Design summary

TEMA size / type	**508 / 2325 · BEU, class R**	Shell MAWP (corroded)	**9.68 MPa**
Shell, OD × wall	**508 × 26.19 mm (20″ SCH 80)**	Head MAWP (corroded)	**11.17 MPa**
Design pressure, both sides	**1,600 kPa(g)**	Governing	**Class 600 nozzle flanges**
Design temperature	**150 °C**	Hydrotest, UG-99(b)	**2,080 kPa(g) per side**
MDMT	**−45 °C at 1,600 kPa(g)**	Joint efficiency, E	**1.0 seamless**
Corrosion allowance	**3.0 mm**	PWHT	**Not required, P-No. 1**

Materials of construction

Component	Material	Thk. mm	S at 150 °C, MPa	Impact test at −45 °C
Shell and bonnet cylinder	SA-333 Gr. 6	26.19	118	Per spec, LTCS
Heads, torispherical	SA-516 Gr. 70N	26.19	138	Cv at −45 °C
Tubesheet	SA-516 Gr. 70N	47	138	Cv at −45 °C
Girth flanges	SA-516 Gr. 70N	51	138	Cv at −45 °C
Tubes, U-bent	SA-179	2.11	92	UCS-66(b)(3)
Nozzle flanges	SA-350 LF2	B16.5	Group 1.1	Cv at −45 °C
Studs / nuts	SA-193 B7 / SA-194 2H	3/4″	172	Exempt to −48 °C

Element pressures and MAWP

Element	Design P, kPa(g)	tr + CA, mm	t corroded, mm	MAWP, MPa
Shell, 20″ SCH 80	1,600	6.16	19.92	9.68
Shell cover, torispherical	1,600	6.30	23.19	11.17
Bonnet head, torispherical	1,600	6.30	23.19	11.17
Nozzles N1–N4, Class 600	**1,600**	**–**	**–**	**9.07 (flange)**

Nozzle flange ratings at 150 °C, ASME B16.5 Group 1.1

Marks	Size	Class	Rating, kPa(g)	Design, kPa(g)	Margin
N1 N2 N3 N4	**4″**	**600**	**9,070**	**1,600**	**5.7 ×**
D1, V1–V2	1″	3000 cplg	–	1,600	B16.11

Result: shell, heads, flanges and nozzles satisfy ASME VIII-1 and TEMA class R at 1,600 kPa(g) and 150 °C. Nozzle flanges govern the MAWP.

Shell, UG-27(c)(1), corroded with 12.5 % mill tolerance

Corroded inside radius and thickness

$R = 254.0 - 26.19 + 3.0 = 230.81$ mm

$t = 26.19 \times 0.875 - 3.0 = 19.92$ mm

Required thickness and MAWP

$tr = P \cdot R / (S \cdot E - 0.6 \cdot P) = 1.6 \times 230.81 / (118 - 0.96) = 3.16$ mm + CA = 6.16 mm

$MAWP = S \cdot E \cdot t / (R + 0.6 \cdot t) = 118 \times 19.92 / (230.81 + 11.95) = 9.68$ MPa **OK**

Torispherical heads, Appendix 1-4(d)

Shape factor, L = 428 mm, r = 80 mm corroded

$M = \frac{1}{4} \cdot (3 + \sqrt{(L / r)}) = \frac{1}{4} \cdot (3 + \sqrt{(428 / 80)}) = 1.328$

Required thickness and MAWP

$tr = P \cdot L \cdot M / (2 \cdot S \cdot E - 0.2 \cdot P) = 1.6 \times 428 \times 1.328 / (276 - 0.32) = 3.30$ mm + CA = 6.30 mm

$MAWP = 2 \cdot S \cdot E \cdot t / (L \cdot M + 0.2 \cdot t) = 2 \times 138 \times 23.19 / (568.4 + 4.6) = 11.17$ MPa **OK**

Girth flanges, Appendix 2, bolting

Gasket, Ø557 × Ø500 × 4.5, m = 2.75, y = 25.5 MPa

$b0 = N / 2 = 14.25$ mm, $b = 2.5 \cdot \sqrt{b0} = 9.44$ mm

$G = 557 - 2 \cdot b = 538.1$ mm

$H = \pi/4 \cdot G^2 \cdot P = 363.9$ kN

$Hp = 2 \cdot b \cdot \pi \cdot G \cdot m \cdot P = 140.4$ kN

Bolt area, 36 × 3/4″ UNC, Sb = 172.4 MPa

$Wm1 = H + Hp = 504.3$ kN

$Wm2 = \pi \cdot b \cdot G \cdot y = 406.8$ kN

$Am = 504.3$ kN / 172.4 = 2,925 mm²

$Ab = 36 \times 194.8 = 7{,}013$ mm² ≥ Am **OK**

Tubesheet, bundle and supports

Check	Rule	Basis	Status
Stationary tubesheet, U-tube	UHX-12	Ø636 × 47, 136 holes at 25 square, both sides 1,600 kPa(g)	OK
Tube to tubesheet joints	UHX-15	Expanded, two grooves, Fig. UHX-15 type a	OK
Tubes, internal and external	UG-27, UG-28	3/4″ × 14 BWG SA-179	OK
Nozzle reinforcement N1–N4	UG-37	Set-through 4″ SCH 80, A avail ≥ A req	OK
Saddles, fixed and sliding	Zick	Horn, mid-span and wear plate stresses	OK
Impact test exemption	UCS-66	LTCS tested at −45 °C	OK

Hydrostatic test

Shop test pressure per side, UG-99(b)

$Pt = 1.3 \times 1{,}600 \times (118 / 118) = 2{,}080$ kPa(g), horizontal, each side separately **OK**

All checks satisfied. No warnings or errors.