XLZD Cryostat Design

Mass Estimates (As of 03/08/2023)

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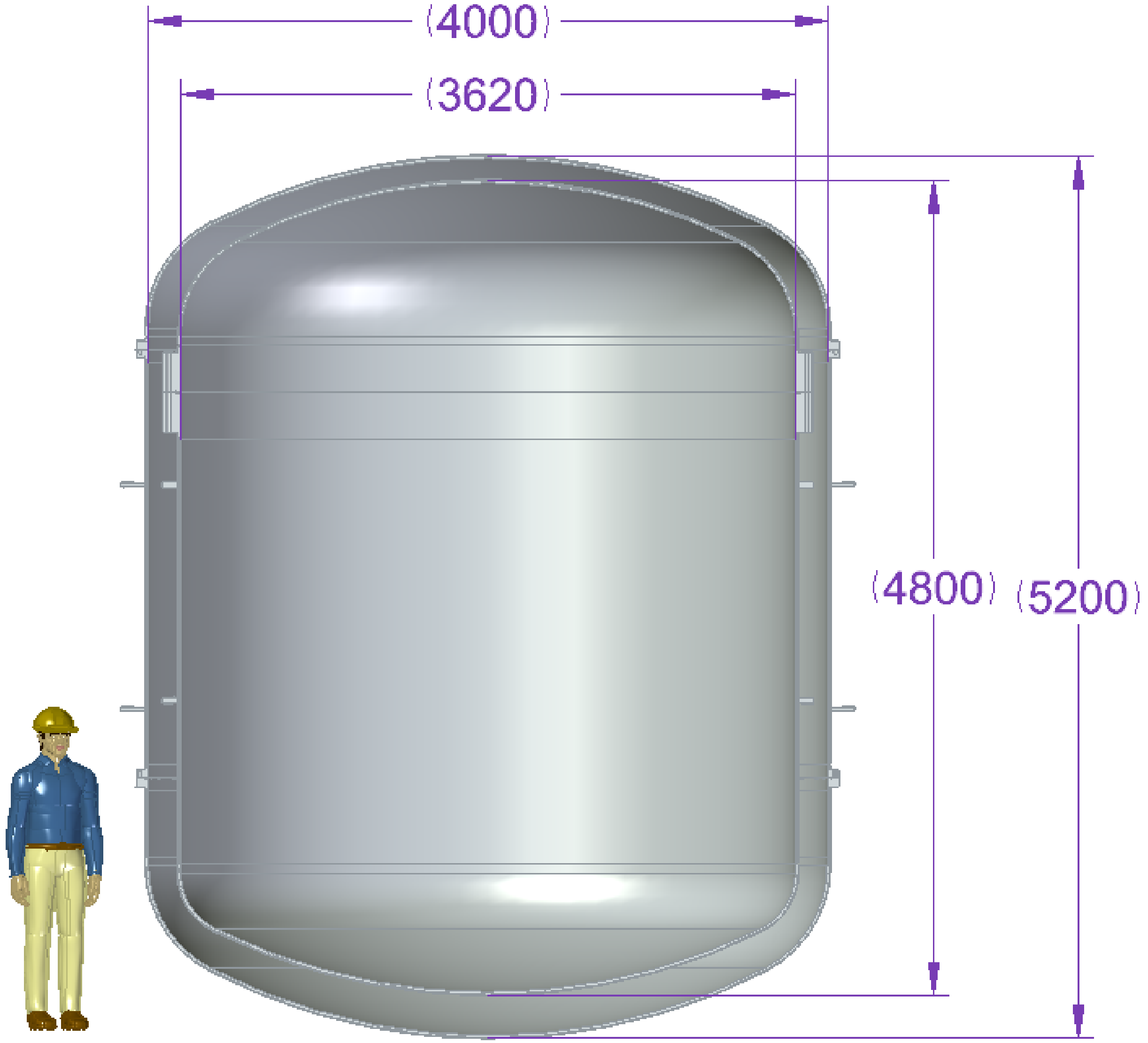
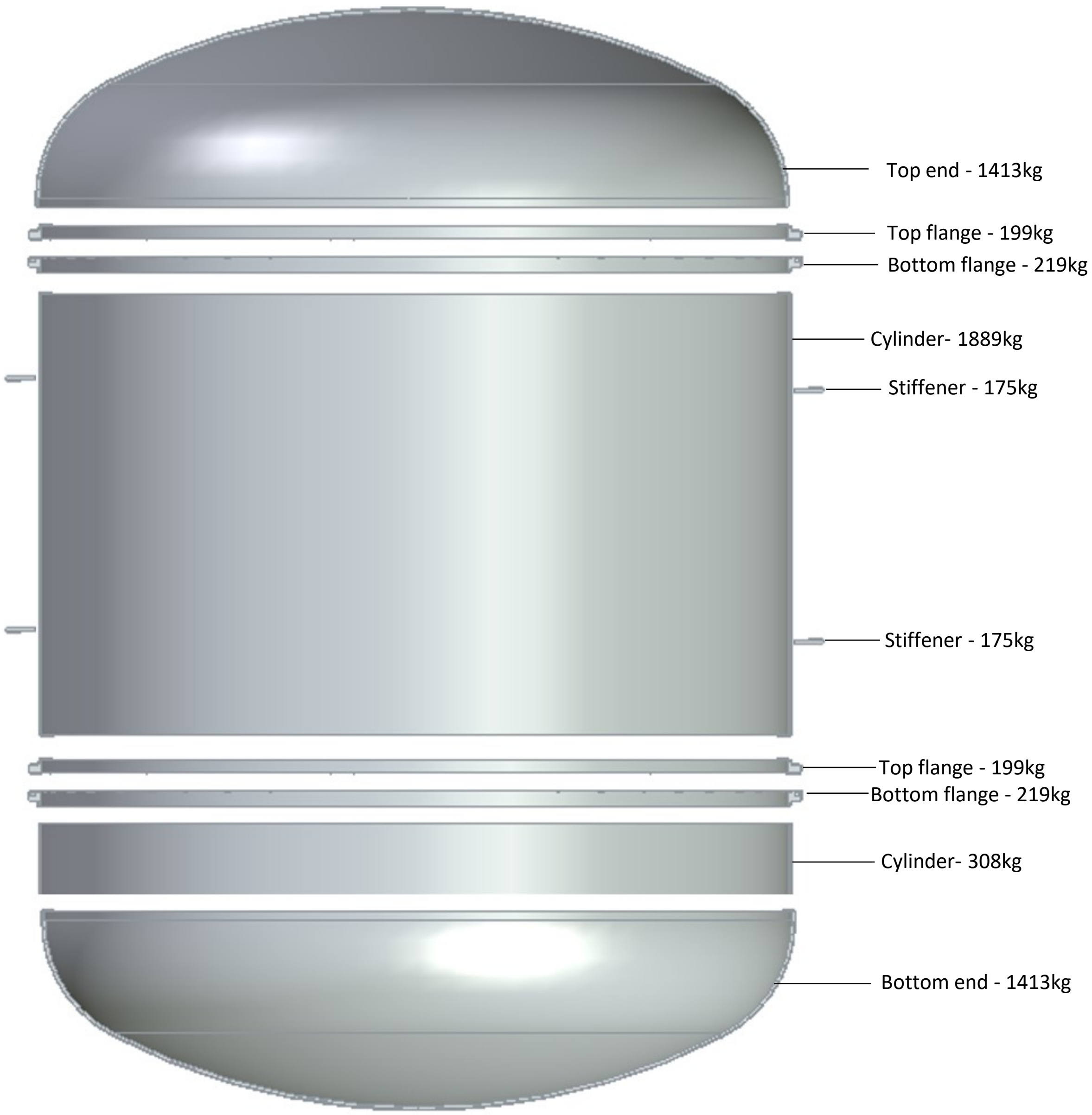
Design Notes:

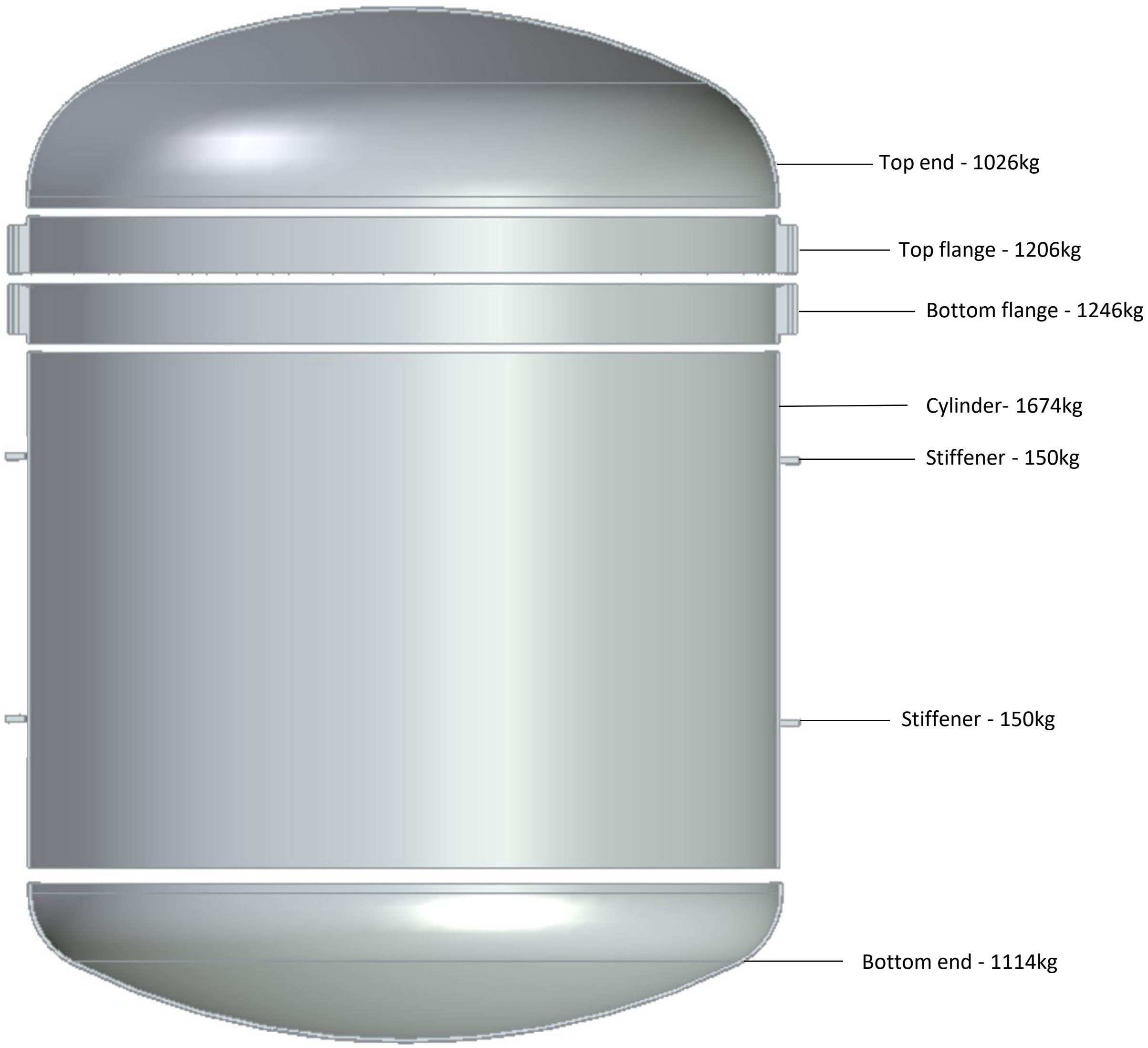
- OVC design pressures: 2bar external, 0.99bar internal
- ICV design pressures: 2bar external, 4.15bar internal
- Both vessels grade 1 titanium (assume T not exceeding 50°C)
- OCV height 5.2m, inner diameter 4.0m
- ICV height 4.8m, inner diameter 3.62m
- 2 equally spaced stiffeners on the OCV requires a 14mm cylinder thickness (no additional stiffening requires a 22mm cylinder thickness)
- 2 equally spaced stiffeners on the ICV requires a 13mm cylinder thickness (no additional stiffening requires a 20mm cylinder thickness)
- No additional stiffening from the bolted flanges yet considered
- No nozzles, openings, or external loads yet considered
- Awaiting additional information from Technetics to determine a more accurate ICV bolted flange thickness
- Stiffening ring dimensions and quantities to be optimised



OCV Masses:



ICV Masses:



Flat Bottom ICV – Preliminary Thickness Calculation

***PD* 5500: 2018 + *A*2: 2019**

3.5.5 *Flat ends and flat plates*

3.5.5.3.1 *Circular flat ends a) Flat ends without openings*

Design pressure $P = 0.415\ N/mm^2$

Nominal design stress $f = 77\ N/mm^2$

Inner diameter of vessel $D_i = 3620mm$

Analysis thickness of cylindrical shell $e_{cyl} = 13mm$

Mean diameter of the shell $D = 3620 + 13 = 3633mm$

Required shell thickness $e_{cylo} = \frac{pD}{2f} = \frac{0.415 \times 3633}{2 \times 77} = 9.79mm$

Ratio $\frac{e_{cyl}}{e_{cylo}} = \frac{13}{9.79} = 1.33$

Ratio $\frac{p}{f} = \frac{0.415}{77} = 0.00539$

Initially from Figure 3.5 − 36, $C \approx 0.67$

Required flat end thickness $e = CD\sqrt{\frac{p}{f}} = 0.67 \times 3633 \times \sqrt{\frac{0.415}{77}} = 178.7mm$

Note C can be taken as 0.41 *provided that* $\frac{e}{e_{cyl}} \le 1.5$ (*Note on Figure* 3.5 − 36)

Assume $C = 0.41$

$e = CD\sqrt{\frac{p}{f}} = 0.41 \times 3633 \times \sqrt{\frac{0.415}{77}} = 109.35$

$\frac{e}{e_{cyl}} = \frac{109.35}{13} = 8.41 \ge 1.5$ ∴ *assumption not valid and C must be taken as* 0.67

∴ *take flat end thickness as 180mm*

Check stress in shell to Annex R, ensuring that it is less than or equal to $2.7f$

$a = \frac{e}{e_{cyl}} = \frac{180}{13} = 13.85$

$b = \frac{D}{e_{cyl}} = \frac{3633}{13} = 279.46$

$I = \frac{1}{2} + \left(\frac{2.943a^3 - 3.74a + b^{1.5} + 0.909ab + 0.385b/a}{1.907a^3 + 4.848a + \frac{1.027}{a} + 2.667b^{0.5} + 5.875a^2/b^{0.5}}\right) = 3.54$

Maximum stress in cylinder $S = I \times \left(\frac{PD}{2e_{cyl}}\right) = 3.54 \times \left(\frac{0.415 \times 3633}{2 \times 13}\right) = 205.3\ N/mm^2$

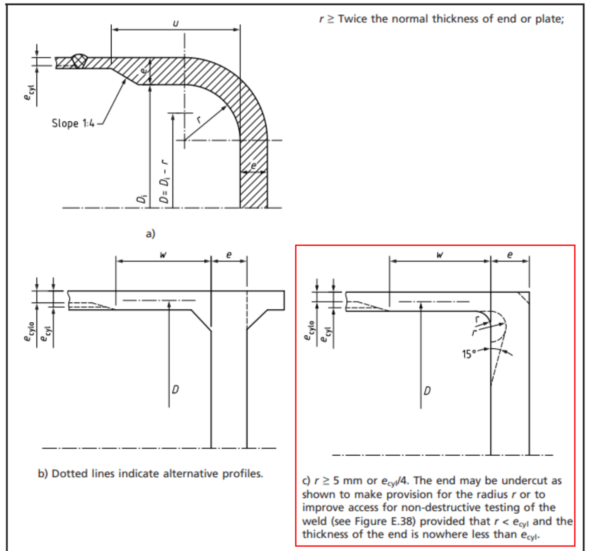
Maximim permitted stress $= 2.7f = 2.7 \times 77 = 207.9\ N/mm^2$ ∴ *Good*

Flat end volume $V = 1.879\ m^3$

Grade 1 Ti density $\rho = 4510\ kg/m^3$

Flat end mass $M = 8476kg$

Figure 3.5-34 **Typical welded flat ends and covers (for typical weld joint details, see Figure E.38)**

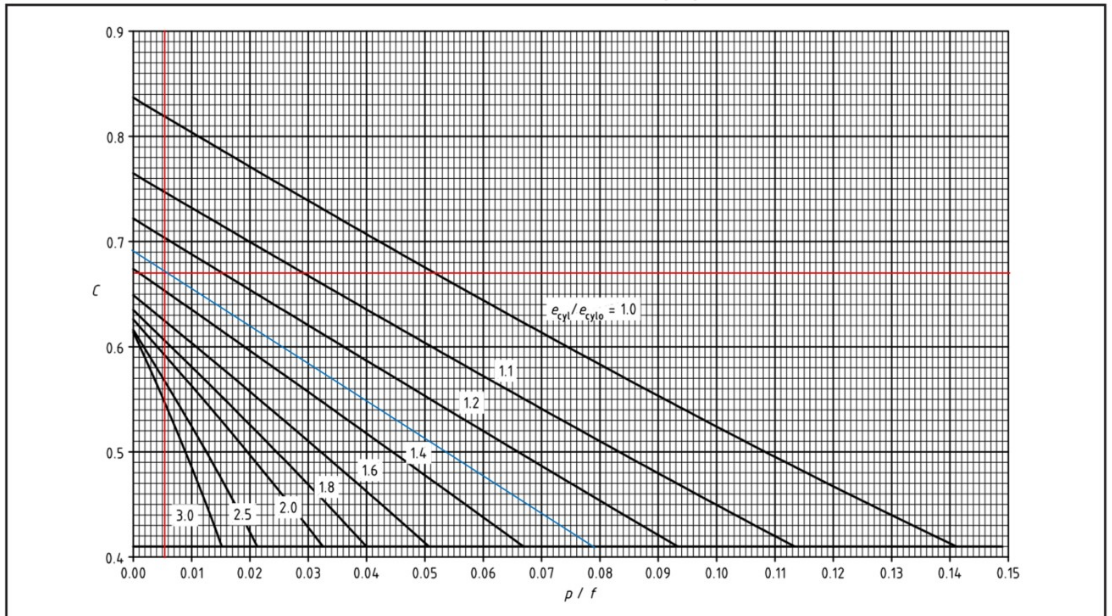


NOTE 1 The analysis thickness of the cylinder, e_{cyl} need only be maintained over a distance w from the end. The analysis thickness of the cylinder may be increased above e_{cyl} (but not so as to exceed e) local to the end and be reduced to a value not less than e_{cylo} at more distant points provided that the total cross-sectional area of the shell walls falling within the distance w from the end is not less than we_{cyl}. C is determined from Figure 3.5-35, Figure 3.5-37 or Table 3.5-8.

NOTE 2 In Figure 3.5-34b) and Figure 3.5-34c), D = mean diameter of cylinder.

Figure 3.5-34b) and Figure 3.5-34c), C is given by Figure 3.5-36, Figure 3.5-37 or Table 3.5-8;

Figure 3.5-36 **Factor C for welded flat ends [to Figure 3.5-34b) and Figure 3.5-34c)] for e_{cyl}/e_{cylo} = 1 to 3**



NOTE C = 0.41 is always valid when $e/e_{cyl} \le 1.5$.