

**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**

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

I.D.

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

O.D.

$$D_o := D_i + 2t \quad D_o = 1.432 \text{ m}$$

Crown radius:

Knuckle radius:

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

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

**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

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

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

Minimum shell thickness:

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

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))

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

Set head thickness:

$$t_h := 12 \text{ mm}$$

### Nozzle wall thickness required

Internal radius of finished opening

$$R_n := 4.28\text{cm}$$

Thickness required for internal pressure:

$$t_{rn} := \frac{P \cdot R_n}{S \cdot E - 0.6 \cdot P} \quad t_{rn} = 0.488\text{ mm}$$

We set nozzle thickness

$t_n := 8\text{mm}$  we are limited by need to maintain CF bolt pattern which has typically a 4inch OD pipe with room for outside fillet weld

$$D_{on} := 2(R_n + t_n) \quad D_{on} = 4\text{ in}$$

External pressure:

nozzles on head are very short; no analysis needed. Nozzle extensions are longer:

$$L_{ff\_ne} := 40\text{cm} \quad t_{ne} := 5\text{mm}$$

$$\frac{L_{ff\_ne}}{2R_n} = 4.673 \quad 2 \frac{R_n}{t_{ne}} = 17.12$$

From charts HA-1 and HA-2 above:

$$A_{ne} := .02 \quad B_{ne} := 13000\text{psi}$$

$$P_{a\_ne} := \frac{4B_{ne}}{3 \left( \frac{2R_n}{t_{ne}} \right)} \quad P_{a\_ne} = 68.875\text{ bar} \quad \text{OK}$$

### UG-37 Reinforcement Required for Openings in Shells and heads