HEAT TRANSFER

[CH21204]

April 06, 2023

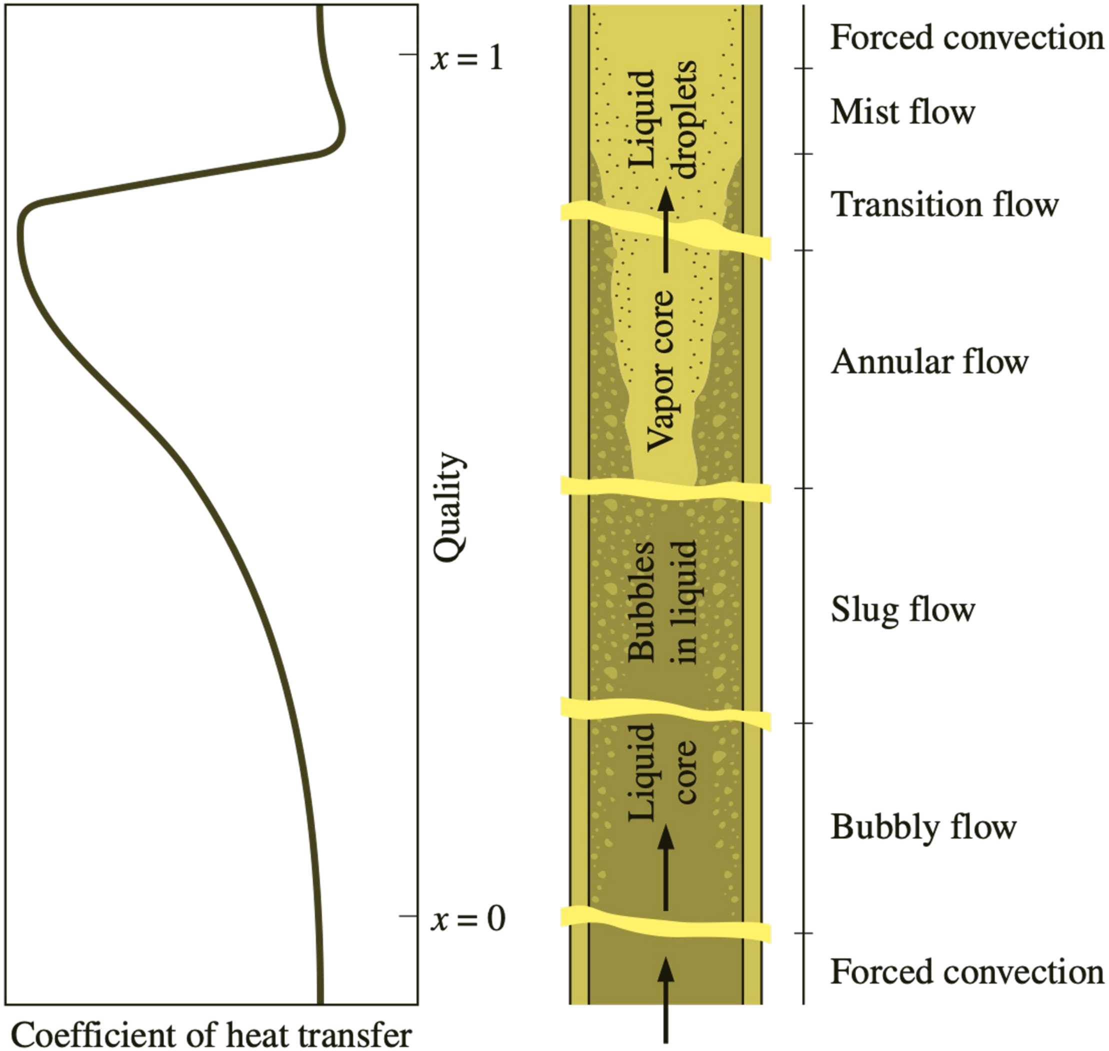
Film Boiling

$$\dot{q}_{\text{film}} = C_{\text{film}} \left[\frac{g k_v^3 \rho_v (\rho_l - \rho_v)[h_{fg} + 0.4 C_{pv} (T_s - T_{\text{sat}})]}{\mu_v D (T_s - T_{\text{sat}})} \right]^{1/4} (T_s - T_{\text{sat}})$$

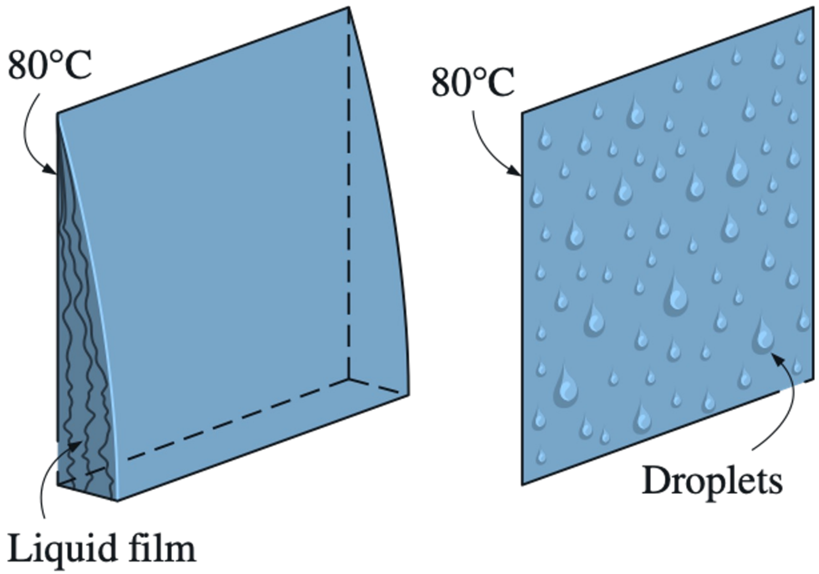
$$C_{\text{film}} = \begin{cases} 0.62 \text{ for horizontal cylinders} \\ 0.67 \text{ for spheres} \end{cases}$$

- vapor properties are to be evaluated at the film/average temperature
- liquid properties and h_{fg} are to be evaluated at the saturation temperature at the specified pressure

FLOW BOILING



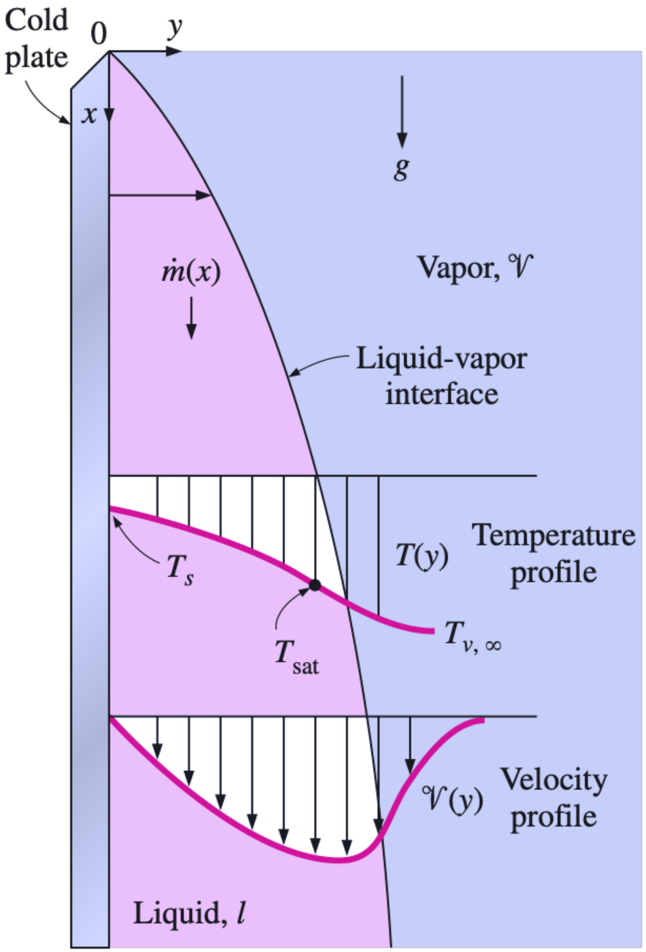
CONDENSATION HEAT TRANSFER



(*a*) Film condensation

(*b*) Dropwise condensation

Dropwise condensation is the preferred mode of condensation in heat transfer applications!



$$\mathrm{Re} = \frac{D_h \rho_l \mathcal{V}_l}{\mu_l} = \frac{4 A_c \rho_l \mathcal{V}_l}{p\mu_l} = \frac{4 \rho_l \mathcal{V}_l \delta}{\mu_l} = \frac{4\dot{m}}{p\mu_l}$$

$D_h = 4A_c/p = 4\delta$ = hydraulic diameter of the condensate flow, m

p = wetted perimeter of the condensate, m

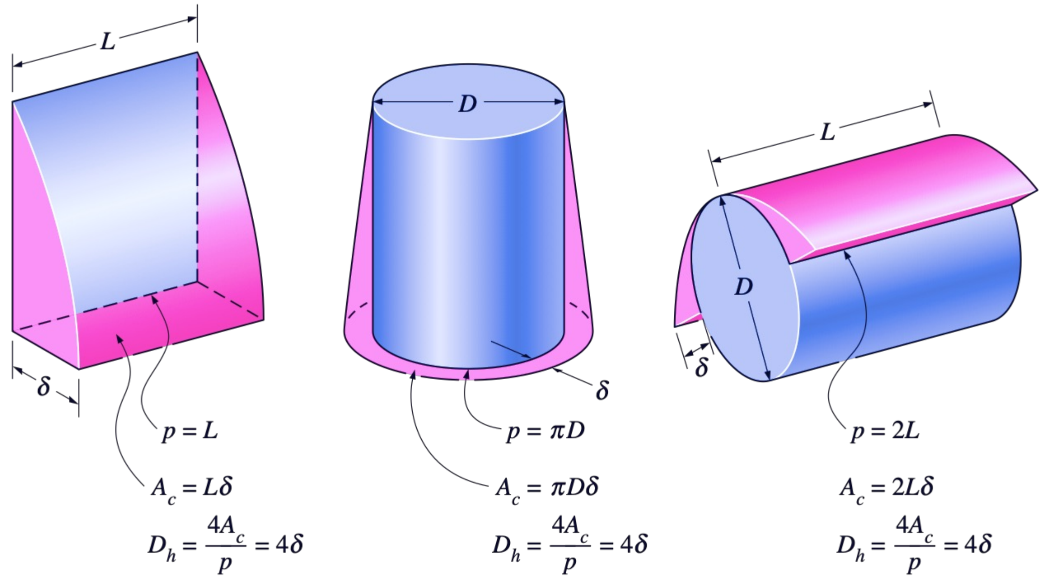
$A_c = p\delta$ = wetted perimeter × film thickness, m^2, cross-sectional area of the condensate flow at the lowest part of the flow

ρ_l = density of the liquid, kg/m^3

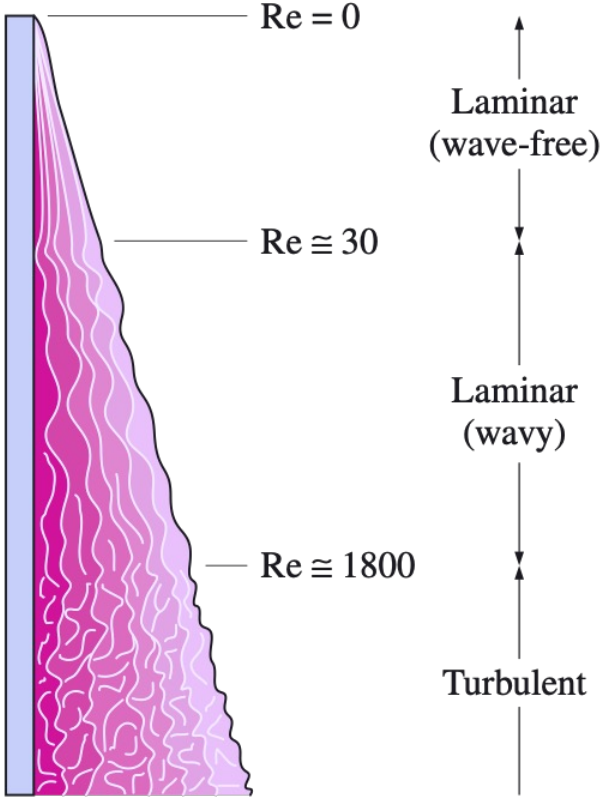
μ_l = viscosity of the liquid, kg/m · s

$\mathcal{V}$ = average velocity of the condensate at the lowest part of the flow, m/s

$\dot{m} = \rho_l \mathcal{V}_l A_c$ = mass flow rate of the condensate at the lowest part, kg/s



(*a*) Vertical plate (*b*) Vertical cylinder (*c*) Horizontal cylinder



$$h_{\text{vert}} = 0.943 \left[\frac{g \rho_l (\rho_l - \rho_v) h^*_{fg} k_l^3}{\mu_l (T_{\text{sat}} - T_s) L} \right]^{1/4} \quad (\text{W/m}^2 \cdot {}^\circ\text{C}),\ 0 < \text{Re} < 30$$

g = gravitational acceleration, m/s^2

ρ_l, ρ_v = densities of the liquid and vapor, respectively, kg/m^3

μ_l = viscosity of the liquid, kg/m · s

$h^*_{fg} = h_{fg} + 0.68 C_{pl} (T_{\text{sat}} - T_s)$ = modified latent heat of vaporization, J/kg

k_l = thermal conductivity of the liquid, W/m · °C

L = height of the vertical plate, m

T_s = surface temperature of the plate, °C

T_{sat} = saturation temperature of the condensing fluid, °C

DROPWISE CONDENSATION

$$h_{\text{dropwise}} = \begin{cases} 51{,}104 + 2044T_{\text{sat}}, & 22°\text{C} < T_{\text{sat}} < 100°\text{C} \\ 255{,}310 & T_{\text{sat}} > 100°\text{C} \end{cases}$$