Buckling Study: Central Flange Cover Seal

Note: The central flange cover seal should be capable of an external pressure of 1 bar.

Nomenclature:
Material: Al 5083
E = elastic modulus, Mpa
Sy = yield point, Mpa
μ = Poisson's ratio
D = diameter of the cylinder, mm
t = thickness of the cylinder, mm
L = length between supports, mm
R = rad of the cylinder, mm
FS = Factor of Safety (Normal)
FSx= Factor of Safety(Exceptional;CODAP)
A = Factor A (ASME BPV Code)
B = Factor B (ASME BPV Code)
Pcr* = critical pressure, bar
Pa* = allowable pressure, bar (@ FS=3)
Pa*x = allowable pressure, bar (@ FS = 2.2)

***** <---- Reference no.

I. Reference:
Theory of Elastic Stability, S. Timoshenko and J. Gere, Second Edition, Eq. 11-12, p. 478:

Conversion:

$MPa := 10^6\ Pa$

$bar := 10^5\ Pa$

Given data:

$E := 71000\ MPa$

$S_y := 117 \cdot MPa$

$\mu := 0.3$

$D := 4100\ mm$

$t := 5\ mm$

$L := 150\ mm$

$FS := 3$

$FSx := 2.2$

$R := \frac{D}{2}$

$n := 32$ <-- value of n when Pcr1 is minimum.

Let $Z := \left(1 + n^2 \frac{L^2}{\pi^2 \cdot R^2}\right)^2$

$$P_{cr1} := \frac{(E \cdot t)}{\left[\left(1 - \mu^2\right) \cdot R\right]} \cdot \left[\frac{\left(1 - \mu^2\right)}{\left[\left(n^2 - 1\right) \cdot Z\right]} + \left[\frac{t^2}{\left(12 \cdot R^2\right)} \cdot \left[n^2 - 1 + \left[\frac{\left(2 \cdot n^2 - 1 - \mu\right)}{Z}\right]\right]\right]\right]$$

$P_{cr1} = 2.463 \circ bar$

$P_{a1} := \frac{P_{cr1}}{FS}$

$P_{a1} = 0.821 \circ bar$ **<-- ASME Allowable; No good**

$P_{a1x} := \frac{P_{cr1}}{FSx}$ **<-- CODAP Allowable, exceptional situation**

$P_{a1x} = 1.119 \circ bar$ **<-- CODAP Allowable, exceptional situation; OK**

II. Reference:
Theory and Design Of Pressure Vessels (Harvey):

Critical Buckling Pressure:

$$P_{cr2} := 2.6 \cdot E \cdot \frac{\left(\frac{t}{D}\right)^{2.5}}{\left(\frac{L}{D}\right)}$$

<-- Eq. 8.5.13, Theory and Design of Pressure Vessels,1985, J. Harvey, p.583

$P_{cr2} = 2.621 \circ bar$

$$P_{a2} := \frac{P_{cr2}}{FS}$$

$P_{a2} = 0.874 \circ bar$ **<-- ASME Allowable; No good**

$$P_{a2x} := \frac{P_{cr2}}{FSx}$$ **<-- CODAP Allowable, exceptional situation**

$P_{a2x} = 1.191 \circ bar$ **<-- CODAP Allowable, exceptional situation; OK**

III. Reference:
Formulas For Stress And Strain (Roark & Young):

Critical Buckling Pressure:

From Table 35, #19b, Formulas For Stress And Strain, Roark & Young, 5th Edition:

$$P_{cr3} := 0.807 \cdot \left[E \cdot \frac{t^2}{(L \cdot R)}\right] \cdot \left[\left[\frac{1}{\left(1 - \mu^2\right)}\right]^3 \cdot \left(\frac{t}{R}\right)^2\right]^{0.25}$$

$P_{cr3} = 2.469 \circ bar$

$$P_{a3} := \frac{P_{cr3}}{FS}$$

$P_{a3} = 0.823 \circ bar$ **<-- ASME Allowable; No good**

$$P_{a3x} := \frac{P_{cr3}}{FSx}$$ **<-- CODAP Allowable, exceptional situation**

$P_{a3x} = 1.122 \circ bar$ **<-- CODAP Allowable, exceptional situation; OK**

IV. Reference:

ASME Boiler And Pressure Vessel Code, Sec. VIII, Div. I, Subsection A, Part UG-28: Thickness of Shells and Tubes Under External Pressure.

Allowable Buckling Pressure at FS = 3:

$$A := 1.3 \cdot \frac{\left(\frac{t}{D}\right)^{1.5}}{\left(\frac{L}{D}\right)}$$

$$B := A \cdot \frac{E}{2}$$

$$P_{a4} := \frac{\frac{4}{3} \cdot B}{\left(\frac{D}{t}\right)}$$

$P_{a4} = 0.874 \cdot bar$ **<-- ASME Allowable; No good**

$P_{a4x} := \left(\frac{FS}{FSx}\right) \cdot P_{a4}$ **<-- CODAP Allowable, exceptional situation**

$P_{a4x} = 1.191 \cdot bar$ **<-- CODAP Allowable, exceptional situation; OK**

Note: During normal conditions, the seal will be under internal pressure , and at this condition it will be supported by the central flange itself. It may get subjected to external pressure loading during leak-checking operations when the cold vessel is brought into vacuum internally. Thus, this external loading condition should be considered an exceptional situation.