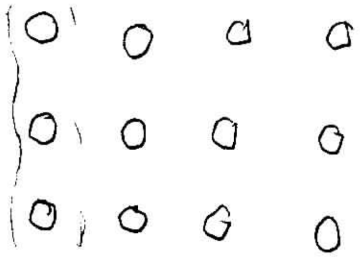
Ex| Same as above, but now a bank of 12 tubes . .

3x4


$$h_{horiz/N\,tubes} = \frac{h_{horiz,1\,tube}}{N^{1/4}} \qquad \boxed{N = 3}$$

$$= 7052\ W/m^2K$$ for each bank

$$A_{surf} \text{ for all 12 tubes} = \underbrace{N_{total}}_{12}(\pi \underbrace{D}_{0.03\,m} \underbrace{L}_{1\,m}) = 1.131\ m^2$$

so

$$q = h\,A_{s,tot}(\underbrace{T_{sat}}_{40°C} - \underbrace{T_s}_{30°C}) = 79{,}870\ W$$

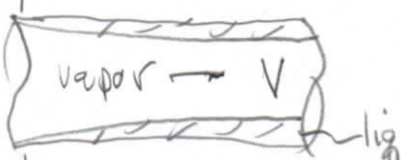
and the rate of steam cond. is

$$\dot{m}_{cond.} = \frac{q}{h^{*}_{fg}} = \frac{79{,}870\ W}{2435 \times 10^3\ J/kg} = 0.0328\ kg/s$$

//

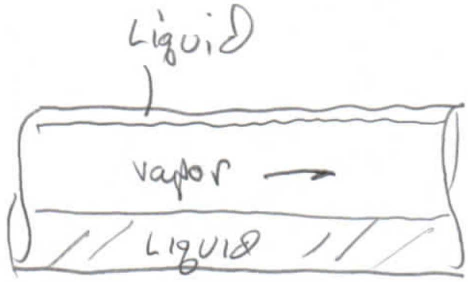
what about cond. inside tubes?

Inlet



High vel. vapor

upto



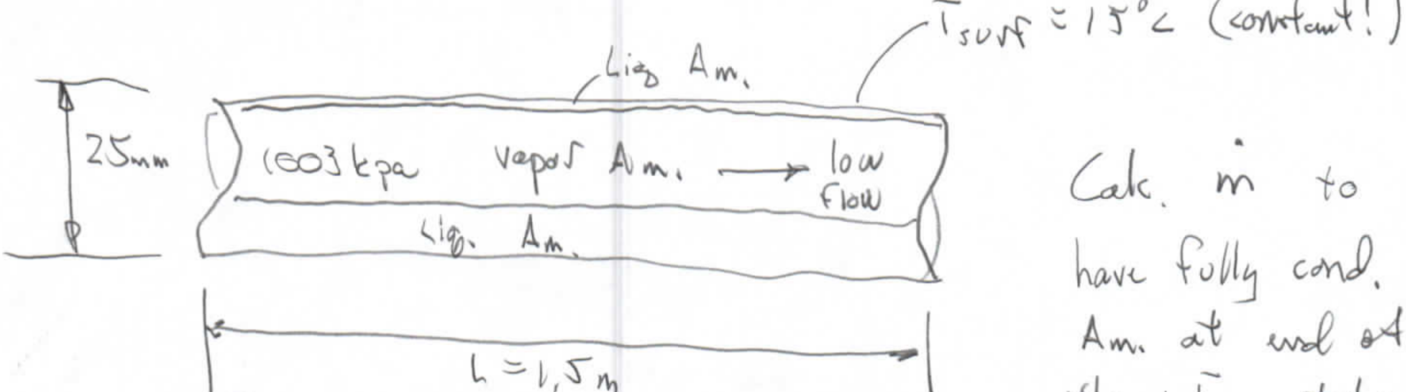
Low velocity vapor

$$h_{\substack{internal \\ horiz}} = 0.555 \left[\frac{\rho g_l (\rho_l - \rho_v) k_l^3}{\mu_l (T_{sat} - T_s) D} \underbrace{\left(h_{fg} + \frac{3}{8} c_{p,l} (T_{sat} - T_s) \right)}_{\text{just an } h^*_{fg}} \right]^{1/4}$$

for $Re_{vapor} = \left. \frac{\rho_v V_v D}{\mu_v} \right|_{inlet} < 35{,}000$ ← Chato for Low Velocities

See Rohsenow for high speed flow.

Ex) Vapor ammonia → Liq. Ammonia
bad for Ca. NOT as bad



Calc. $\dot{m}$ to have fully cond. Am. at end of the 1.5 m tube.

Assume • SS
• "Low flow" so $Re_{vapor} < 35{,}000$ (verify this)
• Tube is T

Prop. For Am @ $P = 1003\ kPa$, $T_{sat.} = 25°C$

@ $T_{sat} = 25°C$, $h_{fg} = 1166 \times 10^3\ J/kg$

$\rho_v = 7.809\ kg/m^3$

$\mu_v = 1.037 \times 10^{-5}\ kg/ms$

@ $T_{film} = \dfrac{T_{sat} + T_s}{2} = \dfrac{(25+15)°C}{2} = 20°C$ we can find

$\rho_l = 610.2\ kg/m^3$ $\qquad C_{p,l} = 4745\ J/kg\,K$

$\mu_l = 1.519 \times 10^{-4}\ kg/m^2$ $\qquad k_l = 0.4927\ W/mK$

Calculations

$$h_{\substack{horiz\\tube}} = 0.555\left[\frac{g\rho_l(\rho_l - \rho_v)k_l^3}{\mu_l(T_{sat} - T_s)D}\underbrace{\left(h_{fg} + \frac{3}{8}C_{pl}(T_{sat} - T_s)\right)}_{h^*_{fg} = 1183.8 \times 10^3\ J/kg}\right]^{1/4}$$

$$= 5976.3\ W/m^2k$$

Surface area for h. transf. $= A_s = \pi D L = 0.11781\ m^2$

so $q = h A_s (T_{sat} - T_s) = 7040\ W$

Rate of cond $\dot{m} = q/h^*_{fg} = 0.005948\ kg/s$

keep $\dot{m}$ below this value for full condensation

Note: $Re_{vapor} = \left.\dfrac{\rho_v V_v D}{\mu_v}\right|_{inlet} = \dfrac{4\dot{m}}{\pi D \mu_v} = 29{,}212 < 35{,}000$

// so low flow assump. is okay.