

**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 JC-057996 - See Remarks 837 2024  
Horiz. or vert. tank Mfr.'s serial no. CRN Drawing no. Nat'l. Bd. no. 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.  
Year 2021 Class 2 Code case no. 2939

*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 35.1 mm 0 mm OD = 457 mm 9200 mm  
Material (spec. no., grade) Nom. thk. Corr. allow. Diameter Length (overall)

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

8. Heads: (a) Matl. A372 Gr.N Cl.100 Q&T (b) Matl. A372 Gr.N Cl.100 Q&T  
Spec. no., grade 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 - If bar, give dimensions -. If bolted, describe or sketch.  
Describe as ogree and weld, bar, etc.

11. MAWP 55 Mpa - at max. temp. 65°C - Min. design metal temp. -40°C at 55Mpa  
(Internal) (External) (Internal) (External)

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. - (b) Matl. -  
Spec. no., grade 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 - - at max. temp. - - Min. design metal temp. - at -  
(Internal) (External) (Internal) (External)

Impact test - At test temperature of -

Hydro., pneu., or comb test pressure -

(07/17)

Tearis Dalmine  
Quality Opt.

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-057996 CRN - National Board No. 837

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 Lugs - Legs - Other - Attached -  
 Yes or no No. No. Describe Where and how

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

Remarks:

0) PSV are responsibility 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	<u>Linde Hyrdogen FuelTech GmbH</u>		
Manufacturer's Design Report on file at	<u>DALMINE S.P.A., Piazza Caduti 6 Luglio 1944, 1, Dalmine (BG),24044 - Italy</u>		
User's Design Specification certified by	<u>Adriana Stefanescu</u>	PE State <u>EUR ING (FEANI)</u>	Reg. No. <u>34872</u>
Manufacturer's Design Report certified by	<u>NADARAJAH CHITHRANJAN</u>	PE State <u>VIRGINIA</u>	Reg. No. <u>0402052630</u>

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.	<u>55812</u>	expires	<u>February 1<del>8</del> 2027</u>
Date	<u>01 March 2024</u>	Co. name	<u>DALMINE S.P.A.</u>
		Signed	<u>[Signature]</u>
		Manufacturer	Representative

CERTIFICATE OF SHOP INSPECTION			
Vessel made by	<u>DALMINE S.P.A.</u>	at	<u>Piazza Caduti 6 Luglio 1944, 1, Dalmine (BG),24044 - Italy</u>
I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and employed by <u>LRQA Verification Ltd.</u> of <u>UK</u>			
have inspected the pressure vessel described in this Manufacturer's Data Report on <u>01 March 2024</u>			
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	<u>01 March 2024</u>	Signed	<u>[Signature]</u>
		Commissions	<u>AI 13420 B</u>
		Authorized Inspector	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-057996 CRN \_\_\_\_\_ National Board No. 837

**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.

*[Signature]*  
**AI 13420**  
01 March 2024





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Customer  
 Linde  
 O-AE-12-D-21-US-S  
 Revision =

## Calculation report

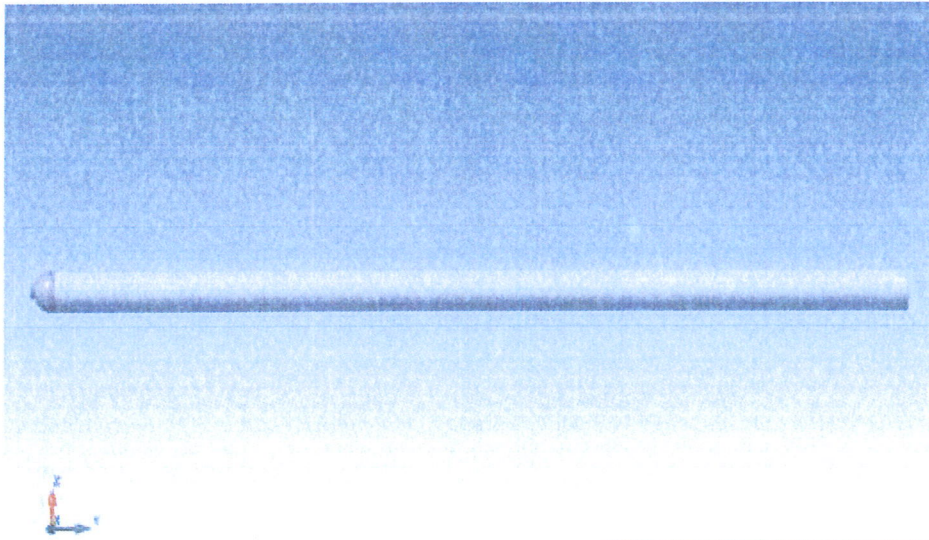
### Asme VIII Div. 2 Ed. 2021 - Metric Units

**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)



**Notes**

Material properties and design allowable stress according to code case 2939

LRQA Italy S.R.L.		LRQA
Name: Alessandro Salvatore Monastero		Signature
Date: 16 February 2024		
Ref No.: AI 13420 - Verify availability only		
Office: Milan		
<small>LRQA001 11/2021</small>		<small>A member of the LRQA Group Limited</small>



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### 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 =  $P_t = 1.25 \cdot MAWP \cdot St/S = 68.80$  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.



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## 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)

Nr	Dead			Dead additional			Live			Liquid	
	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
<b>Total</b>	<b>3396</b>	<b>3396</b>	<b>0</b>	<b>0</b>			<b>0</b>			<b>0</b>	<b>1097</b>

**Total volume: 1.09664 m<sup>3</sup>**

### 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	3318 kg	0 kg	0 kg	0 kg	0 kg	3318 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
<b>Total</b>	<b>3396 kg</b>	<b>0 kg</b>	<b>0 kg</b>	<b>0 kg</b>	<b>0 kg</b>	<b>3396 kg</b>

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



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**Weights for load combination : Test**

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

Nr	Dead	Bolts	Dead additional	Live	Liquid	Total
1	3318 kg	0 kg	0 kg	0 kg	1081 kg	4399 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	3396 kg	0 kg	0 kg	0 kg	1097 kg	4493 kg

Center of gravity: Cx=0 mm, Cy=4730.11 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	3318 kg	0 kg	0 kg	0 kg	0 kg	3318 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	3396 kg	0 kg	0 kg	0 kg	0 kg	3396 kg

Center of gravity: Cx=0 mm, Cy=4719.98 mm, Cz=228.50 mm



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### 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



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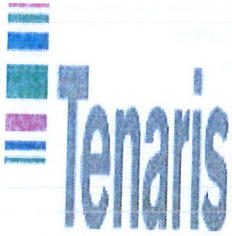
### Material properties summary

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



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

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**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 °	



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**Minimum Design Metal Temperature (MDMT)**

<i>Component</i>	<i>MDMT</i>	<i>T<sub>min</sub> ≥ MDMT</i>
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 T<sub>min</sub>: -40.00 °C / -40.00 °F**

**Impact tests required by Code**

Code	Impact tests required
ASME VIII Div 1	Not required
ASME VIII Div 2	Not required
ASME VIII Div 3	Not required
ASME VIII Div 4	Not required
ASME VIII Div 5	Not required
ASME VIII Div 6	Not required
ASME VIII Div 7	Not required
ASME VIII Div 8	Not required
ASME VIII Div 9	Not required
ASME VIII Div 10	Not required
ASME VIII Div 11	Not required
ASME VIII Div 12	Not required
ASME VIII Div 13	Not required
ASME VIII Div 14	Not required
ASME VIII Div 15	Not required
ASME VIII Div 16	Not required
ASME VIII Div 17	Not required
ASME VIII Div 18	Not required
ASME VIII Div 19	Not required
ASME VIII Div 20	Not required
ASME VIII Div 21	Not required
ASME VIII Div 22	Not required
ASME VIII Div 23	Not required
ASME VIII Div 24	Not required
ASME VIII Div 25	Not required
ASME VIII Div 26	Not required
ASME VIII Div 27	Not required
ASME VIII Div 28	Not required
ASME VIII Div 29	Not required
ASME VIII Div 30	Not required
ASME VIII Div 31	Not required
ASME VIII Div 32	Not required
ASME VIII Div 33	Not required
ASME VIII Div 34	Not required
ASME VIII Div 35	Not required
ASME VIII Div 36	Not required
ASME VIII Div 37	Not required
ASME VIII Div 38	Not required
ASME VIII Div 39	Not required
ASME VIII Div 40	Not required
ASME VIII Div 41	Not required
ASME VIII Div 42	Not required
ASME VIII Div 43	Not required
ASME VIII Div 44	Not required
ASME VIII Div 45	Not required
ASME VIII Div 46	Not required
ASME VIII Div 47	Not required
ASME VIII Div 48	Not required
ASME VIII Div 49	Not required
ASME VIII Div 50	Not required
ASME VIII Div 51	Not required
ASME VIII Div 52	Not required
ASME VIII Div 53	Not required
ASME VIII Div 54	Not required
ASME VIII Div 55	Not required
ASME VIII Div 56	Not required
ASME VIII Div 57	Not required
ASME VIII Div 58	Not required
ASME VIII Div 59	Not required
ASME VIII Div 60	Not required
ASME VIII Div 61	Not required
ASME VIII Div 62	Not required
ASME VIII Div 63	Not required
ASME VIII Div 64	Not required
ASME VIII Div 65	Not required
ASME VIII Div 66	Not required
ASME VIII Div 67	Not required
ASME VIII Div 68	Not required
ASME VIII Div 69	Not required
ASME VIII Div 70	Not required
ASME VIII Div 71	Not required
ASME VIII Div 72	Not required
ASME VIII Div 73	Not required
ASME VIII Div 74	Not required
ASME VIII Div 75	Not required
ASME VIII Div 76	Not required
ASME VIII Div 77	Not required
ASME VIII Div 78	Not required
ASME VIII Div 79	Not required
ASME VIII Div 80	Not required
ASME VIII Div 81	Not required
ASME VIII Div 82	Not required
ASME VIII Div 83	Not required
ASME VIII Div 84	Not required
ASME VIII Div 85	Not required
ASME VIII Div 86	Not required
ASME VIII Div 87	Not required
ASME VIII Div 88	Not required
ASME VIII Div 89	Not required
ASME VIII Div 90	Not required
ASME VIII Div 91	Not required
ASME VIII Div 92	Not required
ASME VIII Div 93	Not required
ASME VIII Div 94	Not required
ASME VIII Div 95	Not required
ASME VIII Div 96	Not required
ASME VIII Div 97	Not required
ASME VIII Div 98	Not required
ASME VIII Div 99	Not required
ASME VIII Div 100	Not required



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**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 = 9200.00 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  $t_r = \frac{D + 2(c + c')}{2} (e^{\frac{P}{SE}} - 1) + c + c_e + c' = 35.08 \text{ mm}$

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  $t_{rh} = \frac{D + 2 \cdot c'}{2} (e^{\frac{P}{SE}} - 1) + c' = 21.43 \text{ mm}$

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



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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).



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**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
<b>Material:</b>	<b>CUSTOM ASTM A372 Grade N 100 - Forgings</b>		
<b>Geometry</b>			
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
<b>Internal pressure</b>			
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		$t_r = \frac{D + 2 \cdot c'}{2} \left( e^{\frac{P}{2SE}} - 1 \right) + c + c_e + c'$	16.81 mm
		<b>t ≥ tr (35.10 mm ≥ 16.81 mm):</b>	<b>Ok</b>
<b>Maximum allowable pressures (at the top of the vessel)</b>			
New & cold		=	110.07 MPa
Hot & corroded		=	110.07 MPa
<b>Hydrostatic test</b>			
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		$t_{rh} = \frac{D}{2} \left( e^{\frac{P}{2S_y}} - 1 \right) + c'$	10.44 mm
		<b>t ≥ trh (35.10 mm ≥ 10.44 mm):</b>	<b>Ok</b>
	<b>Minimum Design Metal Temperature (MDMT)</b>		
Internal pressure			



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**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).*



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**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
<b>Nozzle material</b>	<b>CUSTOM ASTM A372 Grade N 100 - Forgings</b>		
<b>Shell material</b>	<b>CUSTOM ASTM A372 Grade N 100 - Forgings</b>		
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
		<b>tn &gt;= t(4.5.2) (30.00 mm ≥ 6.22 mm): Ok</b>	
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
Eff. length along nozzle wall inside vessel		$L_H = \min [t - c - c' + t_e + F_p \sqrt{R_n(t_n - c_n - c'_n)}, L_{pr1} + t - c - c']$	
Area contributed by the vessel wall		$L_I = \min [F_p \sqrt{R_n(t_n - c_n - c'_n)}, L_{pr2}] =$ $A_1 = (t - c - c_e - c')L_R =$	0 mm 2 891.9 mm <sup>2</sup>



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Nozzle outs. vessel wall area	$A_2 = (t_n - c_n - c'_n)L_H =$	2124.2 mm <sup>2</sup>
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 mm <sup>2</sup>
Area contributed by the outside nozzle fillet weld	$A_{41} = 0.5 \cdot L_{41}^2 =$	0 mm <sup>2</sup>
Area contributed by the pad to vessel fillet weld	$A_{42} = 0.5 \cdot L_{42}^2 =$	0 mm <sup>2</sup>
Area contributed by the inside nozzle fillet weld	$A_{43} = 0.5 \cdot L_{43}^2 =$	0 mm <sup>2</sup>
	$A_{5a} = W \cdot t_e =$	0 mm <sup>2</sup>
	A5b =	0 mm <sup>2</sup>
Area contributed by the reinforcing pad	$A_5 = \min[A_{5a}, A_{5b}] =$	0 mm <sup>2</sup>
Total area		

= 5016.2 mm<sup>2</sup>

$$A_T = A_1 + f_m(A_2 + A_3) + A_{41} + A_{42} + A_{43} + f_{rp} \cdot A_5$$

Effective thickness  $t_{eff} = t - c - c' + \left(\frac{A_5 \cdot f_{rp}}{L_R}\right) = 35.10 \text{ mm}$

Radius of the nozzle opening  $R_{nc} = R_n = 42.50 \text{ mm}$

Nozzle radius for force calculation  $R_{xn} = \frac{(t_n - c_n - c'_n)}{\ln\left[\frac{R_n + (t_n - c_n - c'_n)}{R_n}\right]} = 56.17 \text{ mm}$

Shell radius for force calculation  $R_{xs} = \frac{t_{eff}}{\ln\left[\frac{R_{eff} + t_{eff}}{R_{eff}}\right]} = 210.46 \text{ mm}$

Force from internal pressure in the nozzle  $f_N = P \cdot R_{xn} \cdot L_H = 218752 \text{ N}$

Force from internal pressure in the shell  $f_S = \frac{P \cdot R_{xs}(L_R + (t_n - c_n - c'_n))}{2} = 650489 \text{ N}$

Discontinuity force from internal pressure  $f_Y = \frac{P \cdot R_{xs} \cdot R_{nc}}{2} = 245978 \text{ N}$

Average primary membrane stress  $\sigma_{avg} = \frac{(f_N + f_S + f_Y)}{A_T} = 222.33 \text{ MPa}$

General primary membrane stress  $\sigma_{circ} = \frac{P \cdot R_{xs}}{2 \cdot t_{eff}} = 164.89 \text{ MPa}$

Allowable stress  $S_{allow} = 1.5 \cdot S \cdot E = 495.00 \text{ MPa}$

Maximum local primary membrane stress  $P_L = \max\{2 \cdot \sigma_{avg} - \sigma_{circ}, \sigma_{circ}\} = 279.76 \text{ MPa}$

Area resisting pressure  $A_p = \frac{f_N + f_S + f_Y}{P} = 20276.7 \text{ mm}^2$

PL ≤ Sallow: Ok

$P_{max1} = \frac{S_{allow}}{\frac{2 \cdot A_p}{A_T} - \frac{R_{xs}}{2 \cdot t_{eff}}} = 97.32 \text{ MPa}$

$P_{max2} = 2 \cdot S \left(\frac{t - c - c'}{R_{xs}}\right) = 110.07 \text{ MPa}$

$P_{max} = \min[P_{max1}, P_{max2}] = 97.32 \text{ MPa}$

P ≤ Pmax (55.00 MPa ≤ 97.32 MPa): Ok

### Hydrostatic test

Allowable stress for the vessel at test temperature  $S = 654.55 \text{ MPa}$

Allowable stress for the nozzle at test temperature  $S_n = 654.55 \text{ MPa}$

Nozzle inside radius  $R_n = d/2 + c_n' = 42.50 \text{ mm}$

Shell inside diameter  $D_i = 386.80 \text{ mm}$

Effective radius of the shell  $R_{eff} = 0.5 \cdot D_i + c' = 193.40 \text{ mm}$

Distance from the head center line to the nozzle center line  $DR = 0 \text{ mm}$

Nozzle projection from the outside of the vessel wall  $L_{pr1} = 39.90 \text{ mm}$

Nozzle projection from the inside of the vessel wall  $L_{pr2} = 0 \text{ mm}$



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Weld leg length of the outside nozzle fillet weld	$L_{41} =$	0 mm
Weld leg length of the pad to vessel fillet weld	$L_{42} =$	0 mm
Weld leg length of the inside nozzle fillet weld	$L_{43} =$	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		= 70.81 mm
	$L_H = \min[t - c' + t_e + F_p \sqrt{R_n(t_n - c'_n)}, L_{pr1} + t - c']$	
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	$A_1 = (t - c')L_R$	= 2891.9 mm <sup>2</sup>
Nozzle outs. vessel wall area	$A_2 = (t_n - c'_n)L_H$	= 2124.2 mm <sup>2</sup>
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 mm <sup>2</sup>
Area contributed by the outside nozzle fillet weld	$A_{41} = 0.5 \cdot L_{41}^2$	= 0 mm <sup>2</sup>
Area contributed by the pad to vessel fillet weld	$A_{42} = 0.5 \cdot L_{42}^2$	= 0 mm <sup>2</sup>
Area contributed by the inside nozzle fillet weld	$A_{43} = 0.5 \cdot L_{43}^2$	= 0 mm <sup>2</sup>
	$A_{5a} = W \cdot t_e$	= 0 mm <sup>2</sup>
	$A_{5b} =$	= 0 mm <sup>2</sup>
Area contributed by the reinforcing pad	$A_5 = \min[A_{5a}, A_{5b}]$	= 0 mm <sup>2</sup>
Total area		= 5016.2 mm <sup>2</sup>
	$A_T = A_1 + f_m(A_2 + A_3) + A_{41} + A_{42} + A_{43} + f_{rp} \cdot A_5$	
Effective thickness	$t_{eff} = t - c' + \left( \frac{A_5 \cdot f_{rp}}{L_R} \right)$	= 35.10 mm
Radius of the nozzle opening	$R_{nc} = R_n$	= 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 mm <sup>2</sup>

PL ≤ Sallow: Ok



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

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

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

$P \leq P_{\max}$  (68.80 MPa  $\leq$  193.02 MPa): Ok

Nozzle maximum allowable pressure (bottom)

### Validation warnings

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



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**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  $t_r = \frac{D + 2(c + c')}{2} (e^{\frac{P}{StE}} - 1) + c + c_e + c' = 7.71 \text{ mm}$

**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  $t_{rh} = \frac{D + 2 \cdot c'}{2} (e^{\frac{P}{StE}} - 1) + c' = 4.71 \text{ mm}$

**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



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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)

