$$M_\beta := K_7 \cdot Q \cdot R_m \qquad M_\beta = -2.223 \times 10^3\, N \cdot m$$

c) Circ. stress in shell, without stiffening rings

$$x_1 := 0.78\sqrt{R_m \cdot t_{pv}} \qquad x_1 = 6.456\,cm \qquad x_2 := x_1 \qquad k = 0.1$$

$$\sigma_6 := \frac{-K_5 \cdot Q \cdot k}{t_{pv} \cdot (b + x_1 + x_2)} \qquad \sigma_6 = -3.104\,MPa$$

$L < 8R_m = 1$ $\qquad L = 1.6\,m \qquad b_1 = 14.411\,cm$

$$\sigma_7 := \frac{-Q}{4t_{pv} \cdot (b + x_1 + x_2)} - \frac{12K_7 \cdot Q \cdot R_m}{L \cdot t_{pv}^2} \qquad \sigma_7 = 156.484\,MPa \qquad (4.15.25)$$

too high; we need a reinforcement plate of thickness;

$t_r := 0.5t_{pv}$ strength ratio: $\eta := 1$ (4.15.29)

$$\sigma_{7r} := \frac{-Q}{4(t_{pv} + \eta \cdot t_r) \cdot b_1} - \frac{12K_7 \cdot Q \cdot R_m}{L \cdot (t_{pv} + \eta \cdot t_r)^2} \qquad \sigma_{7r} = 67.28\,MPa \qquad (4.15.28)$$

3) f) Acceptance Criteria

$$S = 1.379 \times 10^8\, Pa \qquad S = 2 \times 10^4\, psi$$

$|\sigma_{7r}| < 1.25S = 1$

4) this section not applicable as $t_r > 2t_{pv} = 0$

4.15.3.6 - Saddle support, horizontal force given below must be resisted by low point of saddle (where height = h_s)

$$F_h := Q \cdot \left(\frac{1 + \cos(\beta) - 0.5 \cdot \sin(\beta)^2}{\pi - \beta + \beta \cdot \sin(\beta)\cos(\beta)}\right) \qquad F_h = 5.242 \times 10^4\, N \qquad h_s := 9cm$$

$$\sigma_h := \frac{F_h}{b \cdot h_s} \qquad \sigma_h = 38.833\,MPa$$

ANGEL Torispheric Head Design, using (2010 ASME PV Code Section VIII, div. 1, UG-32 Formed heads and sections, Pressure on Concave Side, Appendix 1-4 rules eq 3

$P = 1.561 \times 10^{6}\,\mathrm{Pa}$ $\quad E = 1$ $\quad S = 2 \times 10^{4}\,\mathrm{psi}$

I.D.

$D_i := 2R_{i\_pv}$

O.D.

$D_o := D_i + 2t$ $\qquad D_o = 1.435\,\mathrm{m}$

Crown radius:

Knuckle radius:

$L_{cr} := 1D_i$ $\quad L_{cr} = 1.36\,\mathrm{m}$ $\qquad r_{kn} := 0.1D_i$ $\qquad r_{kn} = 0.136\,\mathrm{m}$

$E = 1$ $\quad S_{div1} := 20000\mathrm{psi}$

Appendix 1-4 mandatory Supplemental Design Formulas

Ug-32 does not give equations for a range of crown and knuckle radii; these are found in App 1-4

$$\frac{L_{cr}}{r_{kn}} = 10$$

$$M := \frac{1}{4}\left(3 + \sqrt{\frac{L_{cr}}{r_{kn}}}\right) \qquad M = 1.541$$

Minimum shell thickness:

$$t_{min} := \frac{P \cdot L_{cr} \cdot M}{2S \cdot E - 0.2P} \qquad t_{min} = 11.871\,\mathrm{mm} \qquad (3)$$

note: we will need full weld efficiency for the above thickness to be permissible, as per UG-32(b)

this formula is only valid if the following equation is true (1-4(a))

$$\frac{t_{min}}{L_{cr}} \geq 0.002 = 1 \qquad \frac{t_{min}}{L_{cr}} = 8.729 \times 10^{-3}$$

ANGEL Torispheric Head Design, using (2010 ASME PV Code Section VIII, div. 2, part 4 rules)
2 nozzle head using standard dimension head **DRAFT** D. Shuman, LBNL, July12, 2011

4.3.6.1 Torispheric head with same crown and knuckle thickness, standard dimensions.

(a) Step 1, determine I.D. and assume the following:

thickness:

$t := 9.30\text{mm}$ $t = 0.93\,\text{cm}$ $S_{div2} := 16700\text{psi}$ 304L, 316L under div 2

crown and knuckle radii:

$L_{cr} = 1.36\,\text{m}$ $r_{kn} = 13.6\,\text{cm}$

(b) Step 2- Compute the following ratios and check:

$$0.7 \le \frac{L_{cr}}{D_i} \le 1.0 = 1$$

$$\frac{r_{kn}}{D_i} \ge 0.06 = 1$$

$$20 \le \frac{L_{cr}}{t} \le 2000 = 1$$

for all true, continue, otherwise design using part 5 rules

(c) Step 3 calculate:

thickness, this is an iterated value after going through part 4.5.10.1
(openings) further down in the document

$$\beta_{th} := \operatorname{acos}\left(\frac{0.5D_i - r_{kn}}{L_{cr} - r_{kn}}\right) \qquad \beta_{th} = 1.11\,\text{rad}$$

$$\phi_{th} := \frac{\sqrt{L_{cr}\cdot t}}{r_{kn}} \qquad \phi_{th} = 0.827\,\text{rad}$$

$$R_{th} := \begin{cases} \dfrac{0.5D_i - r_{kn}}{\cos(\beta_{th} - \phi_{th})} + r_{kn} & \text{if } \phi_{th} < \beta_{th} \\ 0.5D_i & \text{if } \phi_{th} \ge \beta_{th} \end{cases} \qquad \begin{matrix} \phi_{th} < \beta_{th} = 1 \\ \phi_{th} \ge \beta_{th} = 0 \end{matrix}$$

$$R_{th} = 0.703\,\text{m}$$

(d) Step 4 compute:

$$C_{1ts} := \begin{cases} \left[9.31\left(\dfrac{r_{kn}}{D_i}\right) - 0.086\right] & \text{if } \dfrac{r_{kn}}{D_i} \le 0.08 \qquad \dfrac{r_{kn}}{D_i} \le 0.08 = 0 \qquad (4.3.12) \\ \left[0.692\left(\dfrac{r_{kn}}{D_i}\right) + 0.605\right] & \text{if } \dfrac{r_{kn}}{D_i} > 0.08 \qquad \dfrac{r_{kn}}{D_i} > 0.08 = 1 \qquad (4.3.13) \end{cases}$$