FORM A-1 MANUFACTURER'S DATA REPORT FOR PRESSURE VESSELS

As Required by the Provisions of the ASME Code Rules, Section VIII, Division 2

1. Manufactured and certified by DALMINE S.P.A. Piazza Caduti 6 Luglio 1944, 1, Dalmine (BG) 24044 - Italy
(Name and address of manufacturer)

2. Manufactured for Linde Hyrdogen FuelTech GmbH
(Name and address of purchaser)

3. Location of installation Tainan, Taiwan
(Name and address)

4. Type: Horizontal Gas Cylinder (Horiz. or vert. tank) | JC-057995 (Mfr.'s serial no.) | - (CRN) | See Remarks (Drawing no.) | 836 (Nat'l. Bd. no.) | 2024 (Year built)

5. The chemical and physical properties of all parts meet the requirements of material specifications of the ASME BOILER AND PRESSURE VESSEL CODE. The design, construction, and workmanship conform to ASME Code, Section VIII, Division 2.
2021 (Year) | 2 (Class) | 2939 (Code case no.)

Items 6 to 11 incl. to be completed for single wall vessels, jackets of jacketed vessels, or shells of heat exchangers

6. Shell: A372 Gr.N Cl.100 Q&T (Material (spec. no., grade)) | 35.1 mm (Nom. thk.) | 0 mm (Corr. allow.) | OD = 457 mm (Diameter) | 9200 mm (Length (overall))

7. Seams: SMLS (Longitudinal) | Q 920°C±40°C / T 680°C±15°C (Heat treatment) | UT - MT (Nondestructive examination)
SMLS (Girth) | See Line 7 (Heat treatment) | UT - MT (Nondestructive examination) | 1 (No. of courses)

8. Heads: (a) Matl. A372 Gr.N Cl.100 Q&T (Spec. no., grade) (b) Matl. A372 Gr.N Cl.100 Q&T (Spec. no., grade)

	Location (Top, Bottom, End)	Minimum Thickness	Corrosion Allowance	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure (Convex or Concave)
(a)	END	35,1	-	-	-	-	-	228.5	-	CONCAVE
(b)	END	35,1	-	-	-	-	-	228.5	-	CONCAVE

9. If removable, bolts used (describe other fastenings): - (Matl. spec. no., grade, size, number)

10. Jacket closure - (Describe as ogee and weld, bar, etc.) If bar, give dimensions -. If bolted, describe or sketch.

11. MAWP 55 Mpa (Internal) - (External) at max. temp. 65°C (Internal) - (External) Min. design metal temp. -40°C at 55Mpa
Impact test Yes with minimum Lateral Expansion 0.8 mm At test temperature of -40°C
Hydro., pneu., or comb test pressure Hydrostatic Test Pressure at 68 Mpa (688 Bar)

Items 12 and 13 to be completed for tube sections

12. Tubesheets: - (Stationary matl. (spec. no., grade)) | - (Diam. (subject to pressure)) | - (Nom. thk.) | - (Corr. allow.) | - (Attach. (wld., bolted))
- (Floating matl. (spec. no., grade)) | - (Diam.) | - (Nom. thk.) | - (Corr. allow.) | - (Attach. (wld., bolted))

13. Tubes: - (Matl. (spec. no., grade)) | - (O.D.) | - (Nom. thk.) | - (Number) | - (Type (straight or "U"))

Items 14 to 18 incl. to be completed for inner chambers of jacketed vessels, or channels of heat exchangers

14. Shell: - (Material (spec. no., grade)) | - (Nom. thk.) | - (Corr. allow.) | - (Diameter) | - (Length (overall))

15. Seams: - (Longitudinal) | - (Heat treatment) | - (Nondestructive examination)
- (Girth) | - (Heat treatment) | - (Nondestructive examination) | - (No. of courses)

16. Heads: (a) Matl. - (Spec. no., grade) (b) Matl. - (Spec. no., grade)

	Location (Top, Bottom, End)	Minimum Thickness	Corrosion Allowance	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure (Convex or Concave)
(a)	-	-	-	-	-	-	-	-	-	-
(b)	-	-	-	-	-	-	-	-	-	-

17. If removable, bolts used (describe other fastenings): - (Matl. spec. no., grade, size, number)

18. MAWP - (Internal) - (External) at max. temp. - (Internal) - (External) Min. design metal temp. - at -
Impact test - At test temperature of -
Hydro., pneu., or comb test pressure -

(07/17)

Tenaris Dalmine Quality Dpt. AI 13420 01 March 2024

FORM A-1

Manufactured by DALMINE S.P.A Piazza Caduti 6 Luglio 1944, 1, Dalmine (BG) 24044 - Italy

Manufacturer's Serial No. JC-057995 CRN - National Board No. 836

Items below to be completed for all vessels where applicable.

19. Nozzles inspection and safety valve openings

Purpose (Inlet, Outlet, Drain, etc.)	No.	Diam. or Size	Type	Material	Nom. Thk.	Reinforcement Material	How Attached	Location
Inlet/Outlet	2	OD145 / ID85	w.e.	See Remarks	35.1	N/A	Integrally	ENDS
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-

20. Body Flanges

Body Flanges on Shells

No.	Type	ID	OD	Flange Thk	Min Hub Thk	Material	How Attached	Location	Bolting			
									Num & Size	Bolting Material	Washer (OD, ID, thk)	Washer Material
-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-

Body Flanges on Heads

No.	Type	ID	OD	Flange Thk	Min Hub Thk	Material	How Attached	Location	Bolting			
									Num & Size	Bolting Material	Washer (OD, ID, thk)	Washer Material
-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-

21. Support Skirt No (Yes or no) Lugs - (No.) Legs - (No.) Other - (Describe) Attached - (Where and how)

22. Service: Fatigue analysis required Yes (Yes or no) and Compressed Gaseous Hydrogen (Describe contents or service)

Remarks:

0) PSV are responsability of the USER;1) Where not specify unit of measurement are mm for dimensions, MPa for pressure and °C for temperature; 2) Drawing No. 11432 Rev. = (O-AE-12-D-21-US-S) ; 3) Vessel (Gas Cylinder) is Integrally Forged Vessel without welds Material A372 Gr.N Cl.100 Q&T; 4) Heat No. - 926792/9 ; 5) Test Resalt SATISFACTORY (see Inspection Certificate No. 05/24/00036 dated 09/02/2024)

CERTIFICATION OF DESIGN

User's Design Specification on file at Linde Hyrdogen FuelTech GmbH

Manufacturer's Design Report on file at DALMINE S.P.A., Piazza Caduti 6 Luglio 1944, 1, Dalmine (BG),24044 - Italy

User's Design Specification certified by Adriana Stefanescu PE State EUR ING (FEANI) Reg. No. 34872

Manufacturer's Design Report certified by NADARAJAH CHITHRANJAN PE State VIRGINIA Reg. No. 0402052630

CERTIFICATE OF SHOP COMPLIANCE

We certify that the statements in this report are correct and that all details of design, material, construction, and workmanship of this vessel conform to the ASME Code for Pressure Vessels, Section VIII, Division 2.

"U2" Certificate of Authorization No. 55812 expires February 10, 2027

Date 01 March 2024 Co. name DALMINE S.P.A. (Manufacturer) Signed (Representative)

CERTIFICATE OF SHOP INSPECTION

Vessel made by DALMINE S.P.A. at Piazza Caduti 6 Luglio 1944, 1, Dalmine (BG),24044 - Italy

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and employed by LRQA Verification Ltd. of UK, have inspected the pressure vessel described in this Manufacturer's Data Report on 01 March 2024, and state that, to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with ASME Code, Section VIII, Division 2. By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's' Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date 01 March 2024 Signed (Authorized Inspector) Commissions AI 13420 B (National Board Authorized Inspector Commission number)

FORM A-1

Manufactured by DALMINE S.P.A., Piazza Caduti 6 Luglio 1944, 1, Dalmine (BG),24044 - Italy

Manufacturer's Serial No. JC-057995 CRN _____ National Board No. 836

CERTIFICATE OF FIELD ASSEMBLY COMPLIANCE

We certify that the field assembly construction of all parts of this vessel conforms with the requirements of Section VIII, Division 2 of the ASME BOILER AND PRESSURE VESSEL CODE.

"U2" Certificate of Authorization No. _____ expires _____

Date _____ Co. name _____ Signed _____

Assembler that certified and constructed field assembly — Representative

CERTIFICATE OF FIELD ASSEMBLY INSPECTION

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and employed by _____ of _____ have compared the statements in this Manufacturer's Data Report with the described pressure vessel and state that parts referred to as data items _____ not included in the certificate of shop inspection, have been inspected by me and that, to the best of my knowledge and belief, the Manufacturer has constructed and assembled this pressure vessel in accordance with the ASME Code, Section VIII, Division 2.

The described vessel was inspected and subjected to a hydrostatic test of _____ .

By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date _____ Signed _____ Commissions _____

Authorized Inspector — National Board Authorized Inspector Commission number

(07/17)

Tenaris Dalmine
Quality Dpt.

AI 13420
01 March 2024

Company name
Address
City
Telephone, Fax
Website, Email address
Date _____ Calc. _____ Contr._____ Appr._____

Customer
Linde

O-AE-12-D-21-US-S

Revision =

Calculation report

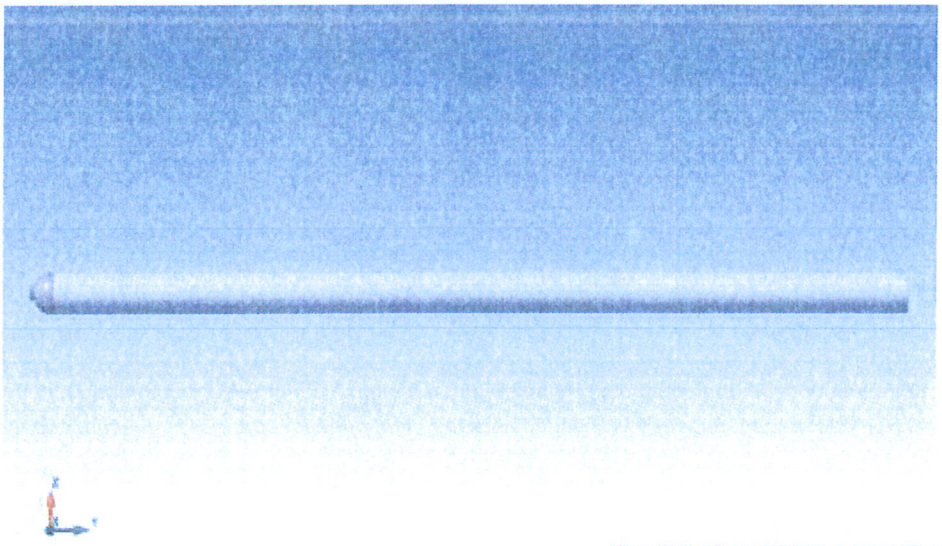
Asme VIII Div. 2 Ed. 2021 - Metric Units

Project: ASME LINDE TAIWAN
Item: 550 bar Div.2 L=9200
Customer: Linde
Drawing: O-AE-12-D-21-US-S
Revision: A
Date: 31/03/2023

Internal design pressure	P	=	55.00 MPa
Internal design temperature	T	=	65 °C
Internal corrosion allowance	c	=	0 mm
External corrosion allowance	ce	=	0 mm
Joint efficiency	E	=	1.00
Minimum design temperature		=	-40 °C

Code notes:

Vessel class: 2 (see Annex 1-B.2)



LRQA Italy S.R.L.
Name: Alessandro Salvatore Monastra
Date: 16 February 2024
Ref No.: AI 13420 - Verify availability only
Office: Milan
Signature
LRQA
A member of the LRQA Group Limited

Notes

Material properties and design allowable stress according to code case 2939

Table of contents

Test pressure - Hydrostatic (MPa)

Component	*P*	*Static head (design)*	*Static head (test)*	*MAP N&C*	*MAWP H&C*	*Stress ratio*	*Maximum test pressure*
O-AE-12-D-21-US-S Cylindrical shell	55.00	0	0.004	55.04	55.04	1	109.16
O-AE-12-D-21-US-S Hemispherical head	55.00	0	0.004	110.07	110.07	1	218.32
O-AE-12-D-21-US-S Nozzle	55.00	0	0.002	97.32	97.32	1	193.02

All pressures in MPa.

Item design pressure P = 55.00 MPa
Item MAWP (Hot & Corroded conditions) = 55.04 MPa (limited by O-AE-12-D-21-US-S Cylindrical shell)
Item MAP (New & Cold conditions) = 55.04 MPa (limited by O-AE-12-D-21-US-S Cylindrical shell)
Item lowest stress ratio = 1.000 (limited by O-AE-12-D-21-US-S Cylindrical shell)
Item test pressure = Pt = 1.25 · MAWP · St/S = 68.80 MPa
Item maximum allowable test pressure = 109.16 MPa

Maximum Pressures (MPa)

Component	*MAP N&C*	*MAWP H&C*
O-AE-12-D-21-US-S Cylindrical shell	55.04	55.04
O-AE-12-D-21-US-S Hemispherical head	110.07	110.07
O-AE-12-D-21-US-S Nozzle	176.25	176.25
O-AE-12-D-21-US-S Nozzle (Opening)	97.32	97.32

All pressures in MPa.

Weights

Components

Nr	Component
1	O-AE-12-D-21-US-S Cylindrical shell
2	O-AE-12-D-21-US-S Hemispherical head
3	O-AE-12-D-21-US-S Nozzle

Weight of components (kg)

	Dead			Dead additional			Live			Liquid	
Nr	Net	Corroded	Bolts	Value	Erection	Test	Value	Erection	Test	Operating	Test
1	3318	3318	0	0			0			0	1081
2	71	71	0	0			0			0	15
3	7	7	0	0			0			0	0
Total	3396	3396	0	0			0			0	1097

Total volume: 1.09664 m³

Definitions

Dead-net: uncorroded weight of component excluding eventual bolts and additional dead weight
Dead-corroded: corroded weight of component excluding eventual bolts and additional dead weight
Bolts: weight of bolts (when applicable)
Dead additional: additional dead weight on component
Live: additional live weight on component
Liquid-operating: weight of liquid contained in component in operating conditions (depending on liquid level)
Liquid-test: weight of liquid contained in component in hydrostatic test conditions
Insulation: weight of insulation on component, when present

Weights for load combination : Erection

Load combination type : Erection; Dead weight factor : 1; Live weight factor : 0; Dead weight type : Gmin

Nr	Dead	Bolts	Dead additional	Live	Liquid	Total
1	3 318 kg	0 kg	0 kg	0 kg	0 kg	3 318 kg
2	71 kg	0 kg	0 kg	0 kg	0 kg	71 kg
3	7 kg	0 kg	0 kg	0 kg	0 kg	7 kg
Total	3 396 kg	0 kg	0 kg	0 kg	0 kg	3 396 kg

Center of gravity: Cx=0 mm, Cy=4 719.98 mm, Cz=228.50 mm

Weights for load combination : Test

Load combination type : HydrostaticTest; Dead weight factor : 1; Live weight factor : 0; Dead weight type : Gmin

Nr	Dead	Bolts	Dead additional	Live	Liquid	Total
1	3 318 kg	0 kg	0 kg	0 kg	1 081 kg	4 399 kg
2	71 kg	0 kg	0 kg	0 kg	15 kg	86 kg
3	7 kg	0 kg	0 kg	0 kg	0 kg	7 kg
Total	3 396 kg	0 kg	0 kg	0 kg	1 097 kg	4 493 kg

Center of gravity: Cx=0 mm, Cy=4 730.11 mm, Cz=228.50 mm

Weights for load combination : Operating

Load combination type : Operating; Dead weight factor : 1; Live weight factor : 1; Dead weight type : Gmax

Nr	Dead	Bolts	Dead additional	Live	Liquid	Total
1	3 318 kg	0 kg	0 kg	0 kg	0 kg	3 318 kg
2	71 kg	0 kg	0 kg	0 kg	0 kg	71 kg
3	7 kg	0 kg	0 kg	0 kg	0 kg	7 kg
Total	3 396 kg	0 kg	0 kg	0 kg	0 kg	3 396 kg

Center of gravity: Cx=0 mm, Cy=4 719.98 mm, Cz=228.50 mm

Bill of materials

Component	*Dimensions*	*Material*
O-AE-12-D-21-US-S Cylindrical shell	Id = 386.80 mm, Od = 457.00 mm, Tk = 35.10 mm, L = 9 200.00 mm	CUSTOM ASTM A372 Grade N 100 - Forgings
O-AE-12-D-21-US-S Hemispherical head	Id = 386.80 mm, Od = 457.00 mm, Tk = 35.10 mm	CUSTOM ASTM A372 Grade N 100 - Forgings
O-AE-12-D-21-US-S Nozzle	Id = 85.00 mm, Od = 145.00 mm, Tk = 30.00 mm, L = 75.00 mm	CUSTOM ASTM A372 Grade N 100 - Forgings

Material properties summary

CUSTOM ASTM A372 Grade N 100 - Forgings @ 65.00 °C

Temp.	*Allowable (1)*	*0.2% Yield strength*	*Tensile strength*	*Elasticity*	*Thermal expansion*
Room	330.00 MPa	689.00 MPa	793.00 MPa	1.91E+05 MPa	1.15E-05 1/°C
Design	330.00 MPa	673.00 MPa	793.00 MPa	1.89E+05 MPa	1.19E-05 1/°C
Test					

Notes

(1) Allowable stress calculation may vary upon component type, conditions and other factors. Refer to each component's calculation page for its allowable stress value

Nozzle connections

Name	Flange	Material	OD	Tk
O-AE-12-D-21-US-S Nozzle		CUSTOM ASTM A372 Grade N 100	145.00 mm	30.00 mm

Nozzle positions

Name	Placed on	Type	Distance from reference	Orientation	Other
O-AE-12-D-21-US-S Nozzle	O-AE-12-D-21-US-S Hemispherical head	Radial/ Set in	0 mm	0 °	

Company name
Address
City
Telephone, Fax
Website, Email address
Date _____ Calc. _____ Contr._____ Appr._____

Customer
Linde

O-AE-12-D-21-US-S

Revision =

Minimum Design Metal Temperature (MDMT)

Component		*MDMT*	*Tmin ≥ MDMT*
O-AE-12-D-21-US-S Cylindrical shell		Impact tests required	
O-AE-12-D-21-US-S Hemispherical head		Impact tests required	
O-AE-12-D-21-US-S Nozzle		Impact tests required	

Item minimum design temperature Tmin: -40.00 °C / -40.00 °F

Impact tests required by Code

Cylindrical shell - O-AE-12-D-21-US-S Cylindrical shell

According to: Asme VIII Div. 2 Ed. 2021, 4.3.3 - Metric Units

Calculation temperature		T =	65 °C
Material:	**CUSTOM ASTM A372 Grade N 100 - Forgings**		
Geometry			
Allowable stress at room temperature		ST =	330.00 MPa
Joint efficiency		E =	1.00
Corrosion allowance		c =	0 mm
External corrosion allowance		ce =	0 mm
Inside diameter		D =	386.80 mm
Wall undertolerance		c' =	0 mm
Length		L =	9 200.00 mm
Adopted thickness		t =	35.10 mm
Internal pressure			
Allowable stress		S =	330.00 MPa
Internal pressure		Pi =	55.00 MPa
Overpressure due to static head		Ph =	0 MPa
Calculation pressure		P = Pi + Ph =	55.00 MPa
Required thickness	$t_r = \frac{D+2(c+c')}{2}(e^{\frac{P}{S\cdot E}}-1)+c+c_e+c'$ =		35.08 mm
			t ≥ tr (35.10 mm ≥ 35.08 mm): Ok
Maximum allowable pressures (at the top of the vessel)			
New & cold		=	55.04 MPa
Hot & corroded		=	55.04 MPa
Hydrostatic test			
Static head		Ph = ρgh =	0.004 MPa
Item MAWP		MAWP_Item =	55.04 MPa
Item or side hydrostatic test pressure		Pt = 1.25 · MAWP · St/S =	68.80 MPa
Allowable stress for the test condition		= 0,95·Sy =	654.55 MPa
Calculation pressure		P = Pt + Ph =	68.80 MPa
Minimum required thickness	$t_{rh} = \frac{D+2\cdot c'}{2}(e^{\frac{P}{S_h\cdot E}}-1)+c'$ =		21.43 mm
			t ≥ trh (35.10 mm ≥ 21.43 mm): Ok

Minimum Design Metal Temperature (MDMT)

Internal pressure		
Cylindrical shell		
Material:		CUSTOM ASTM A372 Grade N 100
Curve of fig. 3.7 / 3.8:		None
Governing Thickness	tg =	35.10 mm

PostWeld Heat Treatment: No

Minimum Design Metal Temperature (MDMT)

Impact tests required by Code: Yes

Note: All quenched and tempered steels listed in Table 3-A.2 shall be subject to Charpy V-notch testing, the corresponding MDMT shall not be colder than -104°C (-155°F).

Hemispherical head - O-AE-12-D-21-US-S Hemispherical head

According to: Asme VIII Div. 2 Ed. 2021, 4.3.5 - Metric Units

Calculation temperature	T =	65 °C
Material: CUSTOM ASTM A372 Grade N 100 - Forgings		
Geometry		
Allowable stress at room temperature	ST =	330.00 MPa
Joint efficiency	E =	1.00
Corrosion allowance	c =	0 mm
External corrosion allowance	ce =	0 mm
Wall undertolerance	c' =	0 mm
Inside diameter	D =	386.80 mm
Consider head radii after forming?:		Yes
Adopted thickness	t =	35.10 mm
Minimum head thickness after forming	t-c' =	35.10 mm
Internal pressure		
Allowable stress	S =	330.00 MPa
Internal pressure	Pi =	55.00 MPa
Overpressure due to static head	Ph =	0 MPa
Calculation pressure	P = Pi + Ph =	55.00 MPa
Required thickness	$t_r = \frac{D + 2 \cdot c'}{2}(e^{\frac{P}{2 \cdot S \cdot E}} - 1) + c + c_e + c' =$	16.81 mm
	t ≥ tr (35.10 mm ≥ 16.81 mm): Ok	
Maximum allowable pressures (at the top of the vessel)		
New & cold	=	110.07 MPa
Hot & corroded	=	110.07 MPa
Hydrostatic test		
Static head	Ph = ρgh =	0.004 MPa
Item MAWP	MAWP_Item =	55.04 MPa
Item or side hydrostatic test pressure	Pt = 1.25 · MAWP · St/S =	68.80 MPa
Allowable stress for the test condition	= 0,95·Sy =	654.55 MPa
Calculation pressure	P = Pt + Ph =	68.80 MPa
Minimum required thickness	$t_{rh} = \frac{D}{2}(e^{\frac{P}{2 \cdot S_t \cdot E}} - 1) + c' =$	10.44 mm
	t ≥ trh (35.10 mm ≥ 10.44 mm): Ok	

Minimum Design Metal Temperature (MDMT)

Internal pressure

Hemispherical head

Material:		CUSTOM ASTM A372 Grade N 100
Curve of fig. 3.7 / 3.8:		None
Governing Thickness	tg =	35.10 mm
PostWeld Heat Treatment:		No
Minimum Design Metal Temperature (MDMT)		
Impact tests required by Code:		Yes

Note: All quenched and tempered steels listed in Table 3-A.2 shall be subject to Charpy V-notch testing, the corresponding MDMT shall not be colder than -104°C (-155°F).

Reinforcement of opening - O-AE-12-D-21-US-S Nozzle

According to: Asme VIII Div. 2 Ed. 2021, 4.5.10 - Metric Units

Calculation temperature		T =	65 °C
Nozzle material	**CUSTOM ASTM A372 Grade N 100 - Forgings**		
Shell material	**CUSTOM ASTM A372 Grade N 100 - Forgings**		
Allowable stress from Annex 3.A for the vessel at the design temperature		S =	330.00 MPa
Shell allowable stress at room temperature		S0 =	330.00 MPa
Allowable stress from Annex 3.A for the nozzle at the design temperature		Sn =	330.00 MPa
Nozzle allowable stress at room temperature		Sn0 =	330.00 MPa
Shell thickness		t =	35.10 mm
Nozzle thickness		tn =	30.00 mm
Nozzle inside diameter		d =	85.00 mm
Nozzle outside diameter		Od =	145.00 mm
Joint efficiency		E =	1.00000
Nozzle internal corrosion allowance		cni =	0 mm
Nozzle external corrosion allowance		cne =	0 mm
Nozzle total corrosion allowance		cn =	0 mm
Nozzle undertolerance		cn' =	0 mm
Nozzle position:			Radial
Nozzle connection:			Set in
Weld joint type:			7 - Full penetration welds
Offset from shell border		=	0 mm
Angular offset:			0 °
Offset k between nozzle and shell axis		=	0 mm
Width of the reinforcing pad		W =	0 mm
Thickness of the reinforcing pad		te =	0 mm
Minimum required nozzle neck thickness per Table 4.5.2		t(4.5.2) =	6.22 mm
			tn >= t(4.5.2) (30.00 mm ≥ 6.22 mm): Ok
Nozzle inside radius		Rn = d/2 + cni + cn' =	42.50 mm
Shell inside diameter		Di =	386.80 mm
Effective radius of the shell		Reff=0.5·Di+c =	193.40 mm
Distance from the head center line to the nozzle center line		DR =	0 mm
Nozzle projection from the outside of the vessel wall		Lpr1 =	39.90 mm
Nozzle projection from the inside of the vessel wall		Lpr2 =	0 mm
Weld leg length of the outside nozzle fillet weld		L41 =	0 mm
Weld leg length of the pad to vessel fillet weld		L42 =	0 mm
Weld leg length of the inside nozzle fillet weld		L43 =	0 mm
Effective length along the vessel wall	$L_R = \min\left[\sqrt{R_{eff}(t-c-c')}, 2\cdot R_n\right]$	=	82.39 mm
	$C_n = \min\left[\left(\frac{(t-c-c')+t_e}{(t_n-c_n-c_n')}\right)^{0.35}, 1.0\right]$	=	1.00000
Eff. length outside vessel		=	70.81 mm
	$L_H = \min[t-c-c'+t_e+F_p\sqrt{R_n(t_n-c_n-c_n')}, L_{pr1}+t-c-c']$		
Eff. length along nozzle wall inside vessel	$L_I = \min[F_p\sqrt{R_n(t_n-c_n-c_n')}, L_{pr2}]$	=	0 mm
Area contributed by the vessel wall	$A_1 = (t-c-c_e-c')L_R$	=	2 891.9 mm²

Nozzle outs. vessel wall area	$A_2 = (t_n - c_n - c'_n)L_H$	=	2 124.2 mm²
Nozzle material factor	$f_{rn} = \frac{S_n}{S}$	=	1.00000
Pad material factor	$f_{rp} = \frac{S_p}{S}$	=	0
Nozzle ins. vessel wall area	$A_3 = (t_n - 2 \cdot c_n - 2 \cdot c'_n)L_I$	=	0 mm²
Area contributed by the outside nozzle fillet weld	$A_{41} = 0.5 \cdot L_{41}^2$	=	0 mm²
Area contributed by the pad to vessel fillet weld	$A_{42} = 0.5 \cdot L_{42}^2$	=	0 mm²
Area contributed by the inside nozzle fillet weld	$A_{43} = 0.5 \cdot L_{43}^2$	=	0 mm²
	$A_{5a} = W \cdot t_e$	=	0 mm²
	A5b	=	0 mm²
Area contributed by the reinforcing pad	$A_5 = \min[A_{5a}, A_{5b}]$	=	0 mm²
Total area	$A_T = A_1 + f_m(A_2 + A_3) + A_{41} + A_{42} + A_{43} + f_{rp} \cdot A_5$	=	5 016.2 mm²
Effective thickness	$t_{eff} = t - c - c' + \left(\frac{A_5 \cdot f_{rp}}{L_R}\right)$	=	35.10 mm
Radius of the nozzle opening	Rnc = Rn	=	42.50 mm
Nozzle radius for force calculation	$R_{xn} = \frac{(t_n - c_n - c'_n)}{\ln\left[\frac{R_n + (t_n - c_n - c'_n)}{R_n}\right]}$	=	56.17 mm
Shell radius for force calculation	$R_{xs} = \frac{t_{eff}}{\ln\left[\frac{R_{eff} + t_{eff}}{R_{eff}}\right]}$	=	210.46 mm
Force from internal pressure in the nozzle	$f_N = P \cdot R_{xn} \cdot L_H$	=	218 752 N
Force from internal pressure in the shell	$f_S = \frac{P \cdot R_{xs}(L_R + (t_n - c_n - c'_n))}{2}$	=	650 489 N
Discontinuity force from internal pressure	$f_Y = \frac{P \cdot R_{xs} \cdot R_{nc}}{2}$	=	245 978 N
Average primary membrane stress	$\sigma_{avg} = \frac{(f_N + f_S + f_Y)}{A_T}$	=	222.33 MPa
General primary membrane stress	$\sigma_{circ} = \frac{P \cdot R_{xs}}{2 \cdot t_{eff}}$	=	164.89 MPa
Allowable stress	$S_{allow} = 1.5 \cdot S \cdot E$	=	495.00 MPa
Maximum local primary membrane stress	$P_L = \max[(2 \cdot \sigma_{avg} - \sigma_{circ}), \sigma_{circ}]$	=	279.76 MPa
Area resisting pressure	$A_p = \frac{f_N + f_S + f_Y}{P}$	=	20 276.7 mm²
			PL ≤ Sallow: Ok
	$P_{max1} = \frac{S_{allow}}{\frac{2 \cdot A_p}{A_T} - \frac{R_{xs}}{2 \cdot t_{eff}}}$	=	97.32 MPa
	$P_{max2} = 2 \cdot S\left(\frac{t - c - c'}{R_{xs}}\right)$	=	110.07 MPa
Nozzle maximum allowable pressure (bottom)	$P_{max} = \min[P_{max1}, P_{max2}]$	=	97.32 MPa
			P ≤ Pmax (55.00 MPa ≤ 97.32 MPa): Ok

Hydrostatic test

Allowable stress for the vessel at test temperature	S	=	654.55 MPa
Allowable stress for the nozzle at test temperature	Sn	=	654.55 MPa
Nozzle inside radius	Rn = d/2 + cn'	=	42.50 mm
Shell inside diameter	Di	=	386.80 mm
Effective radius of the shell	$R_{eff} = 0.5 \cdot D_i + c'$	=	193.40 mm
Distance from the head center line to the nozzle center line	DR	=	0 mm
Nozzle projection from the outside of the vessel wall	Lpr1	=	39.90 mm
Nozzle projection from the inside of the vessel wall	Lpr2	=	0 mm

Weld leg length of the outside nozzle fillet weld	L41	=	0 mm
Weld leg length of the pad to vessel fillet weld	L42	=	0 mm
Weld leg length of the inside nozzle fillet weld	L43	=	0 mm
Effective length along the vessel wall	$L_R = \min\left[\sqrt{R_{eff}(t-c')}, 2 \cdot R_n\right]$	=	82.39 mm
	$C_n = \left[\left(\frac{(t-c')+t_e}{(t_n-c'_n)}\right)^{0.35}, 1.0\right]$	=	1.00000
Eff. length outside vessel	$L_H = \min[t-c'+t_e+F_p\sqrt{R_n(t_n-c'_n)}, L_{pr1}+t-c']$	=	70.81 mm
Eff. length along nozzle wall inside vessel	$L_I = \min[F_p\sqrt{R_n(t_n-c'_n)}, L_{pr2}]$	=	0 mm
Area contributed by the vessel wall	$A_1 = (t-c')L_R$	=	2 891.9 mm²
Nozzle outs. vessel wall area	$A_2 = (t_n-c'_n)L_H$	=	2 124.2 mm²
Nozzle material factor	$f_{rn} = \frac{S_n}{S}$	=	1.00000
Pad material factor	$f_{rp} = \frac{S_p}{S}$	=	0
Nozzle ins. vessel wall area	$A_3 = (t_n-2\cdot c'_n)L_I$	=	0 mm²
Area contributed by the outside nozzle fillet weld	$A_{41} = 0.5 \cdot L_{41}^2$	=	0 mm²
Area contributed by the pad to vessel fillet weld	$A_{42} = 0.5 \cdot L_{42}^2$	=	0 mm²
Area contributed by the inside nozzle fillet weld	$A_{43} = 0.5 \cdot L_{43}^2$	=	0 mm²
	$A_{5a} = W \cdot t_e$	=	0 mm²
	A5b	=	0 mm²
Area contributed by the reinforcing pad	$A_5 = \min[A_{5a}, A_{5b}]$	=	0 mm²
Total area	$A_T = A_1 + f_m(A_2+A_3) + A_{41} + A_{42} + A_{43} + f_{rp} \cdot A_5$	=	5 016.2 mm²
Effective thickness	$t_{eff} = t - c' + \left(\frac{A_5 \cdot f_{rp}}{L_R}\right)$	=	35.10 mm
Radius of the nozzle opening	Rnc = Rn	=	42.50 mm
Nozzle radius for force calculation	$R_{xn} = \frac{(t_n-c'_n)}{\ln\left[\frac{R_n+(t_n-c'_n)}{R_n}\right]}$	=	56.17 mm
Shell radius for force calculation	$R_{xs} = \frac{t_{eff}}{\ln\left[\frac{R_{eff}+t_{eff}}{R_{eff}}\right]}$	=	210.46 mm
Force from internal pressure in the nozzle	$f_N = P \cdot R_{xn} \cdot L_H$	=	273 629 N
Force from internal pressure in the shell	$f_S = \frac{P \cdot R_{xs}(L_R+(t_n-c'_n))}{2}$	=	813 671 N
Discontinuity force from internal pressure	$f_Y = \frac{P \cdot R_{xs} \cdot R_{nc}}{2}$	=	307 684 N
Average primary membrane stress	$\sigma_{avg} = \frac{(f_N+f_S+f_Y)}{A_T}$	=	278.10 MPa
General primary membrane stress	$\sigma_{circ} = \frac{P \cdot R_{xs}}{2 \cdot t_{eff}}$	=	206.26 MPa
Allowable stress	$S_{allow} = 1.5 \cdot S \cdot E$	=	981.83 MPa
Maximum local primary membrane stress	$P_L = \max[(2 \cdot \sigma_{avg} - \sigma_{circ}), \sigma_{circ}]$	=	349.94 MPa
Area resisting pressure	$A_p = \frac{f_N+f_S+f_Y}{P}$	=	20 276.7 mm²

PL ≤ Sallow: Ok

$$P_{max\,1} = \frac{S_{allow}}{\frac{2 \cdot A_p}{A_T} - \frac{R_{xs}}{2 \cdot t_{eff}}} = 193.02\ \text{MPa}$$

$$P_{max\,2} = 2 \cdot S\left(\frac{t - c'}{R_{xs}}\right) = 218.33\ \text{MPa}$$

Nozzle maximum allowable pressure (bottom)

$$P_{max} = \min[P_{max\,1}, P_{max\,2}] = 193.02\ \text{MPa}$$

P ≤ Pmax (68.80 MPa ≤ 193.02 MPa): Ok

Validation warnings

- Welds check has been disabled by the user (e.g. because the vessel is integrally forged)

Nozzle - O-AE-12-D-21-US-S Nozzle

According to: Asme VIII Div. 2 Ed. 2021, 4.3.3 - Metric Units

Calculation temperature		T =	65 °C
Material:	**CUSTOM ASTM A372 Grade N 100 - Forgings**		
Geometry			
Allowable stress at room temperature		ST =	330.00 MPa
Joint efficiency		E =	1.00
Corrosion allowance		c =	0 mm
External corrosion allowance		ce =	0 mm
Inside diameter		D =	85.00 mm
Wall undertolerance		c' =	0 mm
Length		L =	75.00 mm
Adopted thickness		t =	30.00 mm
Internal pressure			
Allowable stress		S =	330.00 MPa
Internal pressure		Pi =	55.00 MPa
Overpressure due to static head		Ph =	0 MPa
Calculation pressure	P = Pi + Ph	=	55.00 MPa
Required thickness	$t_r = \frac{D+2(c+c')}{2}(e^{\frac{P}{S\cdot E}}-1)+c+c_e+c'$	=	7.71 mm
		t ≥ tr (30.00 mm ≥ 7.71 mm): Ok	
Maximum allowable pressures (at the top of the vessel)			
New & cold (opening)		=	97.32 MPa
Hot & corroded (opening)		=	97.32 MPa
New & cold (cylinder)		=	176.25 MPa
Hot & corroded (cylinder)		=	176.25 MPa
Hydrostatic test			
Static head	Ph = ρgh	=	0.002 MPa
Item or side hydrostatic test pressure	Pt = 1.25 · MAWP · St/S	=	68.80 MPa
Allowable stress for the test condition	= 0,95·Sy	=	654.55 MPa
Calculation pressure	P = Pt + Ph	=	68.80 MPa
Minimum required thickness	$t_{rh} = \frac{D+2\cdot c'}{2}(e^{\frac{P}{S_k\cdot E}}-1)+c'$	=	4.71 mm
		t ≥ trh (30.00 mm ≥ 4.71 mm): Ok	

Minimum Design Metal Temperature (MDMT)

Internal pressure

Nozzle - Nozzle to wall - nozzle

Material:		CUSTOM ASTM A372 Grade N 100
Curve of fig. 3.7 / 3.8:		None
Governing Thickness	tg =	30.00 mm

PostWeld Heat Treatment: No

Minimum Design Metal Temperature (MDMT)

Impact tests required by Code: Yes

Note: All quenched and tempered steels listed in Table 3-A.2 shall be subject to Charpy V-notch testing, the corresponding MDMT shall not be colder than -104°C (-155°F).

Validation warnings

- Welds check has been disabled by the user (e.g. because the vessel is integrally forged)