Simulation of Two Phase Flows

(28-082)

Section 11, Convective boiling

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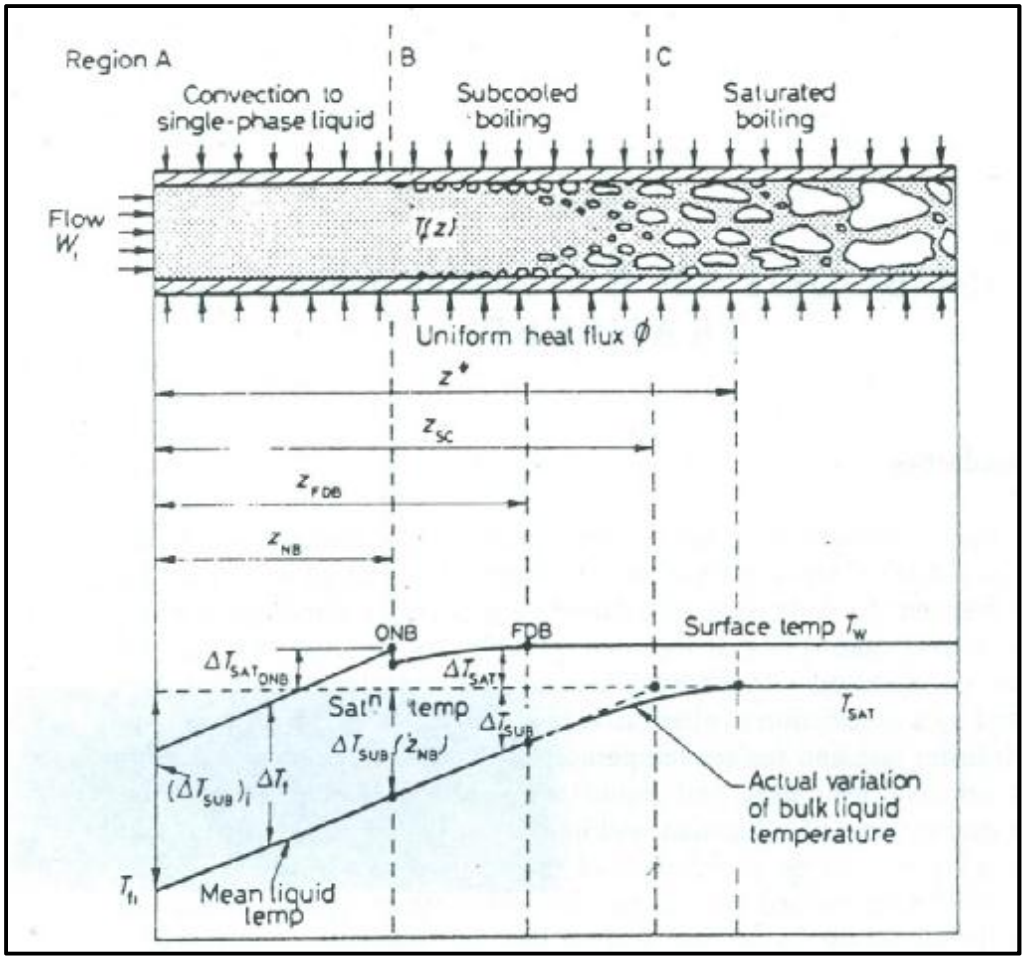
Subcooled boiling



$$fp\,Dz = W_f c_{pf}\left(T_f(z) - T_{fi}\right)$$

$$T_f(z) = T_{fi} + \frac{4fz}{GDc_{pf}}$$

$$z_{sc} = \frac{GDc_{pf}}{4f}\left(T_{SAT} - T_{fi}\right)$$

$$T_w = T_f(z) + \Delta T_f$$

$$\Delta T_f = f/h_{f0}$$

Subcooled boiling

$$\frac{h_{f0}D}{k_f} = 0.17\left[\frac{GD}{m_f}\right]^{0.33}\left[\frac{c_p m}{k}\right]_f^{0.43}\left[\frac{\mathrm{Pr}_f}{\mathrm{Pr}_w}\right]^{0.25}\left[\frac{D^3 r_f^2 g b \Delta T}{m_f^2}\right]^{0.1}$$

$$\frac{h_{f0}D}{k_f} = 0.023\left[\frac{GD}{m_f}\right]^{0.8}\left[\frac{c_p m}{k}\right]_f^{1/3}$$

$$T_W = T_{fi} + f\left[\frac{4z}{Gc_{pf}D} + \frac{1}{h_{f0}}\right]$$

$$z_{NB} = \frac{Gc_{pf}D}{4}\left[\frac{(\Delta T_{SUB})_i + (\Delta T_{SAT})_{ONB}}{f} - \frac{1}{h_{f0}}\right]$$

$$z_{SC} - z_{NB} = \frac{Gc_{pf}D}{4}\left[\frac{1}{h_{f0}} - \frac{(\Delta T_{SAT})_{ONB}}{f}\right]$$

Onset of subcooled nucleate boiling

$$T_f\left(z_{NB}\right)=T_{fi}+\frac{4f\,z_{NB}}{GDc_{pf}}$$

$$\Delta T_{SUB}\left(z_{NB}\right)=\frac{4f}{GDc_{pf}}\left(z_{SC}-z_{NB}\right)$$

$$T_{SAT}\le T_W \longrightarrow T_{SAT}\le T_{fi}+f\left[\frac{4z}{Gc_{pf}D}+\frac{1}{h_{f0}}\right] \longrightarrow T_{SAT}\le T_f\left(z\right)+f/h_{f0}$$

$$\Delta T_{SUB}\left(z\right)\le f/h_{f0}$$

$$\left(\Delta T_{SUB}\right)_i\le f\left[\frac{4z}{Gc_{pf}D}+\frac{1}{h_{f0}}\right]$$

$$\left(T_W\right)_{SCB}=T_{SAT}+y\,f^n \longrightarrow \left(T_W\right)_{SCB}=\left(T_W\right)_{SPL} \longrightarrow T_f\left(z\right)+f/h_{f0}=T_{SAT}+y\,f^n$$

Onset of subcooled nucleate boiling

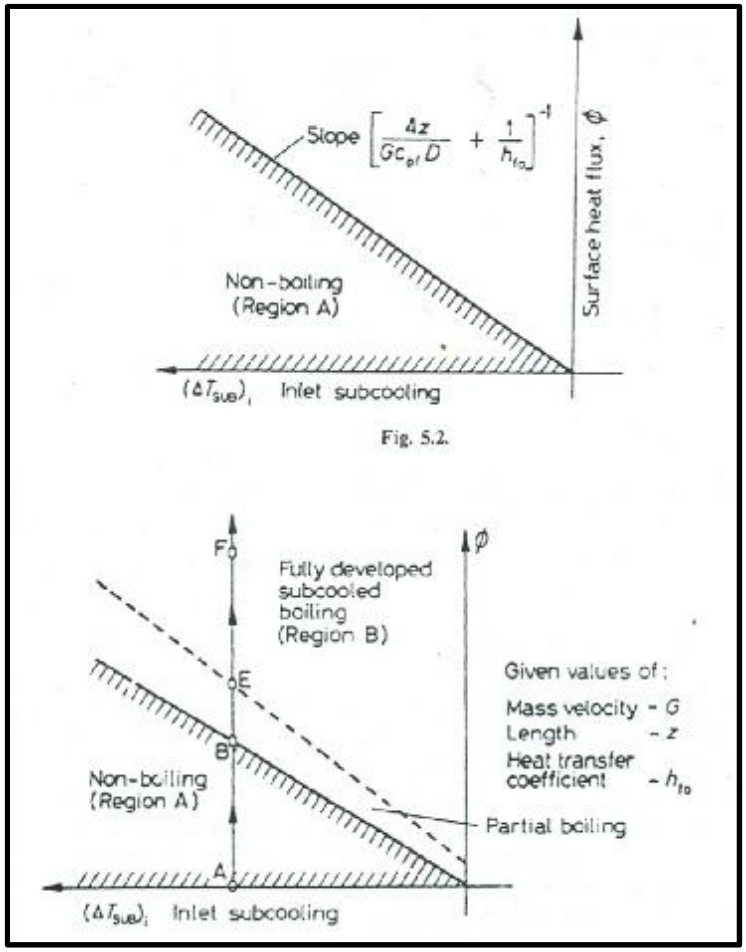
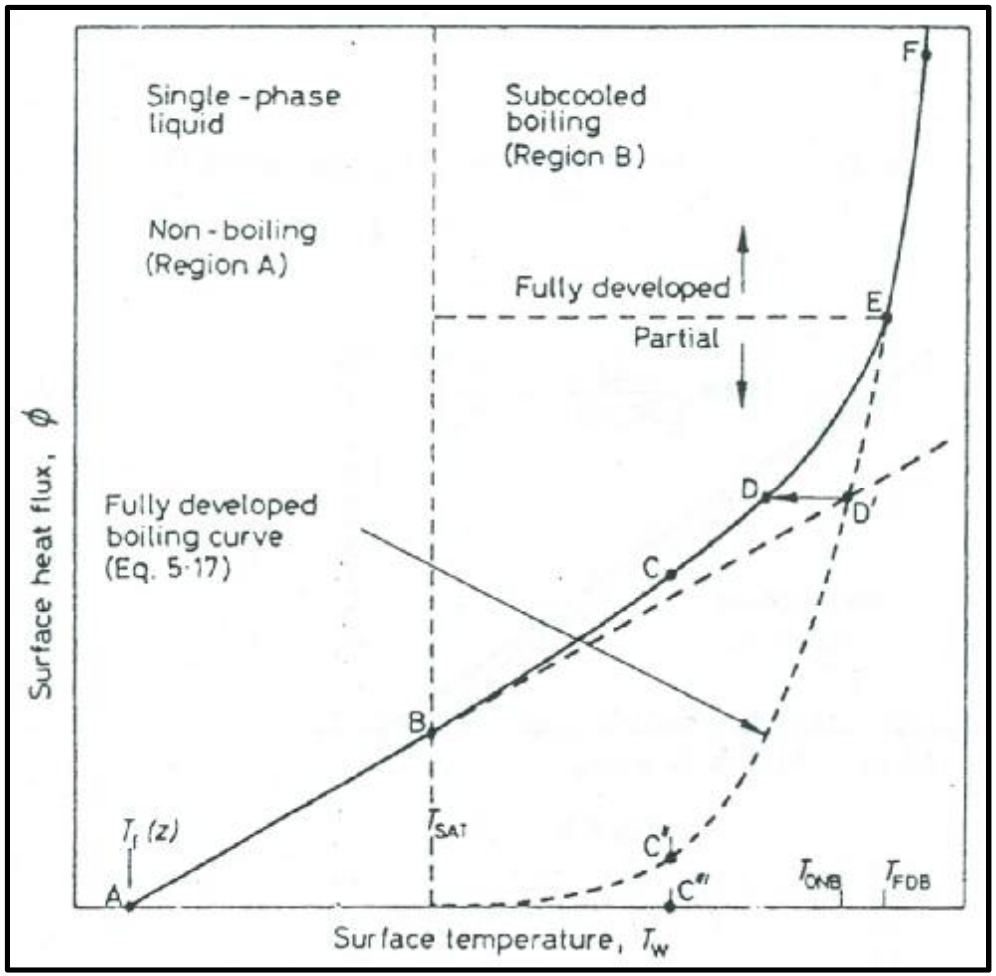


Fig. 5.2.

Region of heat transfer in convective boiling



Onset of subcooled nucleate boiling

$$T_g = \frac{RT_{SAT}T_g}{Ji_{fg}M}\ln(1+z)+T_{SAT}$$

$$z = \frac{2s}{p_f r_c}$$

$$\frac{dT_g}{dr} = \frac{2kRT^2_{SAT}s}{Ji_{fg}Mp_f r^2(1+z)}\left[1-\frac{RT_{SAT}}{Ji_{fg}M}\ln(1+z)\right]^{-2}$$

$$1 \quad \frac{RT_{SAT}}{Ji_{fg}M}\ln(1+z)$$

$$\frac{dT_g}{dr} = \frac{-B}{r^2(1+z)}$$

$$B = \left[\frac{2s\,T_{SAT}v_{fg}}{Ji_{fg}}\right]$$

Onset of subcooled nucleate boiling

$$r_{CRIT} = -\frac{s}{p_f} + \left[\left(\frac{s}{p_f} \right)^2 + \left(\frac{Bk_f}{f} \right) \right]^{1/2}$$

$$\left(T_w - T_{SAT} \right)_{ONB} = \frac{\left[\frac{RT^2_{SAT}}{Ji_{fg}M} \right] \ln\left(1 + z_{CRIT}\right)}{\left[1 - \frac{RT_{SAT} \ln\left(1 + z_{CRIT}\right)}{Ji_{fg}M} \right]} + \frac{f_{ONB} r_{CRIT}}{k_f}$$

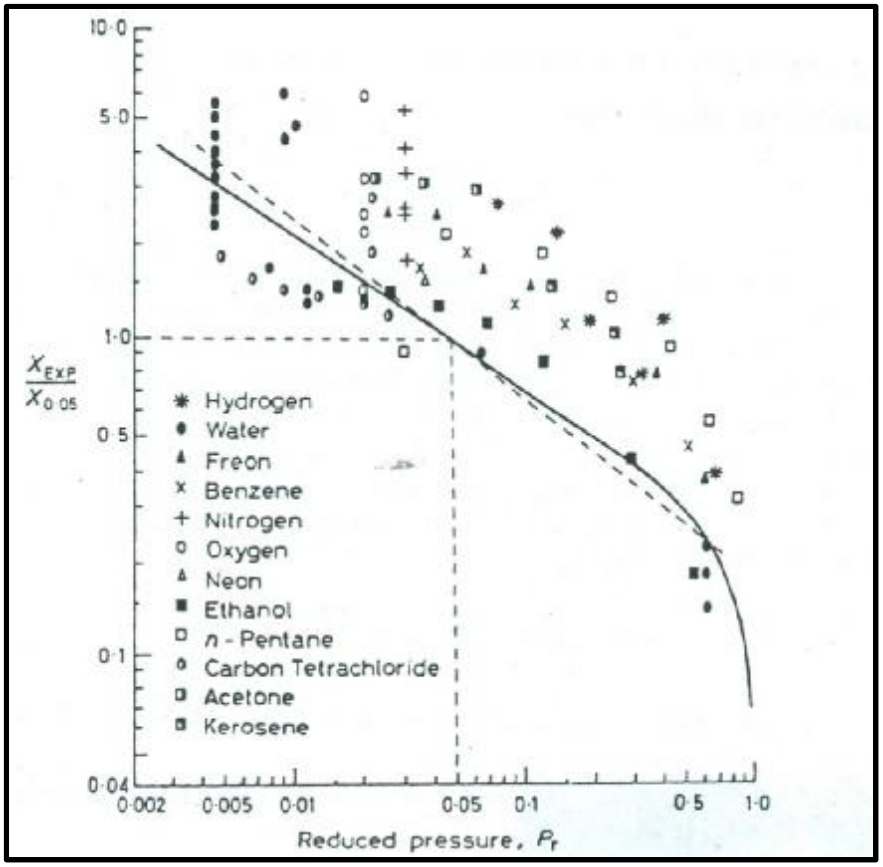
$$z = \frac{2s}{p_f r_{crit}} \longrightarrow z \quad 1 \longrightarrow \frac{dT_g}{dr} = \frac{-B}{r^2} \longrightarrow r_{CRIT} = \sqrt{\frac{Bk_f}{f}}$$

Onset of subcooled nucleate boiling

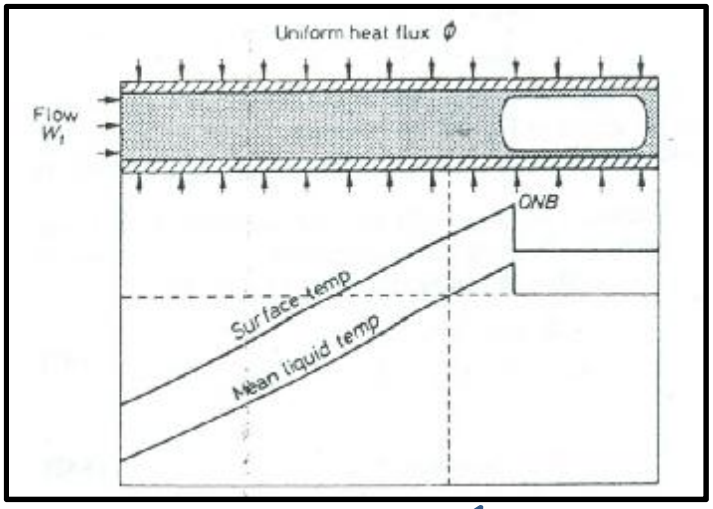
$$\left(T_w - T_{SAT}\right)_{ONB} = \frac{B}{r_{CRIT}} + \frac{f_{ONB} r_{CRIT}}{k_f}$$

$$f_{ONB} = \frac{k_f}{4B}\left(T_w - T_{SAT}\right)^2_{ONB} = \frac{k_f}{4B}\left(\Delta T_{SAT}\right)^2_{ONB}$$

$$X = \left[\frac{\left(\Delta T_{SAT}\right)_{ONB}}{f^2_{ONB}\,\mathrm{Pr}_f}\right] = \left[\frac{4B}{k_f}\right]^{0.5} = \left[\frac{8s\,T_{SAT}}{Ji_{fg} k_f\, r_g}\right]^{0.5}$$



Onset of subcooled nucleate boiling



Superheated liquid

Streamline around a bubble nucleus