm	Nozzle Path:	None	
Nozzle ID (new):	106.00	mm	Nozzle Wall Thickness(new):	3.00	mm
Nozzle ID (corroded):	106.00	mm	Nozzle Wall Thickness(corroded):	3.00	mm
Outer "h" Limit:	7.50	mm	Upper Weld Leg Size(Weld 41):	3.00	mm
Internal "h" Limit:	7.50	mm	Internal Weld Leg Size(Weld 43):	0.00	mm
OD, Limit of Reinforcement:	212.00	mm	Outside Groove Weld Depth:	12.00	mm

Minimum Design Metal Temperature

Minimum Design Metal Temperature: -196 °C
Other Exemption

Host Component: Shell 1 - De 1120 Pe FV Pi 1,5 bar

Material:	SB-209		Shell wall thickness(new):	12.00	mm
Material Stress(S_V):	41.40	MPa	Shell wall thickness(corroded):	12.00	mm

Nozzle Detail Information

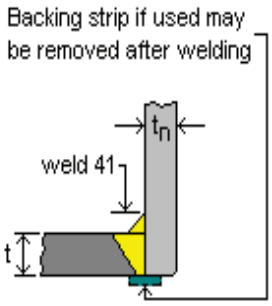

Fig. UW-16.1 (c)

Upper Weld Leg Size(Weld 41): 3.00 mm

Nozzle Wall Thickness(t_n): 3.00 mm

Outside Groove Weld Depth: 12.00 mm

Nozzle passes through the vessel, attached by a groove weld.
Nozzle is adequate for UG-45 requirements.
Opening is adequately reinforced for Internal Pressure.
Opening is adequately reinforced for External Pressure.
Weld Strength Paths are adequate.

Required Shell Thickness per Paragraph UG-37(a)

$$\mathbf{tr} = \frac{PRo}{SE + 0.4P} = \frac{0.1500 * 560.00}{41.40 * 1 + 0.4 * 0.1500} = \mathbf{2.03} \text{ mm}$$

Nozzle Required Thickness Calculations

Required Nozzle Thickness for Internal Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{PRn}{SE - 0.6P} = \frac{0.1500 * 53.00}{41.40 * 1 - 0.6 * 0.1500} = \mathbf{0.19} \text{ mm}$$

Required Nozzle Thickness for External Pressure per Paragraph UG-37(a)

$$\mathbf{trn} = \frac{3 * Do * Pa}{4B} = \frac{3 * 112.00 * 0.1000}{4 * 19.69} = \mathbf{0.44} \text{ mm}$$

Strength Reduction Factors

$$\mathbf{fr1} = \min\left[\frac{Sn}{Sv}, 1.0000\right] = \min\left[\frac{41.40}{41.40}, 1.0000\right] = 1.0000 \qquad \mathbf{fr2} = \min\left[\frac{Sn}{Sv}, 1.0000\right] = \min\left[\frac{41.40}{41.40}, 1.0000\right] = 1.0000$$

$$\mathbf{fr3} = \min\left[\frac{Sn}{Sv}, 1.0000\right] = \min\left[\frac{41.40}{41.40}, 1.0000\right] = 1.0000$$

UG-45 Thickness Calculations

Nozzle Thickness for Pressure Loading (plus corrosion)

$$t_a = \frac{PRn}{SE - 0.6P} + Ca + \text{ext. } Ca = \frac{0.1500 * 53.00}{41.40 * 1.00 - 0.6 * 0.1500} + 0.00 + 0.00 = \mathbf{0.19} \text{ mm}$$

Nozzle Thickness for Internal Pressure (plus corrosion) Based on Host

$$t_{b1} = \frac{PRo}{SE + 0.4P} + Ca + \text{ext. } Ca = \frac{0.1500 * 560.00}{41.40 * 1 + 0.4 * 0.1500} + 0.00 + 0.00 = \mathbf{2.03} \text{ mm}$$

Nozzle Thickness for External Pressure (plus corrosion) Based on Host

$$t_{b2} = \frac{PRo}{SE + 0.4P} + Ca + \text{ext. } Ca = \frac{0.1000 * 560.00}{41.40 * 1 + 0.4 * 0.1000} + 0.00 + 0.00$$

$= \text{Greater Of } (1.35_{(\text{Calculated})}, 1.50_{(\text{Minimum Allowed})}) + 0.00 \text{ (corrosion)} + 0.00 \text{ (ext. corrosion)} = \mathbf{1.50}$ mm

Minimum Thickness (plus corrosion) per Table UG-45

t_{b3} = minimum thickness (Table UG-45) + Ca + ext. Ca = **5.27** mm

Nozzle Minimum Thickness Based on Host and Table UG-45

$t_b = \min[t_{b3}, \max(t_{b1}, t_{b2})]$ = **2.03** mm

$t_{UG-45} = \max(t_a, t_b)$ = **2.03** mm

Wall thickness = tn = **3.00** is greater than or equal to UG-45 value of **2.03**

Nozzle Reinforcement Calculations

Area Required for Internal Pressure

A = d tr F + 2 tn tr F (1 - fr1) = (106.00 * 2.03 * 1.00) + (2 * 3.00 * 2.03 * 1.00 * (1 - 1.0000)) = **215.18** sq. mm

Area Available - Internal Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
106.00 * (1.00 * 12.00 - 1.00 * 2.03) - 2 * 3.00 * (1.00 * 12.00 - 1.00 * 2.03) * (1 - 1.0000) = *1056.82* sq. mm

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (12.00 + 3.00)(1.00 * 12.00 - 1.00 * 2.03) - 2 * 3.00 * (1.00 * 12.00 - 1.00 * 2.03) * (1 - 1.0000) = *299.10* sq. mm

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **1056.82** sq. mm

A2 Formula 1 = 5(tn - trn) fr2 t = 5(3.00 - 0.19) * 1.0000 * 12.00 = *168.60* sq. mm
A2 Formula 2 = 5(tn - trn) fr2 tn = 5(3.00 - 0.19) * 1.0000 * 3.00 = *42.15* sq. mm
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **42.15** sq. mm

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 12.00 * 3.00 * 1.0000 = 180.00 sq. mm
$5 * t_i * t_i * f_{r2}$ = 5 * 3.00 * 3.00 * 1.0000 = 45.00 sq. mm
$2 * h * t_i * f_{r2}$ = 2 * 0.00 * 3.00 * 1.0000 = 0.00 sq. mm
= **0.00** sq. mm

A41 = $(leg)^2 * fr2$ = $(3.00)^2$ * 1.0000 = **9.00** sq. mm

A43 = $(leg)^2$ * fr2 = 0 * 1.0000 = **0.00** sq. mm

Area Available (Internal Pressure) = A1 + A2 + A3 + A41 + A43 = 1107.97 sq. mm, which is **greater** than A (215.18)

Nozzle Reinforcement Calculations

Area Required for External Pressure

A = ½ * (d tr F + 2 tn tr F (1 - fr1)) = ½ * ((106.00 * 6.55 * 1.0) + (2 * 3.00 * 6.55 * 1.0 * (1 - 1.0000))) = **347.15** sq. mm

Area Available - External Pressure

A1 Formula 1 = d(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
106.00 * (1.00 * 12.00 - 1.00 * 6.55) - 2 * 3.00 * (1.00 * 12.00 - 1.00 * 6.55) * (1 - 1.0000) = *577.70* sq. mm

A1 Formula 2 = 2(t + tn)(E1 t - F tr) - 2tn(E1 t - F tr)(1 - fr1) =
2 * (12.00 + 3.00)(1.00 * 12.00 - 1.00 * 6.55) - 2 * 3.00 * (1.00 * 12.00 - 1.00 * 6.55) * (1 - 1.0000) = *163.50* sq. mm

A1 = Larger value of *A1 Formula 1* and *A1 Formula 2* = **577.70** sq. mm

A2 Formula 1 = 5(tn - trn) fr2 t = 5(3.00 - 0.44) * 1.0000 * 12.00 = *153.60* sq. mm
A2 Formula 2 = 5(tn - trn) fr2 tn = 5(3.00 - 0.44) * 1.0000 * 3.00 = *38.40* sq. mm
A2 = Smaller value of *A2 Formula 1* and *A2 Formula 2* = **38.40** sq. mm

A3 = Smaller value of the following :
$5 * t * t_i * f_{r2}$ = 5 * 12.00 * 3.00 * 1.0000 = 180.00 sq. mm
$5 * t_i * t_i * f_{r2}$ = 5 * 3.00 * 3.00 * 1.0000 = 45.00 sq. mm
$2 * h * t_i * f_{r2}$ = 2 * 0.00 * 3.00 * 1.0000 = 0.00 sq. mm
= **0.00** sq. mm

A41 = $(leg)^2 * fr2$ = $(3.00)^2$ * 1.0000 = **9.00** sq. mm

A43 = $(leg)^2$ * fr2 = 0 * 1.0000 = **0.00** sq. mm

Area Available (External Pressure) = A1 + A2 + A3 + A41 + A43 = 625.10 sq. mm, which is **greater** than A (347.15)

Cylindrical Shell Design Information

Design Pressure:	0.1000	MPa	Design Temperature:	-196	°C
Static Head:	0.0000	MPa	Long. Joint Efficiency:	85	%
Shell Material:	SB-209		Factor B Chart:	NFA-12	
Material Condition:	T6 wld.		Material Stress (hot):	41.40	MPa
Shell Length:	2060.00	mm	Material Stress (cold):	41.40	MPa
			Compressive Stress:	66.28	MPa
Corrosion Allowance:	0.00	mm	Actual Circumferential Stress:	3.80	MPa
External Corrosion Allowance:	0.00	mm	Actual Longitudinal Stress:	1.84	MPa
Outside Diameter (new):	980.00	mm			
Outside Diameter (corroded):	980.00	mm	Specific Gravity:	1.00	
Shell Surface Area:	6.34	sq. m	Weight of Fluid:	1460.17	kg
Shell Estimated Volume:	1.46	cu. m	Total Flooded Shell Weight:	1713.10	kg
Circ. Joint Efficiency:	85	%	Shell Weight:	252.93	kg

Minimum Design Metal Temperature Data

Minimum Design Metal Temperature: -196 °C
Other Exemption

External Pressure Data

Design Pressure (Pa):	0.1500	MPa	Design Temperature:	-196	°C
Dimension L:	2020.00	mm			
Ext. Minimum t:	7.40	mm	Ext. Nominal t:	15.00	mm
Minimum L/Do:	2.0612		Nominal L/Do:	2.0612	
Minimum Do/t:	132.4320		Nominal Do/t:	65.3333	
Minimum Factor A:	0.0004195		Nominal Factor A:	0.0012246	
Minimum Factor B:	14.91	MPa	Nominal Factor B:	43.19	MPa

Design Thickness Calculations

Longitudinal Stress Calculations per Paragraph UG-27(c)(2)

$$\mathbf{t} = \frac{PR}{2SE + 0.4P} = \frac{0.1000 * 475.00}{2 * 41.40 * 0.85 + 0.4 * 0.1000}$$

= Greater Of $(0.67_{(Calculated)}, 1.50_{(Minimum\ Allowed)}) + 0.00_{(corrosion)} + 0.00_{(ext.\ corrosion)}$ = minimum of **1.50** mm

Circumferential Stress Calculations per Appendix 1-1(a)(1)

$$\mathbf{t} = \frac{PR_o}{SE + 0.4P} = \frac{0.1000 * 490.00}{41.40 * 0.85 + 0.4 * 0.1000}$$

= Greater of $(1.39_{(Calculated)}, 1.50_{(Minimum\ Allowed)}) + 0.00_{(corrosion)} + 0.00_{(ext.\ corrosion)}$ = minimum of **1.50** mm

Maximum External Pressure Calculation per Paragraph UG-28

$$\mathbf{Pa}\ (\text{using } \textit{nominal}\mathbf{t}) = \frac{4B}{3(D_o / t)} = \frac{4 * 43.19}{3 * (980.00 / 15.00)}$$

= maximum external pressure of **0.8814** MPa

External loads do not control design.

Nominal Shell Thickness Selected = **15.00** mm

MDMT Report by Components

Design MDMT is -196 °C

Component	Material	Curve	Pressure	MDMT
De 1120 Pe FV Pi 1,5 bar	SB-209			Other Exemption
D112	SB-209			Other Exemption
D112	SB-209			Other Exemption
Shell 2 De 980 Pe 1,5 bar Pi FV	SB-209			Other Exemption

The required design MDMT of -196 °C has been met or exceeded for the calculated MDMT values.

ASME Flanges Are Not Included in MDMT Calculations.

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Project	Nikhef Virgo Cryostat
Project Nr.	P100331
Subject	Process calculation
By	ML
Date	30 March

Calculated Total LN2 usage with varying emissivity

Note: This is a verifying calculation, emissivity for vessel and shields considered equal

Emissivity	LN2 usage		Outlet flow regime
	g/s	l/h	Exhaust line (ID 100 mm)
0,1	0,62	2,81	Laminar
0,14	0,9	4	Laminar
0,157	0,99	4,46	Laminar
0,158	1	4,5	Critical
0,2	1,28	5,78	Critical
0,207	1,35	6	Critical

Calculation Heat Losses Normal Operation

Radial heat losses by radiation on AL vessel with two radiation shields			
Note: Emissivity level 0,2	P	127	W
Axial heat losses by radiation on AL vessel with two radiation shields			
	P	9,4	W
Axial heat losses by radiation through shield holes			
	P	72,4	W
Conduction by supporting structure			
	P	5,15	W
Total heat loss			
Note: Emissivity level 0,2			
	P	214	W
Calculation safety factor		20	%
LN2 supply based on evaporating		1,28	g/s
		5,78	l/h

Calculation cool down LN2 useage

	Vessel	527	kg
	Shields	26,7	kg
Details (supports, hoses)	10%	55,4	kg
LN2 useage for cool down		609	kg

Calculation Drain to empty, drain line and LN2 vessel pressure

Note: Drain time 5 hours

Liquid contents vessel	300	l
Flow	13,33	g/s

Pressure versus drain line size

Drain line	Pressure mbar
DN 6	180
DN 8	165
DN 10	160

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Calculation of Heating power (normal operation)		
Note: outlet gas to 20C		
Note: Based on emissivity 0,2		
LN2 useage	1,28	g/s
Total heating power (EH1)	301	W

Calculation of Heating power (Liquid drain mode)		
Note: outlet gas to 20C		
Note: draining in 5 hours		
LN2 useage	13,33	g/s
Evaporation power	2658	W
gas heating power	3122	W
Total heating power (EH2)	5780	W

Calculation of Phase separator supply pressure		
Note: Based on 6 l/h LN2 supply in vessel		
Pressure loss	0,04	bar
Height difference Phase separator/cryostat	0,5	m

Calculation Safety valve discharge capacity		
Heat inleak	3,8	W/cm^2
Surface	13,9	m^2
Evaporating power	390	kW
Evaporated liquid	1,97	kg/s
Gas medium through safety valve	1222	m^3/h
Minimum flow diameter	90,47	mm
Supply line inner diameter	100	mm
Max. Length of pipe after safety valve	833	mm
Note: based on AD2000-A2		

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Project:	P100331 Virgo		Customer: NIKHEF	Line ID:	LN2 supply line to Alu vessel				
Date:	29-11-2010		Rev0	Type :	Start	VIP	Valve	VIP	Outlet
Made by:	ML			Start point ID:	Phase separator outlet				Alu vessel inlet
1) INPUT	CONSTANTS	001	Fluid :	[-]	nitrogen	nitrogen	nitrogen	nitrogen	nitrogen
		002	Critical point	[bara]	34	34	34	34	34
		003		[K]	126	126	126	126	126
		004	Ambient pressure :	[bara]	1,00000	1,00000	1,00000	1,00000	1,00000
		005	Ambient temperature :	[K]	293	293	293	293	293
		006	Normal pressure :	[bara]	1,01325	1,01325	1,01325	1,01325	1,01325
		007	Normal temperature :	[K]	273	273	273	273	273
		008	Gravity :	[m/s2]	9,81	9,81	9,81	9,81	9,81
	VARIABLES	009	p :	[bara]	1,00	1,000	1,040	1,040	1,039
		010	Gas fraction * :	[mass%]	0%	0,0%	0,8%	0,8%	1,3%
		011	Φ_m :	[g/s]	1,350	1,350	1,350	1,350	1,350
		012	DN (or ID valve)	[- / mm]		DN25	6	DN10	
		013	DN vacuum jacket :	[-]		Ø63,5		Ø63,5	
		014	L :	[m]		2,000		0,500	
		015	ΔH :	[m]		-0,500		0,000	
		016	k :	[-]		0,05		0,05	
		017	number of elbows :	[-]		1		1	
		018	λ (reducer) :	[-]					
		019	Number of bridges :	[-]		1		1	
		020	Number of Johnston coupling halfs :	[-]		0		0	
		021	p out:	[bara]					
		022	Kv :	[m3/hr]			1,20		
		023	Nozzle outlet dia :	[-]					
		024	Safety margin on Δp:	[%]	25	25	25	25	
		025	Safety margin on heat leak:	[%]	10	10	10	10	
		026	Power input :	[W]					
2) SUMMARY		101	v :	[m/s]		0,0032	0,1	0,051	
OF RESULTS		102	Particular pressure loss (dyn) :	[mbar]		0,0006	0,0585	0,0135	
		103	Sum of pressure loss (dyn) :	[mbar]		0,0	0,1	0,1	0,1
		104	Sum of pressure loss (dyn+stat):	[mbar]		-39,6	-39,5	-39,5	-39,5
		105	Particular heat leak + friction :	[W]		3,0	0,2	1,4	
		106	Sum of heat leak + friction :	[W]		3,0	3,1	4,5	4,5
		107	Sum of Gas fraction :	[mass%]		0,8%	0,8%	1,3%	
		108	Φv liquid:	[l/hr]		6,0	6,0	6,0	6,0

ml:
0,9 g/s is 4 l/hour LN2 normale operation
1,35 g/s is 6 l/hour LN2 maximum operation

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Project:	P100331 Virgo		Customer: NIKHEF	Line ID:	GN2 outlet from Alu vessel					
Date:	29-11-2010		Rev0	Type :	START	VIP	VALVE	PIPE	HEATER	OUTLET
Made by:	ML			Start point ID:	Alu vessel					Heater outlet
1) INPUT	CONSTANTS	001	Fluid :	[-]	nitrogen	nitrogen	nitrogen	nitrogen	nitrogen	nitrogen
		002	Critical point	[bara]	33,96	33,96	33,96	33,96	33,96	33,96
		003		[K]	126,19	126,19	126,19	126,19	126,19	126,19
		004	Ambient pressure :	[bara]	1,00000	1,00000	1,00000	1,00000	1,00000	1,00000
		005	Ambient temperature :	[K]	293	293	293	293	293	293
		006	Normal pressure :	[bara]	1,01325	1,01325	1,01325	1,01325	1,01325	1,01325
		007	Normal temperature :	[K]	273	273	273	273	273	273
		008	Gravity :	[m/s2]	9,81	9,81	9,81	9,81	9,81	9,81
	VARIABLES	009	p :	[bara]	1,00	1,00	1,00	1,00	1,00	1,00
		010	T :	[K]	78,00	78,00	90,22	90,40	90,40	302,48
		011	Φ_m :	[g/s]	0,900	0,90	0,90	0,90	0,90	0,90
		012		[%]	1	100%	100%	100%	100%	100%
		013	DN (or ID valve)	[- / mm]		4"	100	4"		
		014	DN vacuum jacket	[-]		DN150 - Ø168,3				
		015	L :	[m]		1,000		1,000		
		016	ΔH :	[m]		0,500		0,000		
		017	k :	[-]		0,05		0,05		
		018	number of elbows :	[-]		1		0		
		019	λ (reducer) :	[-]						
		020	Number of bridges :	[-]		2				
		021	Number of Johnston coupling halfs :	[-]		0				
		022	Mean delta T :	[K]						
		023	Kv :	[m3/hr]			655			
		024	p out :	[bar]						
		025	pump efficiency :	[%]						
		026	pump inlet dia :	[-]						
		027	Nozzle outlet dia :	[-]						
		028	Safety margin on Δp:	[%]	25	25	25	25		
		029	Safety margin on heat leak:	[%]	10	10	10	10		
		030	p out :	[bar]						
		031	Power input :	[W]					200	
2) SUMMARY OF RESULTS		101	v :	[m/s]		0,0254	0,0299	0,0299	0,0000	
		102	Particular pressure loss (dyn) :	[mbar]		0,0	0,0	0,0	0,0	
		103	Sum of pressure loss (dyn) :	[mbar]		0,0	0,0	0,0	0,0	0,0
		104	Sum of pressure loss (dyn+stat):	[mbar]		0,2	0,2	0,2	0,2	0,2
		105	Particular heat leak + friction :	[W]		12,1	0,2	0,0	0,0	
		106	Sum of heat leak + friction :	[W]		12,1	12,3	12,3	12,3	12,3
		107	ΔT :	[K]		12,220	0,180	0,000	212,085	
		108	T out :	[K]		90,22	90,40	90,40	302,48	302,48
		109	Re :	[-]		2088	-	1812	-	-
		110	Flow regime :	[-]		Laminar	-	Laminar	-	-
		111	λ :	[-]		0,031	-	0,035	-	-

ml:
0,9 g/s is 4 l/hour LN2 normal operation
1,35 g/s is 6 l/uur LN2 maximum operation