**Flange (main service flange) thickness**: **DRAFT, needs further analysis** D. Shuman, 2/7/11

inner radius max. allowable pressure

$R_{i\_pv} = 0.66\,m$ $MAWP_{pv} = 15.4\,bar$ (gauge pressure)

Assume we use only O-rings to seal, with minimal compressive load; then there is no moment from gasket.There is no O-ring type figure in fig. UG-34 but we should be able to say (fig UG-34(p)) is equivalent (also no moment). Then, From UG-34 (sec. VIII-div. 1), eq (1):

minimum flat head thickness:

$$t := d\cdot\sqrt{\frac{C\cdot P}{S\cdot E}} \qquad t := 2R_{i\_pv}\cdot\sqrt{\frac{.25\cdot MAWP_{pv}}{S_{max\_Ti\_g3}}} \qquad t = 7.68\,cm$$

However, we have a large central opening in this flange; this is covered in UG-39, specifically UG-39 (c)(1) which specifies Appendix 14 and related factors in Appendix 2 for design of flat heads with large central hole, where d(hole)>0.5d(head). Also, UG-39(c)(2) allows multiple openings around said large central hole if head is area reinforced per UG-39(b)(1). However, Appendix 14 is for integral flat heads with large central openings, which we do not have (in Scope 14-1(a)), and Appendix 2, (Scope 2-1(a)) is for bolted flange connections having no flange to flange contact outside the bolt circle, which also does not apply because we have flange to flange contact outside the bolt circle when using either an Helicoflex gasket or O-ring seal. None of the above sections make any direction elsewhere, so we are stranded at this point with no clear direction. However, there happens to be an non-mandatory Appendix Y, for bolted joint metal-to-metal contact outside of bolt circle, which is what we have:

From sec. VIII div 1, non-mandatory appendix Y for bolted joints having metal-to-metal contact outside of bolt circle. First define, per Y-3:

hub thickness at flange

$g_1 := t_{pv\_min\_g3}$ $g_1 = 0.902\,cm$ (ti grade 3)

Flange OD

$A := 150cm$

Flange ID

$B := 2R_{i\_pv}$ $B = 1.32\,m$

define:

$B_1 := B + g_1$ $B_1 = 1.329\,m$

B.C dia, C:

$C := 1.42m$

Gasket dia

$G := 1.34m$

Force of Pressure on head

$H := .785G^2\cdot MAWP_{pv}$ $H = 2.2\times 10^6\,N$ =

Helicoflex gasket, 8mm xsec dia.

Groove width, depth

$G_g := 1\text{cm}$ $\qquad F_g := .7\text{cm}$

Sealing force, unit, assume silver jacket, from helicoflex lit.:

$Y_2 := 490\frac{N}{mm}$ $\qquad D_j := G$ $\quad D_j = 1.34\,m$ $\quad F_j := 2\pi \cdot D_j \cdot Y_2$ $\qquad F_j = 4.126 \times 10^6\,N$

We will use 72 bolt holes, so as to intersperse with Xe flow holes which exit sideways

$n := 72$

Start by making trial assumption for bolt, dia., bolt hole dia D, and nut width (across flats OK; we will rotate nut on main service flange, not nut on vessel flange:

$d_{b\_t} := 36mm$ $\quad D_t := 38mm$ $\qquad w_n := 0.5 \cdot 55mm$ $\qquad w_n = 27.5\,mm$

Then, define the following:

$R_. := \frac{C - B}{2} - g_1$ $\quad R_. = 4.098\,cm$ $\qquad$ check, must be > $\quad w_n = 0.028\,m$

$H_G := F_j$ $\qquad H_G = 4.126 \times 10^6\,N$

$h_G := 0.5(C - G)$ $\qquad h_G = 4\,cm$

$H_D := .785 \cdot B^2 \cdot MAWP_{pv}$ $\qquad H_D = 2.135 \times 10^6\,N$

$h_D := D_t$ $\qquad h_D = 3.8\,cm$

$H_T := H - H_D$ $\qquad H_T = 6.518 \times 10^4\,N$

$h_T := 0.5(C - B)$ $\qquad h_T = 50\,mm$

$M_p := H_D \cdot h_D + H_T \cdot h_T + H_G \cdot h_G$ $\qquad M_p = 2.494 \times 10^5\,J$

From Y-9, Trial bolt are required

$$A_{b'} := \frac{\left(H + \frac{2M_p}{A - C}\right)}{S_{max\_Ti\_g9}} \qquad A_{b'} = 0.048\,m^2$$

$$d_{b'} := \frac{4}{\pi} \cdot \sqrt{\frac{A_{b'}}{72}} \qquad d_{b'} = 32.739\,mm$$ check, must be < $\quad D_t = 3.8\,cm$

Choosing ISO fine thread, with pitch; thread depth

$p_t := 2mm$ $\quad d_t := .614 \cdot p_t$

Minimum bolt dia is then;

$d_{b\_min} := d_{b'} + 2d_t$ $\qquad d_{b\_min} = 35.195\,mm$

We use a 36-2 metric fine thread, to provide cleareace we will need :

$D := 38mm$ $\qquad$ check, should be = $\quad D_t = 0.038\,m$

From Y-9, Trial flange thickness

First compute the following:

$$t_a := 2.45\sqrt{\frac{M_p}{(\pi C - n \cdot D) S_{max\_Ti\_g2}}} \qquad t_a = 9.382\,cm$$

$$t_b := 0.56 B_1 \cdot \sqrt{\frac{MAWP_{pv}}{S_{max\_Ti\_g2}}} \qquad t_b = 9.364\,cm$$

$t_c := t_b$ (choose greater of t_a; t_b)

To proceed we need to classify our flange assembly and categorize our flanges. From Y-5.1 we find we do not have identical flanges, and furthermore, we have a flat head as one flange, so our assembly type is a class 3; there will be some joint rotation, which we must account for in the stres analysis. Our flange types are integral, and so are category 1, from Y-5.2. Initial trial flange thickness, for class 3, category 1 assembly is then, from Table Y-9.1:

$t_{II} := 1.1 t_c \qquad t_{II} = 10.301\,cm$

Assuming for now that this trial thickness is very close to final, we then need to reinforce for the QT/WLS holes and Xe gas feeds per UG-39. We have multiple rim openings which are treated in UG-39(c)(2):

for opening (QT) of: $d_{qt} := 1.7cm$ (Xe) $d_{Xe} := 0.8cm$

$f_{r1} := 1 \quad t := t_{II} \quad t_n := 0cm$ t from UG-34, d,t_n,f_r1 from UG-37

Area of reinforcement required, per opening:

$$A_{rq} := 0.5 d_{qt} \cdot t + t \cdot t_n \cdot (1 - f_{r1}) \qquad A_{rq} = 6.532\,cm^2$$

$$A_{rx} := 0.5 d_{Xe} \cdot t + t \cdot t_n \cdot (1 - f_{r1}) \qquad A_{rx} = 3.074\,cm^2$$

Since we have multiple rim openings, we need to check that hole spacing rules are met, per UG-39(b)(2) and (b)(3), as specified per UG-39(c)(2).

distance between Xe hole and QT hole centers; and QT hole centers:

$x_{xq} := 3.11cm \qquad x_{qq} := 4.71cm$

average diameter of hole pair ( 1 Xe for one QT)

$d_{avg} := 0.5(d_{qt} + d_{Xe}) \qquad d_{avg} = 1.25\,cm$

per UG-39(b)(2) we can reinfore each hole individually because :

$x_{xq} > 2d_{avg}$ and $x_{qq} > 2d_{avg}$

and, per UG-39(b)(3), there is no ligament width between two adjacent opening less than 1/4 the dia of the smaller opening, so we can proceed to reinforce each hole individually. We first determine limits of reinforcement:

Fron UG-40 , the limit of reinforcement, widthwise, on each side to the opening, measure parallel to the vessel wall is the greater of UG_40(b)(1) or (b)(2), which turns out to be (b)(2):

$w_l := 0.5 d_{qt} + t_{II} \qquad w_l = 11.151\,cm$

However, the distance between any two openings is considerable less, so the limits of reinforcement for each opening overlap, and we need to account for this, which is treated in sec UG-42. The first sentence of UG-42 Limits of Reinforcement, seems to direct back to UG-39 for multiple holes in flat heads, which appears to give us no guidance. However, reading on in UG-42 (a), we see there are references to openings in heads, so the referral appears directed only to spacing requirements. We proceed with UG-42, specifically referring now to fig. UG-42. Sketch (b) is the appropriate sketch (more than 2 openings with overlapping limits), so we then refer to UG-42(b), and find, since the distance between centers of any two openings is greater than 1.33x their average diameter, we are required to have an area of reinforcement between them equal to 50% minimum of the total area required for the two openings.

Width of plate between QT and Xe openng:

$h_{xq} := x_{xq} - d_{avg} \qquad h_{xq} = 1.86\,\text{cm}$

Width of plate between 2 QT's:

$h_{qq} := x_{qq} - d_{qt} \qquad h_{qq} = 3.01\,\text{cm}$

Total area of reinforcement required for both openings (1 Xe, 1 QT)

$A_{rxq} := A_{rx} + A_{rq} \qquad A_{rxq} = 9.605\,\text{cm}^2$

Additional plate thickness required:

$$t_r := \frac{0.5A_{rxq}}{h_{xq}} \qquad t_r = 2.582\,\text{cm}$$

Although further apart, the QT openings are larger. If we consider a plane through 2 QT openings then the reinforcement area required beween them is:

$$t_{r'} := \frac{A_{rq}}{h_{qq}} \qquad t_{r'} = 2.17\,\text{cm}$$

We choose the higher of the two and compute resulting plate thickness:

**Resulting main service flange thickness** ( based on trial min. thickness of Appendix Y-9)

$t_{sf} := t_{II} + t_r \qquad t_{sf} = 12.88\,\text{cm}$