#### Pressão interna máxima em tanque de armazenamento atmosférico de teto cônico fixo

## Pressão interna considerando a ruptura da ligação teto-costado

A pressão interna máxima é a que corresponde à falha da ligação teto-costado que, conforme a norma de projeto e construção de tanques API Std 650, deve ser "frágil" para garantia de proteção do tanque na emergência de sobrepressão interna.

# Verificação se é frágil a ligação teto-costado conforme API Std 650



## Forças atuantes:

- V = Vertical component of roof force per unit circumference,
- $\mathbf{F}_{shell} = \mathbf{Force in shell per unit circumference},$ 
  - H = Horizontal component of roof force per unit circumference,
  - P = Internal pressure in the tank,
  - R = radius of the tank.



Fig. 2.5---Side view of equilibrium forces on compression ring



Fig. 2.6-Top view of equilibrium forces on compression ring

$$V = F_{\text{shell}} = \frac{RP}{2}$$
(2.3.1)

 $H = \frac{V}{\tan \theta} = \frac{RP}{2 \tan \theta}$ (2.3.2)

Equilibrium of the compression force in the ring and the horizontal force, as shown in Figure 2.6, gives:

$$2RH = 2F_{comp}.$$
 (2.3.3)

The force in the compression ring Fcomp, is equal to the compression stress  $\sigma$ comp, times the compression area A:

$$\mathbf{F}_{\rm comp} = \boldsymbol{\sigma}_{\rm comp} \mathbf{A}. \tag{2.3.4}$$

Substituting equations (2.3.2) and (2.3.3) into (2.3.4), gives:

$$A = \frac{RH}{\sigma_{comp}} = \frac{R^2 P}{2\sigma_{comp} \tan \theta}.$$
 (2.3.5)  
$$P = \frac{(\sigma \text{comp}).(2.A.\text{tg}\theta)}{P^2}$$

Assuming yielding occurs when the bottom is about to uplift, then equation (2.3.5) can be written as:

$$A = \frac{W}{2\pi\sigma_{\text{yield}}\tan\theta}$$
(2.3.6)

where W is the total weight of the shell.

The Areal is the existent area and is calculated with the figure called as "compression ring":



In = thickness of angle leg.

- t<sub>b</sub> = thickness of bar.
- te = thickness of shell plate.
- th = thickness of roof plate.
- ts = thickness of thickened plate in shell.
- we = maximum width of participating shell.
  - $= 0.6 (R_{e}t_{s})^{0.5}$

maximum width of participating roof.

- = 0.3(R<sub>2</sub>I<sub>b</sub>)<sup>0.5</sup> or 12 inches, whichever is less.
- Re = inside radius of tank shell.
- R<sub>2</sub> = length of the normal to the roof, measured from the vertical centerline of the tank.
  - $= R_c/(\sin \theta).$

Note: All dimensions and thicknesses shown are in inches.

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# If Areal is lower than Acalculated with the expression (2.3.6), the attachment between floor and shell is frangible.

Equation (2.3.6) is the basis of the area inequality rule. From this equation follow the remaining equations given in API 650 for frangible roofs.

To avoid uplift of the bottom, considering a factor of safety n = 1.6 and neglecting wind moment, the maximum design pressure and the weight of shell are related by (Note: in API 650, the unit of P is inches of water, and the density of the roof plates is about 8 times of that of water):

$$(P - 8\rho_{water}t_h)\frac{\pi D^2}{4} = \frac{W}{n}$$
. (2.3.7)

Substituting W in equations (2.3.6) into (2.3.7) we have:

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$$P = \frac{8A\sigma_{\text{yield}}\tan\theta}{nD^2} + 8\rho_{\text{water}}t_{\text{h}}.$$
 (2.3.8)

Assume a compressive yield stress of 32,000 psi (as described in Appendix F, Section F.6), substitute into equation (2.3.8), and convert units by 1 inch of water = 0.03606 psi, gives the equation for calculating maximum design pressure as stated in API 650 F.4.1 (neglecting the wind moment term):

$$P = \frac{30,800A \tan \theta}{D^2} + 8t_h.$$
(2.3.9)

If the design Pressure (P) has already been established, equation (2.3.9) can be inverted to obtain the total required area expression as in API 650 F.5.1:

$$A = \frac{(P - 8t_h)D^2}{30,800 \tan \theta}.$$
 (2.3.10)

Modifying (2.3.9) by equating the maximum uplift where, force by pressure Pmax, to the weight of the shell gives:

$$0.25\pi D^2(P_{max} - 8\rho_{water}t_h) = W.$$
 (2.3.11)

Rearranging equation (2.3.11) and converting units to inches of water gives the equation in API F.4.2 less the wind moment term which is new in the API 650 ninth edition:

$$P_{max} = \frac{0.245W}{D^2} + 8t_h.$$
(2.3.12)

If the area A satisfies equation (2.3.6), then the uplift pressure Pmax, is also the calculated failure pressure, Pf.

From equation (2.3.7), the relation between Pf and the design pressure P is:

$$0.25\pi D^2(P_f - 8\rho_{water}t_h)$$

 $= W = 0.25\pi D^2 n (P - 8\rho_{water} t_h), \quad (2.3.13)$ 

or, in terms of inches of water:

$$P_f = 1.6P - 4.8t_h.$$
 (2.3.14)

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The above derivations are based on using static equilibrium and the original geometry to calculate the inward force on the compression ring due to roof lifting.

The resulting equations demonstrate that the basis of the inequality rule is to ensure that yielding of the compression ring will occur before uplift of the bottom.

Yielding and subsequent loss of stiffness are expected to cause buckling of the

compression ring, followed by gross deformation of the roof, shell, and associated failure of the roof-to-shell weld.