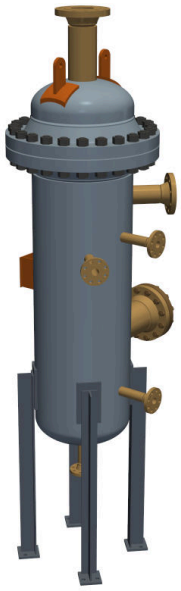
VCAL VERTICAL PRESSURE VESSEL
MECHANICAL CALCULATION DOSSIER

ASME VIII Division 1 design with Division 2 (Part 4 design-by-rule and Part 5 elastic stress analysis) verification; supports to ASCE 7-10 with UBC-97 response-spectrum seismic analysis (CalculiX modal analysis + SRSS in Python); lifting lugs; foundation loads.



PROJECT:	VCAL - VERTICAL PRESSURE VESSEL, 30 barg / 350 °C
PURCHASE ORDER:	-
DOCUMENT TITLE:	MECHANICAL CALCULATION DOSSIER
DOCUMENT NUMBER:	VCAL-06-CSH-00001
RELATED DOCUMENTS:	VCAL-06-DWG-00001 GENERAL ARRANGEMENT DRAWING (2 SHEETS); 3D MODEL VCAL_REV00.step
REVISION / DATE:	00 / 11/11/2026

Rev	DESCRIPTION	PREPARED	CHECKED	APPROVED	DATE
00	Issued for review	Claude (AI)	Pending	Pending	11/11/2026

COMPANY DOCUMENT APPROVAL STATUS		
A	Approved with no comments. Works can proceed.	
B	Approved with comments as noted. Contractor can proceed implementing the comments indicated by Company.	
C	NOT APPROVED. Revise and/or resubmit. Contractor cannot proceed with works.	

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PART A - ASME VIII DIVISION 1 PRESSURE DESIGN

6 ASME VIII DIVISION 1

6.1 Materials and allowable stresses (ASME II-D, metric)

COMPONENT	MATERIAL	S at 40 °C	S at 350 °C	Sy 40 / 350 °C	Su	SOURCE (II-D 2019)
Shell, nozzle necks	SA-106 Gr.B (seamless)	118	117	240 / 177	415	Table 1A p.82 line 10; Table Y-1 p.724 line 44
Heads, pads, lugs	SA-516 Gr.70	138	128	260 / 193	485	Table 1A p.86 line 33; Table Y-1 p.732 line 24
Flanges	SA-105	138	122	250 / 183	485	Table 1A p.86 line 19; Table Y-1 p.732 line 11
Stud bolts	SA-193 B7 (d<=64)	172	172	725 / 568	860	Table 3 p.464 line 32; Table Y-1 p.748 line 17

Units MPa. Modulus of elasticity (TM-1, carbon steel): 202 GPa at 25 °C, 179 GPa at 350 °C. Mean thermal expansion 20-350 °C (TE-1, group 1): 13.6 x 10^{-6} /°C.

6.2 Shell under internal pressure (UG-27 / Appendix 1-1)

P = 3.00 + 8.3 kPa static head = 3.008 MPa; Ro = 305.0 mm; S = 117 MPa; E = 1.0
t = P·Ro / (S·E + 0.4·P) = 7.76 mm (circumferential); longitudinal: 3.85 mm
Required nominal pipe wall = (t + CA) / 0.875 = (7.76 + 3) / 0.875 = **12.30 mm**
Selected: NPS 24 SCH.40 = 17.48 mm → minimum 15.29 mm, corroded 12.29 mm ≥ 7.76 mm **OK**
MAWP (hot, corroded) = S·E·t / (Ro - 0.4·t) = 4.79 MPa; MAP (new, cold) = 6.04 MPa

SCH.40 (heavier than the pressure minimum, SCH.XS) was chosen so that all openings are integrally reinforced without pads and to give margin for the nozzle and support loads at 350 °C.

6.3 2:1 ellipsoidal heads (UG-32(c) / Appendix 1-4(c))

HEAD	P (MPa)	t = P·Do·K / (2SE + 2P(K-0.1))	t + CA	min. after forming	MAWP (MPa)	MAP (MPa)	
Bottom	3.010	7.02 mm (K = 1.0)	10.02 mm	14 mm	4.76	6.61	OK
Top	3.000	7.00 mm (K = 1.0)	10.00 mm	14 mm	4.77	6.61	OK

S = 128 MPa (SA-516 Gr.70 at 350 °C), E = 1.0 (seamless head). Nominal plate 16 mm; straight flange 50.8 mm ≥ UG-32(k). Thickness difference at the head / shell weld = 1.48 mm < 3 mm: no taper required (UW-9(c)).

6.4 External pressure - full vacuum (UG-28 / UG-33)

Shell: L = 1658 mm (bottom T.L. + h/3 to the body flange), Do/t = 49.6, L/Do = 2.72 → A = 0.00131 (Fig. G), B = 58.4 MPa (Fig. CS-2, 370 °C curve)
Pa = 4B / (3·Do/t) = **1.57 MPa** ≥ 0.103 MPa **OK**
Heads (UG-33(d)): Ro = 0.9·Do = 549 mm, t = 11.0 mm → A = 0.125 / (Ro/t) = 0.00250, B = 67.0 MPa, Pa = B / (Ro/t) = **1.34 MPa** **OK**; UG-33(a)(1): t(1.67·Pext) = 0.41 mm

6.5 Body flange - ASME B16.5 NPS 24 Class 300 (UG-44)

The body flange is a pair of standard ASME B16.5 weld-neck flanges (SA-105, material group 1.1). Per UG-44(a) the flange is accepted on its pressure-temperature rating: **37.6 bar at 350 °C** ≥ 30 bar **OK**. O.D. 914.4 mm, thickness 69.9 mm, bolt circle 812.8 mm, 24 stud bolts 1 1/2" (bolt spacing 106 mm = 2.79 bolt diameters).

External loads at the joint (UG-44(b)): $16 \cdot M_E + 4 \cdot F_E \cdot G \le \pi \cdot G^3 \cdot [(P_R - P_D) + F_M \cdot P_R]$, G = 666.8 mm, F_M = 0.5
M_E = max(seismic 0.22, wind 0.22) + N3 piping 6.22 = 6.44 kN·m; F_E = 3.0 kN → 111 ≤ 2458 kN·mm (ratio 0.05) **OK**
Bolting (Appendix 2 loads, information): Wm1 = 1406 kN, Wm2 = 1376 kN → Am = 8174 mm² ≤ Ab = 21744 mm² **OK**

6.6 Nozzles: reinforcement (UG-37), neck thickness (UG-45), welds (UW-16)

NOZZLE	NPS / SCH	d (mm)	t / tr (mm)	tn / trn (mm)	A req.	A avail.	UG-37	UG-45 req / min	tc req / act	
H1	8" / 160	179.1	12.29 / 7.75	17.13 / 2.34	1388	1823	OK	10.16 / 20.13	6.0 / 7.0	OK
L1	2" / 160	48.8	12.29 / 7.76	4.65 / 0.64	379	415	OK (exempt)	6.42 / 7.65	3.3 / 7.0	OK
L2	2" / 160	48.8	12.29 / 7.74	4.65 / 0.64	378	416	OK (exempt)	6.42 / 7.65	3.3 / 7.0	OK
N1	4" / 160	93.3	12.29 / 7.74	8.80 / 1.22	722	859	OK	8.27 / 11.80	6.0 / 7.0	OK
N2	2" / 160	48.8	11.00 / 6.24	4.65 / 0.64	309	405	OK (exempt)	6.42 / 7.65	3.3 / 7.0	OK
N3	6" / 160	137.8	11.00 / 6.22	12.98 / 1.79	870	1302	OK	9.22 / 15.98	6.0 / 7.0	OK
N4	2" / 160	48.8	12.29 / 7.74	4.65 / 0.64	378	416	OK (exempt)	6.42 / 7.65	3.3 / 7.0	OK

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Areas in mm². Corroded condition; nozzle necks with 12.5 % under-tolerance. Shell nozzles: tr from UG-27 with E = 1; head nozzles: tr of a sphere of radius 0.9·D (UG-37(a)). Openings ≤ 60 mm (2" nozzles) are exempt from reinforcement calculation (UG-36(c)(3)) and shown for information. All nozzles are set-in with full-penetration welds and 10 mm cover fillets (Fig. UW-16.1(c)); no reinforcing pads.

6.7 MAWP

COMPONENT	MAWP (MPa) at top, hot and corroded
Shell (Div.1 UG-27)	4.79
Bottom head (Div.1 UG-32)	4.76
Top head (Div.1 UG-32)	4.77
B16.5 Cl.300 flanges incl. body flange (350 C)	3.76
Nozzle H1 reinforcement (Div.2 4.5)	4.27
Nozzle L1 reinforcement (Div.2 4.5)	4.56
Nozzle L2 reinforcement (Div.2 4.5)	4.56
Nozzle N1 reinforcement (Div.2 4.5)	4.12
Nozzle N2 reinforcement (Div.2 4.5)	4.96
Nozzle N3 reinforcement (Div.2 4.5)	4.54
Nozzle N4 reinforcement (Div.2 4.5)	4.56
Vessel MAWP	**3.76 MPa = 37.6 bar(g)** - governed by: B16.5 Cl.300 flanges incl. body flange (350 C)

6.8 Hydrostatic test (UG-99(b))

$P_T = 1.3 \cdot MAWP \cdot (S_{test}/S_{design})_{min} = 1.3 \cdot 3.76 \cdot 1.009 =$ **4.93 MPa (49.3 bar) at the top**; water head 22 kPa
Membrane stress at test: shell 97 MPa ≤ 0.9·Sy = 216 MPa; heads 103 MPa ≤ 234 MPa; B16.5 flange test limit 1.5 x 51.1 = 76.7 bar **OK**

6.9 MDMT (UCS-66)

COMPONENT	CURVE	tg (mm)	MDMT curve (°C)	ratio	reduction (°C)	MDMT (°C)
Shell SA-106 Gr.B pipe NPS 24 SCH.40	B	17.48	-12	0.63	20	-32
Heads SA-516 Gr.70 (as-rolled)	B	16.00	-15	0.64	20	-35
Nozzle neck H1 SA-106 Gr.B SCH.160	B	23.01	-4	0.14	76	-80
Nozzle neck N1 SA-106 Gr.B SCH.160	B	13.49	-20	0.14	76	-96
Nozzle neck N2 SA-106 Gr.B SCH.160	B	8.74	-29	0.14	76	-105
Nozzle neck N3 SA-106 Gr.B SCH.160	B	18.26	-11	0.14	76	-87
ASME B16.5 flanges SA-105 (incl. body flange)	UCS-66(c)(1)	-	-18	-	0	-18
Bolting SA-193 B7 / SA-194 2H	Fig. UCS-66 note (bolting)	-	-48	-	0	-48

Rated MDMT (warmest component) = -18 °C ≤ design MDMT -15 °C **OK**. Impact testing is not required.

6.10 Conclusions - Division 1

All pressure parts satisfy ASME VIII Division 1 for 30 bar(g) / 350 °C and full vacuum. Selected: shell NPS 24 SCH.40 (17.48 mm), heads 16 mm nominal, nozzle necks SCH.160, flanges ASME B16.5 Class 300. MAWP = 37.6 bar(g) (flange rating), hydrostatic test 49.3 bar(g), MDMT -15 °C.

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TAG	FLANGE	P (kN)	Vc (kN)	Vl (kN)	Mt (kN·m)	Ml (kN·m)	Mc (kN·m)	End thrust (kN)
N3	6" CL300 RF	3.00	4.50	4.50	3.38	2.70	2.02	47.7
N4	2" CL300 RF	0.64	0.96	0.96	0.25	0.19	0.14	6.1

7.3 Results

7.3.1 Part 4 - design by rule

Shell (4.3.3): t = (Do/2)·(1 - exp(-P/(S·E))) = 7.68 mm ≤ 12.29 mm corroded; MAWP = 4.85 MPa **OK**
Heads (4.3.7 → 4.3.6 with r = 0.17·D, L = 0.90·D): t = 11.0 mm, L/t = 48.1; P_{ak} (knuckle buckling) = 17.42 MPa, P_{ac} (crown) = 5.27 MPa → P_a = 5.27 MPa ≥ 3.01 MPa; required 6.36 mm **OK**
External pressure (4.4.5 / 4.4.9): shell F_{he} = 197 MPa, FS = 1.87 → P_a = 2.80 MPa; heads (equivalent sphere 0.9·Do) P_a = 3.41 MPa ≥ 0.103 MPa **OK**
Body and nozzle flanges (4.1.11 / 4.16.1): ASME B16.5 Class 300 rating 37.6 bar at 350 °C ≥ 30 bar **OK**

NOZZLE (4.5.5 / 4.5.10)	L_R	L_H	A_T (mm²)	$f_N+f_S+f_Y$ (kN)	P_L (MPa)	1.5·S·E	P_{max} (MPa)	
H1 (8", shell)	60.0	51.5	1669	164.7	124.4	177	4.28	OK
L1 (2", shell)	48.8	22.9	757	71.8	116.7	177	4.56	OK
L2 (2", shell)	48.8	22.9	757	71.6	116.4	177	4.56	OK
N1 (4", shell)	60.0	32.6	1074	108.5	129.0	177	4.12	OK
N2 (2", head)	48.8	21.7	680	64.4	116.3	192	4.97	OK
N3 (6", head)	76.3	39.2	1358	135.7	126.9	192	4.54	OK
N4 (2", shell)	48.8	22.9	757	71.6	116.4	177	4.56	OK

Test pressure (8.2.1): P_T = max(1.43·MAWP, 1.25·MAWP·S_T/S) = 6.36 MPa (Div.2 basis, for reference; the vessel is stamped to Div.1 and tested at 4.93 MPa)

7.3.2 Part 5 - elastic stress analysis (protection against plastic collapse and local failure)

Stresses were linearized along 34 stress classification lines (through-thickness lines at every nozzle junction in the longitudinal and transverse planes, nozzle necks, head crowns and knuckles, and the three main weld lines). Equivalent (von Mises) membrane and membrane + bending stresses are compared with S (general primary membrane), 1.5·S (local primary membrane) and S_{PS} = 3·S (primary + secondary).

STRESS CLASSIFICATION LINE	t (mm)	class	membrane (MPa)	limit	class	memb. + bend. (MPa)	limit	ratio	
H1 shell long.	12.3	PL	124.4	177	PL+Pb+Q	142.8	354	0.70	OK
H1 shell transv.	13.3	PL	43.9	177	PL+Pb+Q	70.5	354	0.25	OK
H1 neck long.	17.1	PL	82.8	177	PL+Pb+Q	108.1	354	0.47	OK
H1 neck transv.	17.1	PL	30.9	177	PL+Pb+Q	57.0	354	0.17	OK
L1 shell long.	12.3	PL	107.0	177	PL+Pb+Q	147.1	354	0.60	OK
L1 shell transv.	12.4	PL	51.1	177	PL+Pb+Q	63.4	354	0.29	OK
L1 neck long.	4.6	PL	34.6	177	PL+Pb+Q	43.5	354	0.20	OK
L1 neck transv.	4.6	PL	29.7	177	PL+Pb+Q	48.3	354	0.17	OK
L2 shell long.	12.3	PL	107.4	177	PL+Pb+Q	151.5	354	0.61	OK
L2 shell transv.	12.4	PL	47.9	177	PL+Pb+Q	59.9	354	0.27	OK
L2 neck long.	4.6	PL	33.5	177	PL+Pb+Q	41.2	354	0.19	OK
L2 neck transv.	4.6	PL	30.5	177	PL+Pb+Q	48.7	354	0.17	OK
N1 shell long.	12.3	PL	111.5	177	PL+Pb+Q	144.9	354	0.63	OK
N1 shell transv.	12.6	PL	50.2	177	PL+Pb+Q	73.7	354	0.28	OK
N1 neck long.	8.8	PL	37.0	177	PL+Pb+Q	65.8	354	0.21	OK
N1 neck transv.	8.8	PL	39.3	177	PL+Pb+Q	58.4	354	0.22	OK
N2 head N	11.0	PL	104.7	192	PL+Pb+Q	134.2	384	0.55	OK
N2 head E	11.0	PL	108.1	192	PL+Pb+Q	125.2	384	0.56	OK
N2 neck	4.6	PL	40.8	177	PL+Pb+Q	56.5	354	0.23	OK
N3 head N	10.9	PL	84.8	192	PL+Pb+Q	107.2	384	0.44	OK
N3 head E	10.9	PL	114.4	192	PL+Pb+Q	146.3	384	0.60	OK
N3 neck	13.0	PL	35.2	177	PL+Pb+Q	64.5	354	0.20	OK
N4 shell long.	12.3	PL	107.0	177	PL+Pb+Q	148.7	354	0.60	OK
N4 shell transv.	12.4	PL	48.6	177	PL+Pb+Q	61.7	354	0.27	OK
N4 neck long.	4.6	PL	34.3	177	PL+Pb+Q	43.0	354	0.19	OK
N4 neck transv.	4.6	PL	29.7	177	PL+Pb+Q	48.1	354	0.17	OK
Shell general (EL.950, 270 deg)	12.3	Pm	63.1	118	Pm+Pb	63.2	177	0.53	OK
Bottom head crown (r = 0.55 Ri)	10.7	Pm	64.6	128	Pm+Pb	74.0	192	0.50	OK

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STRESS CLASSIFICATION LINE	t (mm)	class	membrane (MPa)	limit	class	memb. + bend. (MPa)	limit	ratio	
Bottom head knuckle (r = 0.90 Ri)	10.5	PL	67.9	192	PL+Pb+Q	95.1	384	0.35	OK
Top head crown (r = 0.55 Ri)	10.7	Pm	72.1	128	Pm+Pb	76.4	192	0.56	OK
Top head knuckle (r = 0.90 Ri)	10.5	PL	66.3	192	PL+Pb+Q	95.0	384	0.35	OK
Shell / bottom head (W.L. 01)	12.3	PL	55.9	177	PL+Pb+Q	72.1	354	0.32	OK
Shell / body flange (W.L. 02)	12.3	PL	48.2	177	PL+Pb+Q	50.3	354	0.27	OK
Top head / body flange (W.L. 03)	12.2	PL	38.8	192	PL+Pb+Q	69.8	384	0.20	OK

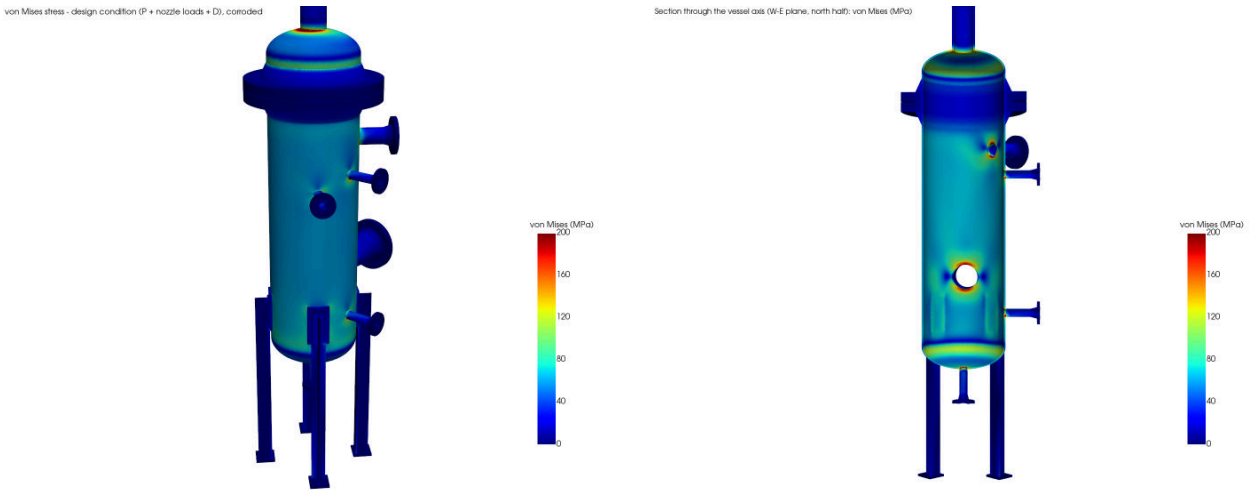


Figure 7-2 - von Mises stress, design condition: global view (left) and section through the vessel axis (right)

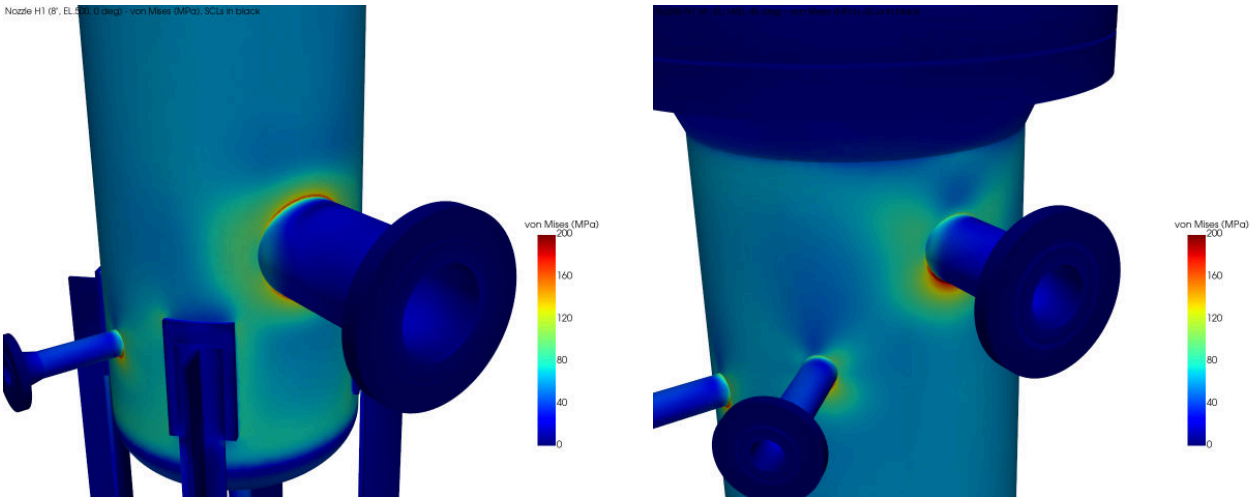


Figure 7-3 - Nozzles H1 (8") and N1 (4"): von Mises stress and SCLs

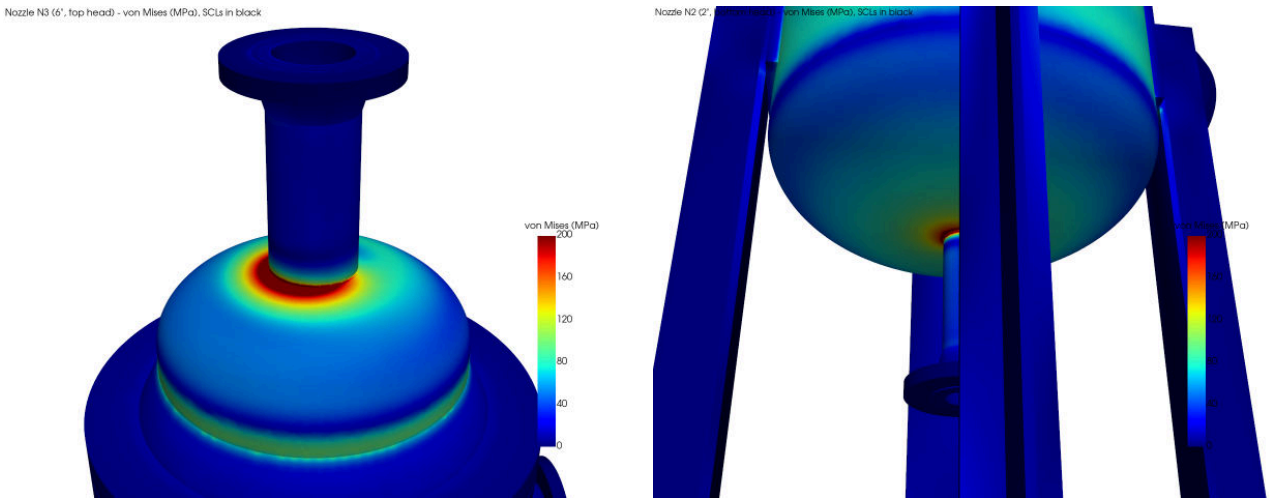


Figure 7-4 - Head nozzles N3 (6", top) and N2 (2", bottom): von Mises stress and SCLs

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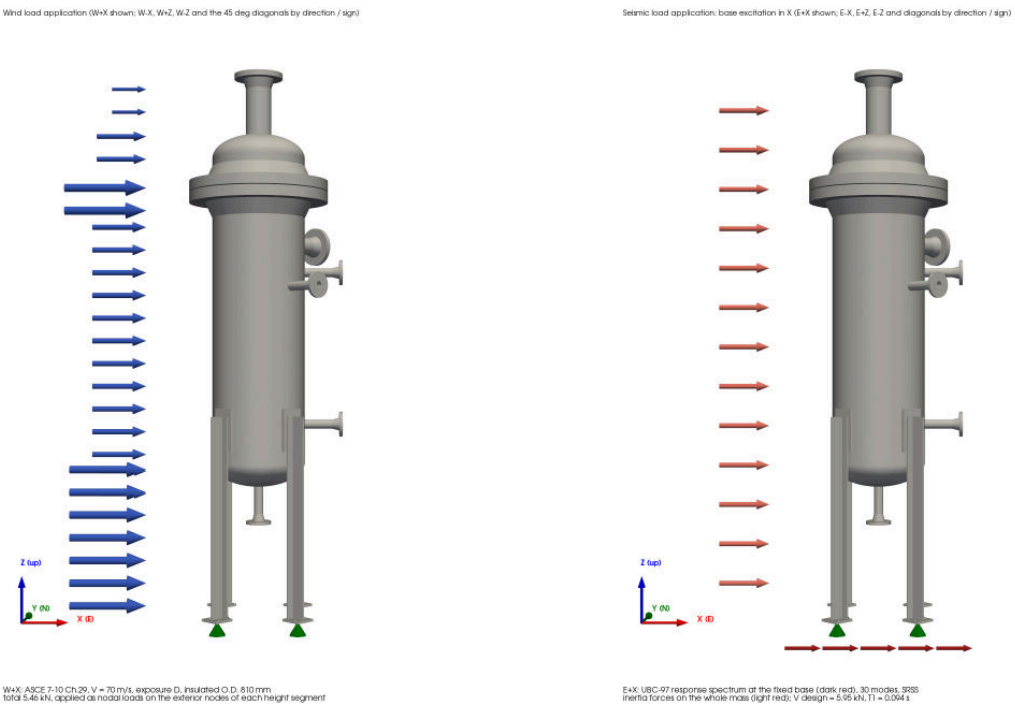


Figure 8-3 - Wind (left) and seismic (right) load application, direction +X shown

8.1.3 Snow, live and thermal loads

Snow (ASCE 7-10 eq. 7.3-1): $p_f = 0.7 \cdot C_e \cdot C_t \cdot I_s \cdot p_g = 1.75$ kN/m² on the plan area of the body flange (0.657 m²) → S = 1.15 kN
Live: L = 2.0 kN (maintenance) on the top head

Thermal (T): the vessel and the leg pads are at the design temperature (350 °C) and the legs cool down exponentially below the pads to ambient (15 °C); the radial growth of the shell (≈ 1.39 mm) bends the four fixed-base legs. The foundation case T is reported at the operating temperature (320 °C); the design-temperature case is used for the secondary-stress check.

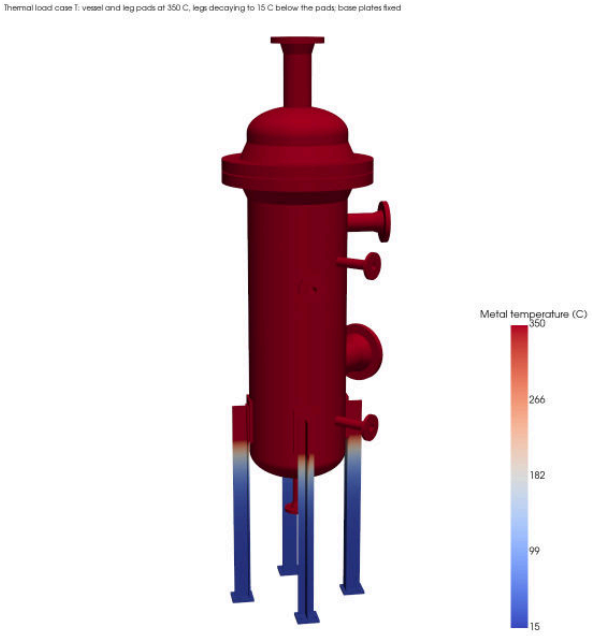


Figure 8-4 - Thermal load case: imposed metal temperatures

8.1.4 Seismic (UBC-97): modal analysis, mass participation and SRSS - step by step

Step 1 - Design spectrum. UBC-97 Zone 2B (Z = 0.2), soil profile SC: $C_a = 0.24$, $C_v = 0.32$ (Tables 16-Q / 16-R). Elastic design response spectrum, Fig. 16-3 (5 % damping): $S_a = C_a + 1.5 \cdot C_a \cdot T/T_0$ for $T \le T_0$; $S_a = 2.5 \cdot C_a = 0.60$ g for $T_0 \le T \le T_s$; $S_a = C_v/T$ for $T > T_s$, with $T_s = C_v/(2.5 \cdot C_a) = 0.533$ s and $T_0 = 0.2 \cdot T_s = 0.107$ s. I = 1.25, R = 2.2 (vessel on legs, Table

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16-P).

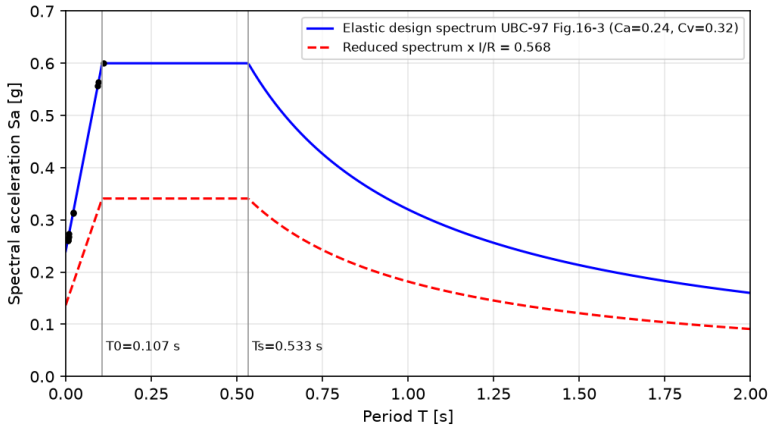


Figure 8-5 - UBC-97 design response spectrum rebuilt in Python, with the calculated modes

Step 2 - Modal analysis (CalculiX *FREQUENCY). Operating condition (mass 1771 kg), base plates fixed, 30 modes extracted. CalculiX returns the eigenvalues ω_i^2, the mass-normalised mode shapes φ_i, the participation factors $\Gamma_{i,d} = \varphi_i^T \cdot M \cdot r_d$ for a unit base motion in each direction d and the effective modal masses $M_{eff,i,d} = \Gamma_{i,d}^2$.

MODE	f (Hz)	T (s)	Sa (g)	Meff X (%)	Meff Y (%)	Meff Z (%)	Σ X (%)	Σ Y (%)	Σ Z (%)
1	8.98	0.1114	0.600	15.5	1.1	0.0	15.5	1.1	0.0
2	10.40	0.0961	0.564	6.7	90.0	0.0	22.3	91.1	0.0
3	10.66	0.0938	0.557	74.5	5.6	0.0	96.8	96.7	0.0
4	45.38	0.0220	0.314	0.0	1.3	0.3	96.8	98.0	0.3
5	46.29	0.0216	0.313	1.2	0.0	0.0	98.0	98.0	0.4
6	102.19	0.0098	0.273	0.0	0.0	0.0	98.0	98.0	0.4
7	121.64	0.0082	0.268	0.0	0.0	51.0	98.0	98.0	51.4
8	143.71	0.0070	0.263	0.0	0.0	40.2	98.0	98.0	91.6
9	151.34	0.0066	0.262	0.0	0.0	0.1	98.0	98.0	91.7
10	151.59	0.0066	0.262	0.0	0.0	0.0	98.0	98.0	91.7
11	162.81	0.0061	0.261	0.0	0.0	3.6	98.0	98.0	95.3
12	169.11	0.0059	0.260	0.0	0.0	0.1	98.0	98.0	95.5
13 - 30	176 - 354						98.4	98.4	97.1

Step 3 - Mass participation. Cumulative effective mass with 30 modes: X 98.4 %, Y (North) 98.4 %, vertical 97.1 % - above the 80 % required and the 90 % of UBC 1631.5.2. Modes 1 to 3 (vessel rocking on the legs in two directions and torsion, coupled by the eccentric handhole) carry 97 % of the horizontal mass.

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PART D - LIFTING LUGS

9 LIFTING LUGS

9.1 Material

COMPONENT	MATERIAL	Sy 40 °C	ALLOWABLE STRESSES	SOURCE
Lug plate 20 mm (item 143)	SA-516 Gr.70	260 MPa	tension 0.6·Sy = 156; shear 0.4·Sy = 104; bearing 0.9·Sy = 234; bending 0.66·Sy = 172 MPa	II-D Table Y-1 p.732 line 24; AISC ASD factors
Pad 16 mm (item 144) and top head	SA-516 Gr.70	260 MPa	local primary 1.5·S = 207 MPa	II-D Table 1A p.86 line 33
Fillet welds 8 mm	E70xx	-	0.49·S = 67.6 MPa (shear)	UW-18(d)

9.2 Load application

Two lugs on the top head at 0° / 180°, radius 215 mm. Design load = **2 x lifting weight** = 2 x 1442 kg x g = 28.3 kN (fabricated vessel without insulation, dynamic factor 2).

LC1 - vertical lift with spreader beam: F = 14.14 kN per lug

LC2 - slings at 60° from the horizontal, towards the vessel axis: F = 16.33 kN per lug (horizontal component 8.17 kN)

Local FE model (CalculiX, 203,186 nodes): lug, pad and a patch of the top head; the pin load is applied as a cosine bearing pressure on the loaded half of the hole and the cut edges of the head patch are fixed.

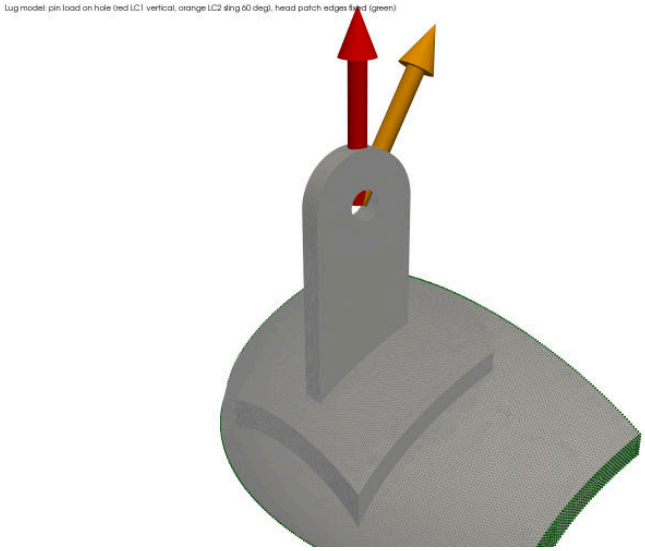


Figure 9-1 - Lifting lug model: load directions (LC1 vertical, LC2 sling at 60°) and supports

9.3 Results

CHECK (hand calculation, LC2)	STRESS (MPa)	ALLOWABLE (MPa)	RATIO	
Tension on the net section through the hole	12.8	156	0.08	OK
Shear tear-out (2 planes)	12.8	104	0.12	OK
Pin bearing (shackle pin 22.4 mm)	36.5	234	0.16	OK
Bending + tension at the base (e = 130 mm)	47.2	172	0.27	OK
Lug-to-pad fillet welds	53.5	67.6	0.79	OK
Punching shear of the head around the pad	2.2	110	0.02	OK

FE RESULT (von Mises, MPa)	LC1	LC2	ALLOWABLE	
Lug plate away from the pin contact	30.4	101.3	172	OK
Pad	24.5	80.9	207	OK
Top head	15.5	33.8	207	OK
Nominal pin bearing F / (d·t)	31.6	36.5	234	OK

Digital SimTec - to be checked and approved by a qualified engineer before fabrication.

Digital SimTec - extract for illustration (www.digitalsimtec.com). Full dossier on request.

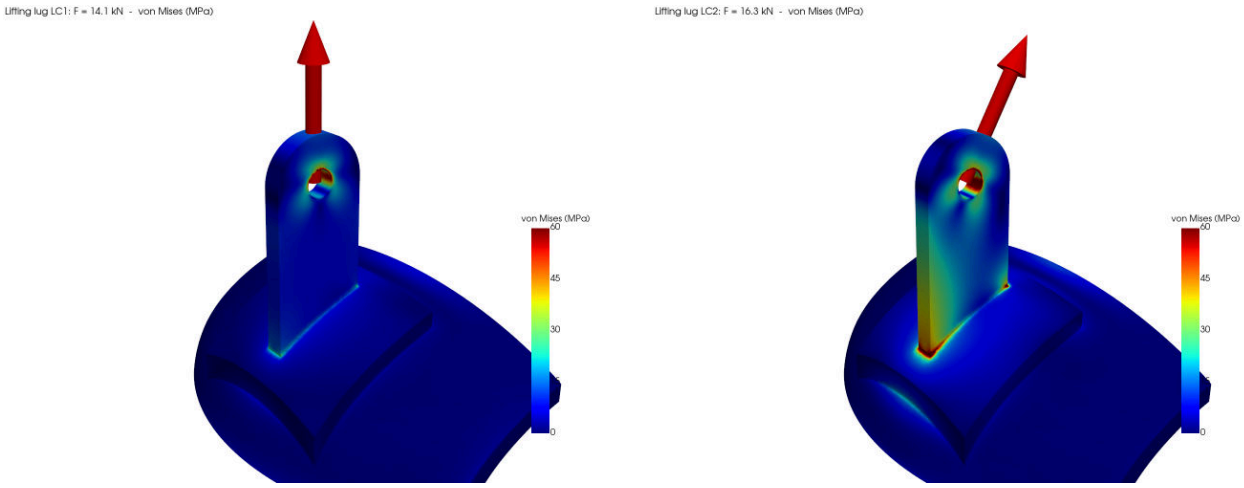


Figure 9-2 - Lifting lug: von Mises stress for LC1 (vertical) and LC2 (sling at 60°)

9.4 Conclusions - lifting lugs

Two lugs of 20 mm plate (R 45, hole Ø26, hole centre 130 mm above the pad) on 150 x 180 x 16 mm pads are adequate for twice the lifting weight in both lifting configurations; the highest utilisation is 0.79. Use shackles of 4.75 t WLL (pin 7/8"); a spreader beam is recommended so that the slings clear the N3 flange.

Digital SimTec - to be checked and approved by a qualified engineer before fabrication.

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10 SUMMARY OF RESULTS

ITEM	RESULT	
Shell NPS 24 SCH.40, Div.1 / Div.2	required 7.76 / 7.68 mm ≤ 12.29 mm corroded	OK
Heads 2:1 ellipsoidal 16 mm (min. 14)	required 10.02 mm (Div.1), 9.36 mm (Div.2)	OK
Full vacuum	Pa = 1.34 MPa (Div.1), 2.80 MPa (Div.2)	OK
Body flange B16.5 NPS 24 CL300	rating 37.6 bar at 350 °C; external loads ratio 0.05	OK
Nozzles (UG-37, UG-45, Div.2 4.5)	all integrally reinforced, no pads	OK
Part 5 elastic analysis (P + nozzle loads)	max. utilisation 0.70	OK
MAWP / hydrotest / MDMT	37.6 bar(g) / 49.3 bar(g) / -15 °C	OK
Weights (fabricated / operating / test)	1442 / 1779 / 2121 kg	
Modal analysis	f1 = 8.98 Hz; effective mass X 98.4 %, Y 98.4 %	OK
Seismic / wind base shear	5.95 kN / 5.46 kN	
Legs T 100x100x11 (AISC 360-10)	UI = 0.87; base plate 0.86; anchors 0.53	OK
Lifting lugs (2 x weight)	hand calculation and FE within the allowables	OK

This design was produced with automated calculations and must be checked and approved by a qualified pressure-vessel engineer before fabrication. Items marked as assumed in Section 5 (fluid, levels, external pressure, MDMT, insulation, site data) must be confirmed.

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