TD4 = Vertical Evaporator

1) Estimation of the heat flux

$$H = 7390\, H_L \left[\frac{q}{G\, h_{LV}} + 0.00015 \frac{1}{X^{0.66}} \right]$$

$$q = H\,(T_p - T_{sat})$$

$$\Rightarrow H = \frac{0.00015 / X^{0.66}}{\left[\frac{1}{7390 H_L} - \frac{(T_p - T_{sat})}{G\, h_{LV}} \right]}$$

with $G = \frac{4\dot{m}}{\pi D^2} = 763 \text{ kg}/\text{m}^2/\text{s}$

$$H_L = \frac{\lambda}{D}\, 0.023 \left(\frac{G(1-x)D}{\mu_L} \right)^{0.8} P_r^{1/3} \qquad P_r = \frac{\mu\, C_p}{\lambda}$$

Fitting $q = f(x)$ $\qquad q = -348\,767\,x + 316\,408$

$$q = a x + b$$

2) Evolution of x with z

Enthalpy balance $h_{LV}\, G \frac{dx}{dz} = \frac{4q}{D}$

$$\frac{dx}{dz} = \frac{4q}{D G h_{LV}} = \frac{4}{D G h_{LV}} (a x + b)$$

$$\frac{dx}{ax+b} = \frac{4\, dz}{D G h_{LV}} \Rightarrow \frac{1}{a} \ln(ax+b) + cte = \frac{4z}{D G h_{LV}}$$

at $z = 0 \quad x = 0$

$$\Rightarrow x = -\frac{b}{a}\left(1 - e^{\frac{4 a z}{D G h_{LV}}}\right)$$

$$x = \frac{316408}{348767}\left(1 - e^{\frac{-348767\times 43}{DGh_{LV}}}\right)$$ Eq 1

$$j_G = \frac{Gx}{\rho_v} \qquad j_L = \frac{G(1-x)}{\rho_L}$$

x	j_L(m/s)	j_G(m/s)	$\rho_L j_L^2$	$\rho_v j_v^2$	flow pattern
0.2	0,64	3,00	329	448	annul
0.3	0,47	4,59	250	1048	annular
0.4	0,4	6,17	147	2512	annular
0.6	0,27	9,22	60	5048	annular

3) Annular flow without droplet entrainment

2 momentum balance équations

$$\frac{d}{dz}\frac{G^2x^2}{\rho_G R_G} = -R_G\frac{dP}{dz} + \frac{\tau_{iG}S_i}{A} + \Gamma_G U_i - \rho_G R_G g$$

$$\frac{d}{dz}\frac{G^2(1-x)^2}{\rho_L R_L} = -R_L\frac{dP}{dz} + \frac{4\tau_p}{D} - \frac{\tau_{iG}S_i}{A} - \Gamma_G U_i - \rho_L R_L g$$

By elimination $\frac{dP}{dz}$ between the 2 équations and neglecting Γ_G, yields to: an explicite equation to compute R_{G1}

$$\frac{dR_G}{dz} G^2 \left[\frac{x^2 R_L}{\rho_G R_G^2} + \frac{(1-x)^2 R_G}{\rho_L R_L^2} \right] = - \tau_{iG} \frac{4\sqrt{R_G}}{D} + \frac{4\tau_p}{D} R_G$$

Eq(2)

$$- (\rho_L - \rho_G) R_G R_L g + G^2 \boxed{\frac{dx}{dz}} \left(\frac{2 x R_L}{\rho_G R_G} + \frac{(1-x)(2R_G - 1)}{\rho_L R_L} \right)$$

calculated with Eq 1

4) Thin liquid film

$$G h_{LV} \frac{dx}{dz} = \frac{4 q_p}{D} \quad \text{with} \quad q_p = \lambda \frac{(T_p - T_{sat})}{\delta}$$

and $\delta = \frac{D}{2}(1 - \sqrt{R_G})$

$$\frac{dx}{dz} = \frac{4}{D G h_{LV}} \frac{\lambda (T_p - T_{sat})}{\frac{D}{2}(1 - \sqrt{R_G})} \qquad \text{Eq}(3)$$

Resolution using Eq 2 with $\frac{dx}{dz}$ computed with Eq(3) → gives the value of R_{G_z}

5) Dry-out observed when $x = 1$, $R_G = 1$, $\delta = 0$

$z \simeq 1.90\text{m}$

6) Pressure gradient

$$\frac{dP}{dz} = \frac{4\tau_p}{D} - (\rho_L R_L + \rho_G R_G) g - \frac{d}{dz} \left[\frac{G^2 x^2}{\rho_G R_G} + \frac{G^2 (1-x)^2}{\rho_L R_L} \right]$$