Two Phase Flows

(Section 2)
Introduction

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Overview on Basic Definitions

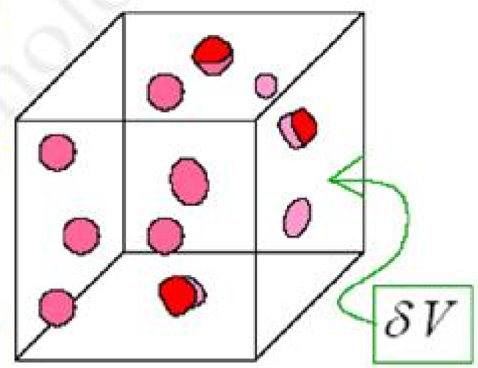
Volume fraction

$$\alpha_c = \lim_{\delta V \to \delta V_0} \frac{\delta V_c}{\delta V} \quad \ldots\text{Continuous phase}$$

δV_c : volume of continuous phase

$$\alpha_d = \lim_{\delta V \to \delta V_0} \frac{\delta V_d}{\delta V} \quad \ldots\text{Dispersed phase}$$

δV_d : volume of dispersed phase



$$\delta V = \delta V_c + \delta V_d \Rightarrow \alpha_d + \alpha_c = 1$$

Void Fraction for Gas- Liquid Two Phase Flow

$$a = \frac{A_g}{A}, (1-a) = \frac{A_f}{A}$$

Overview on Basic Definitions

Mass Quality

quality $= \dfrac{\text{mass flow rate of gas}}{\text{total mass flow rate}}$ or $= \dfrac{\text{mass of gas}}{\text{total mass}}$

↓ **mass flow quality** ↓ **mass quality**

$$x = \frac{W_g}{W_g + W_f} \quad , \qquad (1-x) = \frac{W_f}{W_g + W_f}$$

Mass velocity

$$G = \frac{W}{A} = r\,u = \frac{u}{u}$$

$$W_g = GAx \quad , \qquad W_f = GA(1-x)$$

$$u_g = \frac{W_g}{r_g A_g}, \qquad u_f = \frac{W_f}{r_f A_f}$$

$$u_g = \frac{Q_g}{A_g}, \qquad u_f = \frac{Q_f}{A_f}$$

$$u_g = \frac{Gx}{r_g a}, \qquad u_f = \frac{G(1-x)}{r_f (1-a)}$$

Overview on Basic Definitions

Volumetric Quality

$$b = \frac{Q_g}{Q_g + Q_f}, \quad (1-b) = \frac{Q_f}{Q_g + Q_f}$$

Superficial Velocity

$$j = \frac{Q}{A}, \qquad j_g = \frac{Q_g}{A}, \qquad j_f = \frac{Q_f}{A}$$

$$j_g = a\,u_g = b\,j = \frac{Gx}{r_g}, \qquad j_f = (1-a)u_f = (1-b)j = \frac{G(1-x)}{r_f}$$

$$G_g = r_g J_g = Gx, \qquad G_f = r_f j_f = G(1-x), G = G_g + G_f$$

Slip Ratio

$$\frac{u_g}{u_f} = \frac{r_f A_f W_g}{r_g A_g W_f} = (\frac{x}{1-x})(\frac{r_f}{r_g})(\frac{1-a}{a})$$

Some properties of multiphase flows

- Thermodynamic Equilibrium does not exist.
- Fully developed concept is meaningless.
- 1D assumption can be applied.
- Convective heat transfer is more effective than single phase flows.
- Hydrodynamic and Thermodynamic properties change in direction of flow.
- pressure drop, heat transfer and mass transfer are function of flow patterns.

Measurement Techniques for Void Fractions

$$\text{a local time average gas fraction} = \frac{\text{comulation residence time of the gas phase}}{\text{total time interval}}$$

By means of local electrical and optical probes.

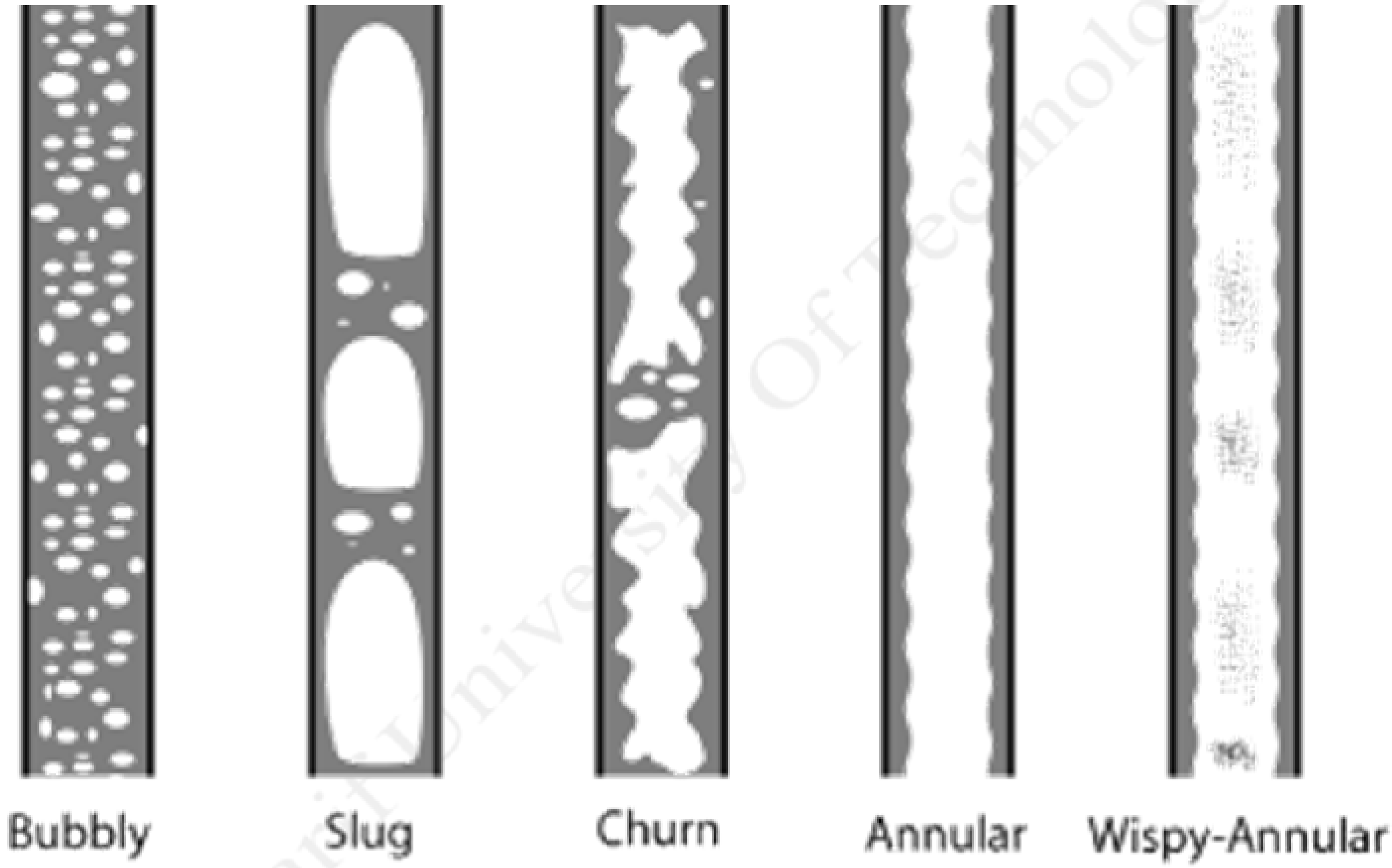
$$\text{an instantenous line-average gas fraction} = \frac{\text{length of line submerged in gas phase}}{\text{total length of line within the channel}}$$

By means of x or gamma ray.

Another (Mechanical) way is using quick closing valve

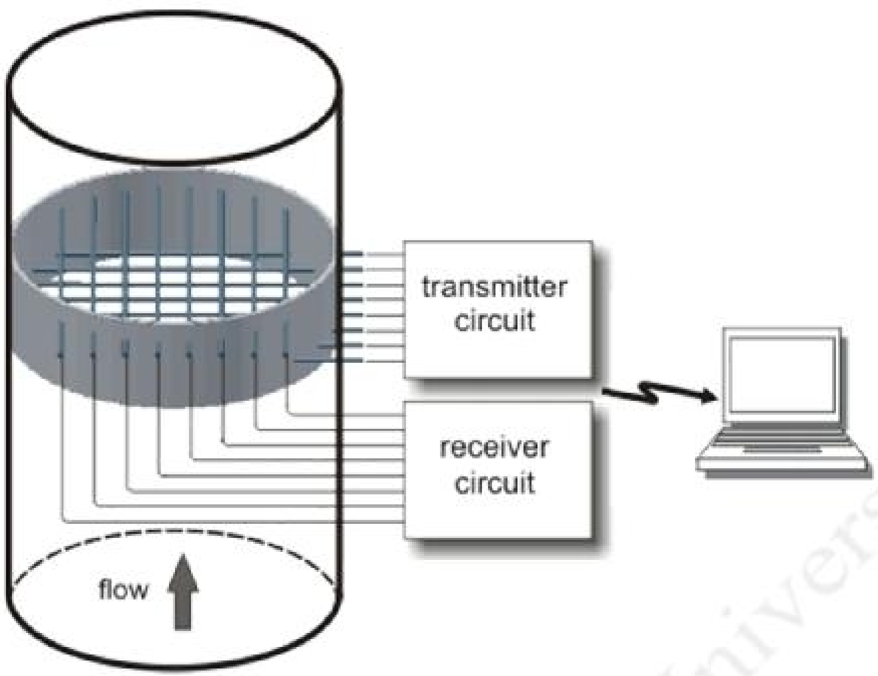
Flow Pattern in Vertical Co-Current Flow

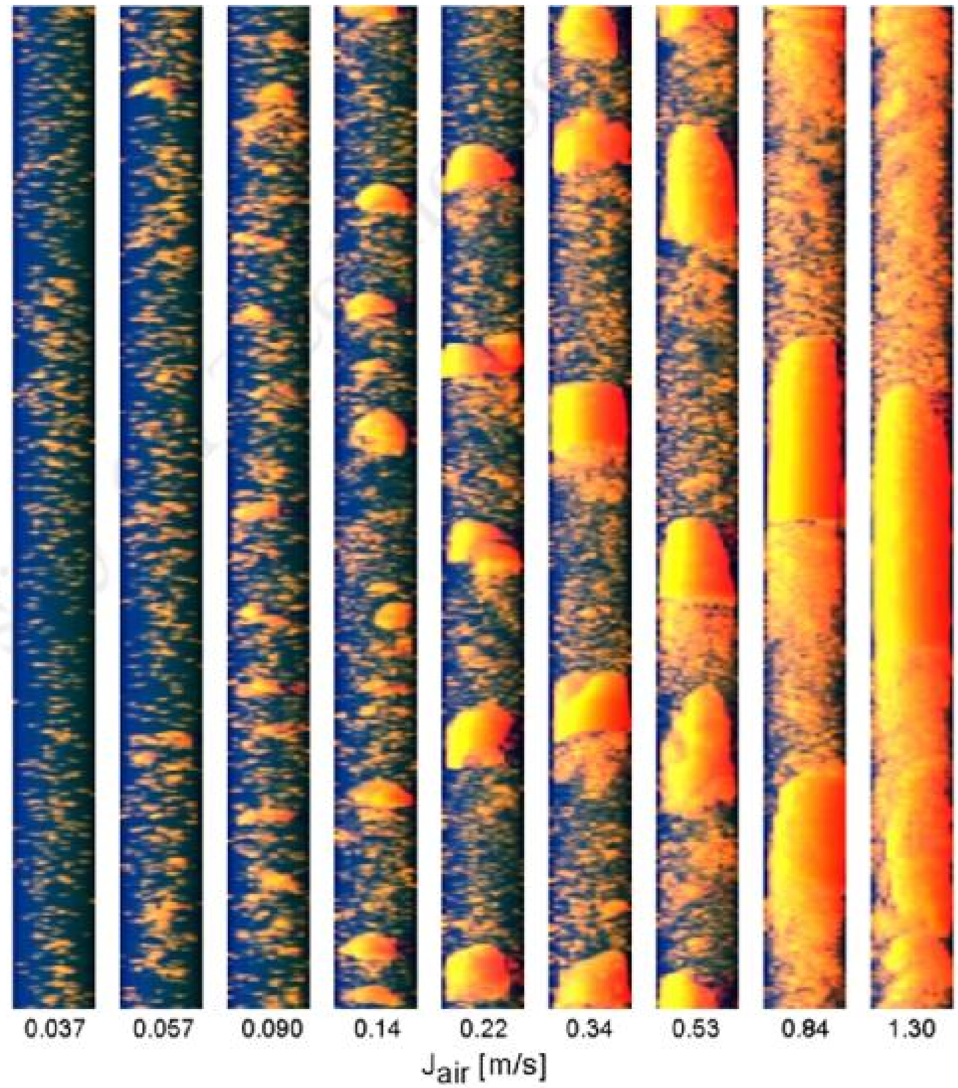
Bubbly	Slug	Churn	Annular	Wispy



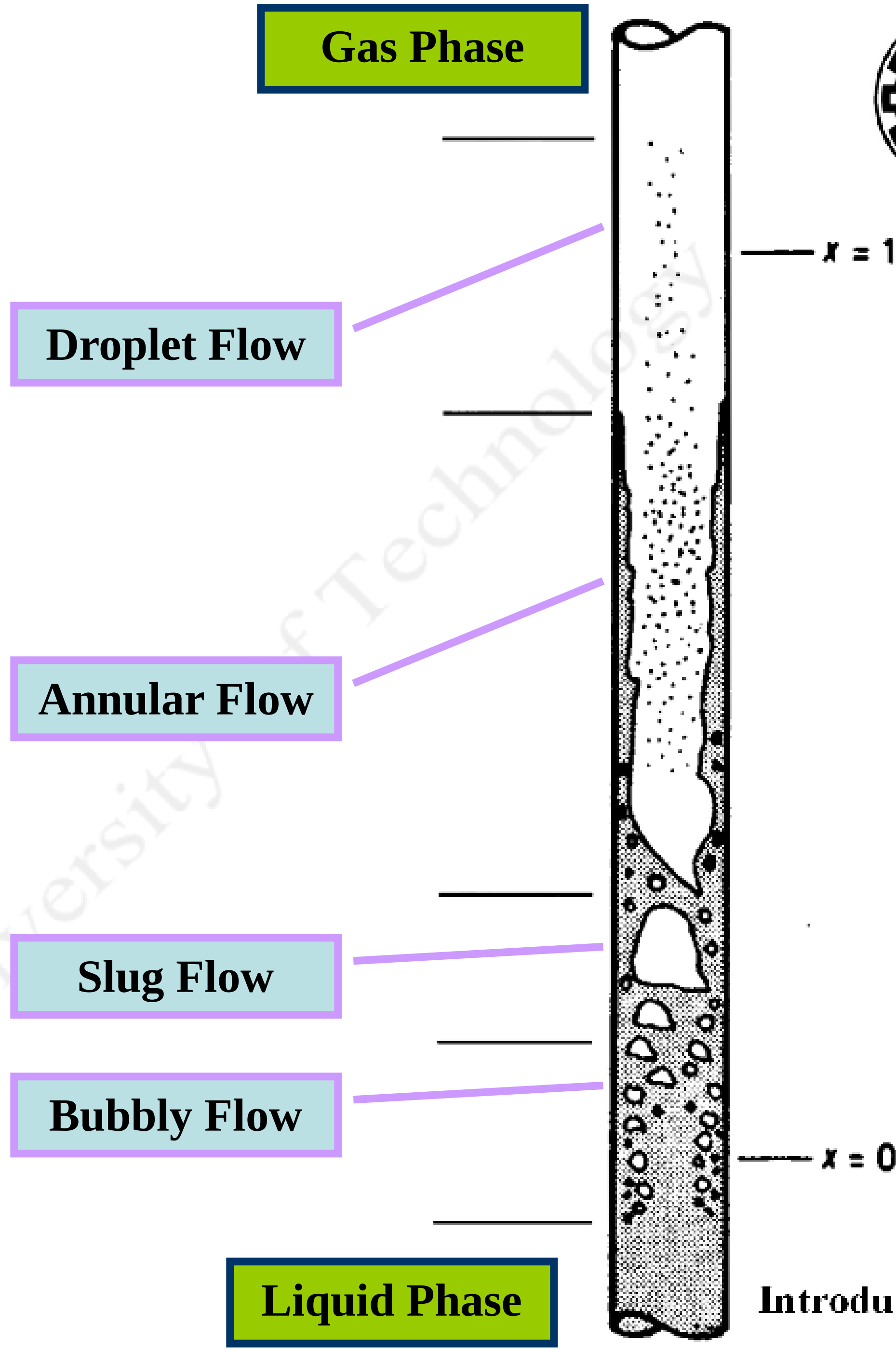
Flow patterns in vertical upward flow in a tube

Transition Flow Pattern



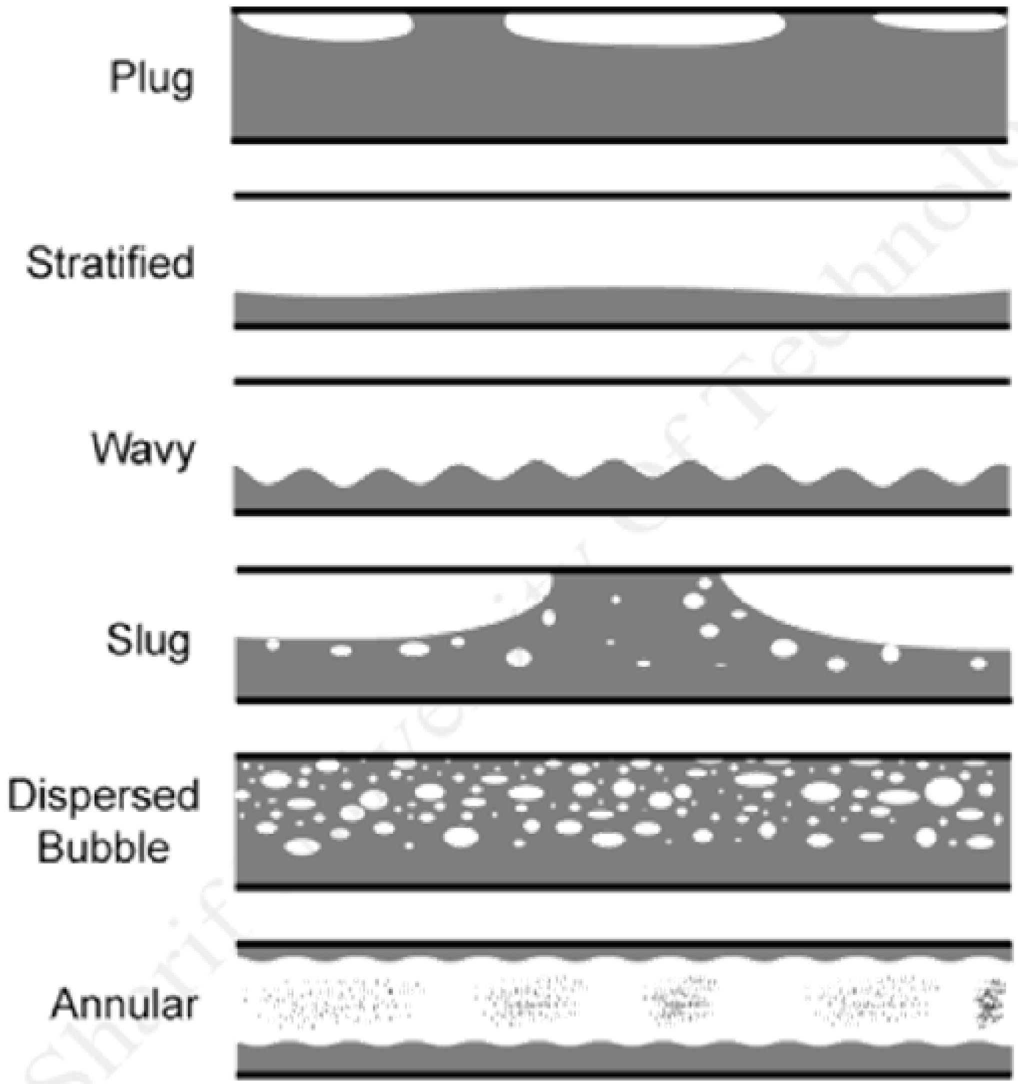


Flow Pattern In Vertical Heated Channels

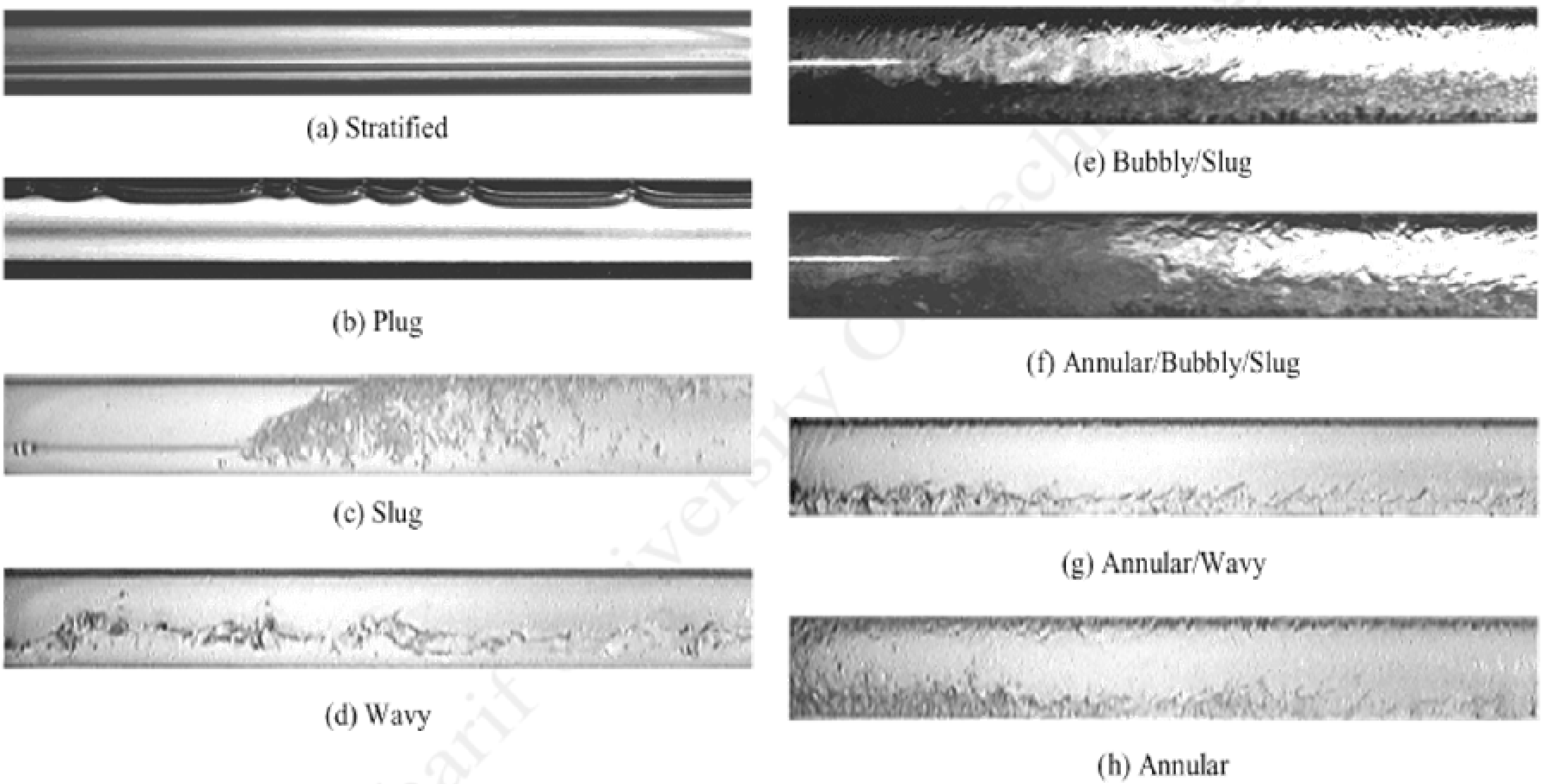


Introduction

Schematic of Flow Pattern in Horizontal Flow



Picture of Flow Pattern in Horizontal Adiabatic Flow



(a) Stratified

(b) Plug

(c) Slug

(d) Wavy

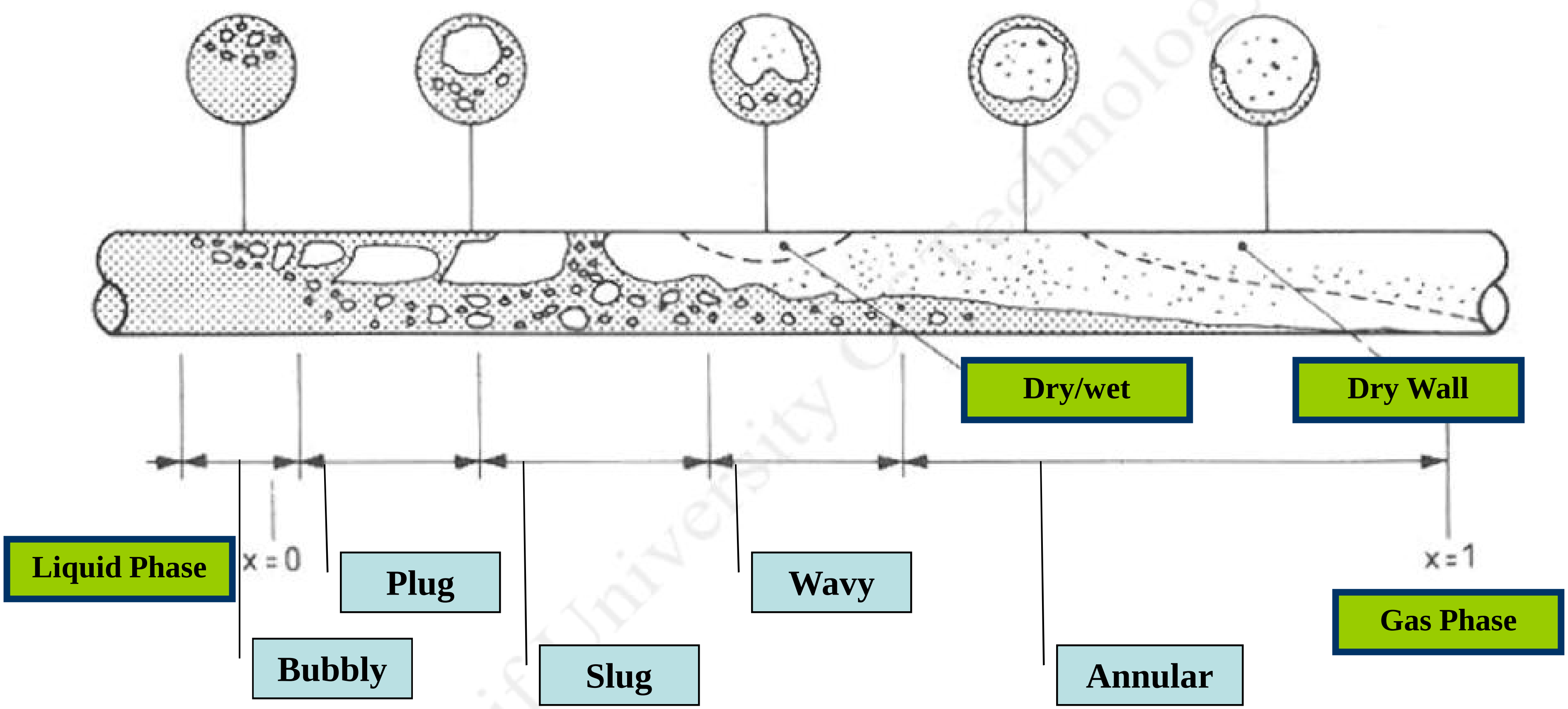
(e) Bubbly/Slug

(f) Annular/Bubbly/Slug

(g) Annular/Wavy

(h) Annular

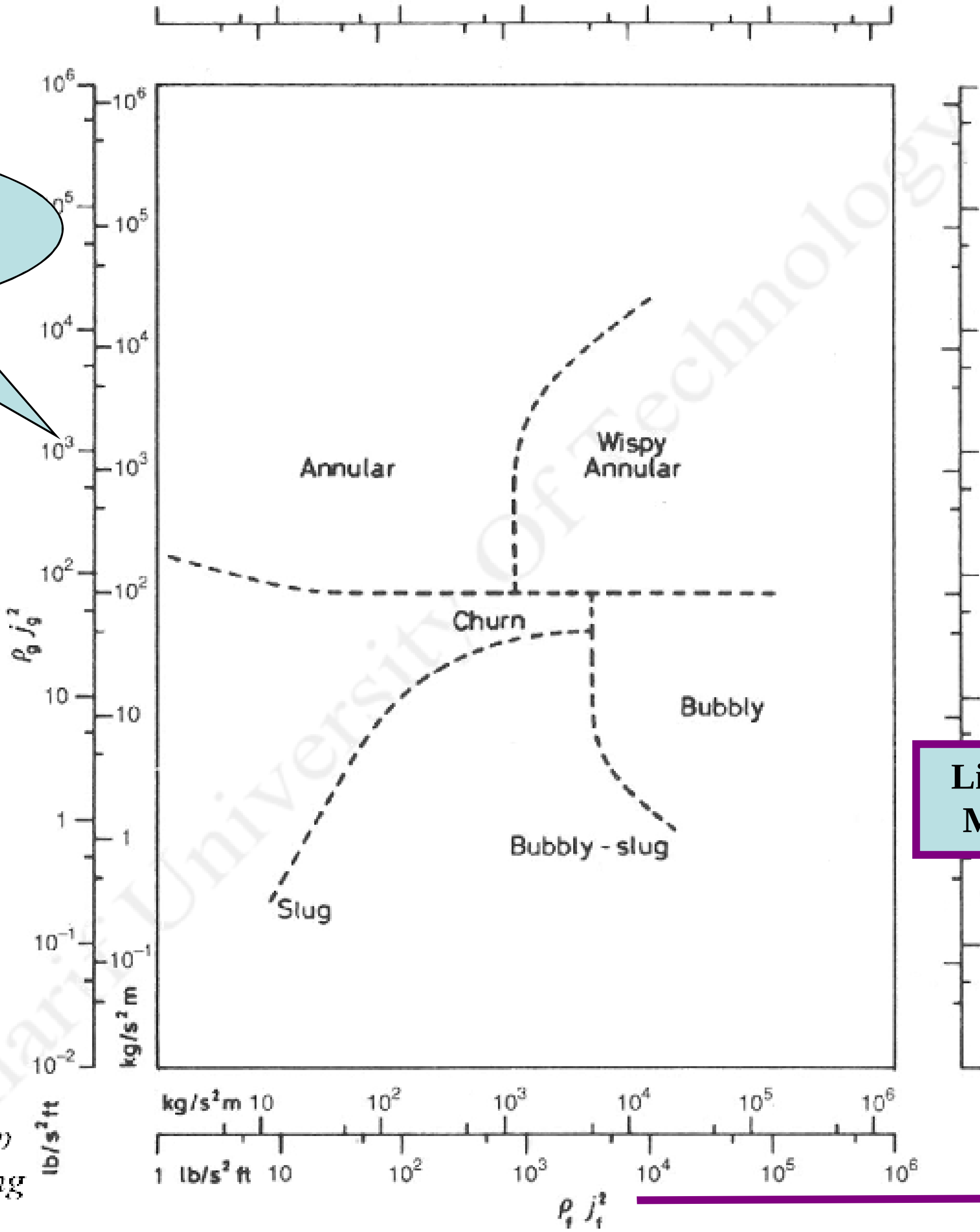
Flow Pattern in Horizontal Heated Channel



Vertical Flow Pattern Map

Hewitt & Roberts 1969

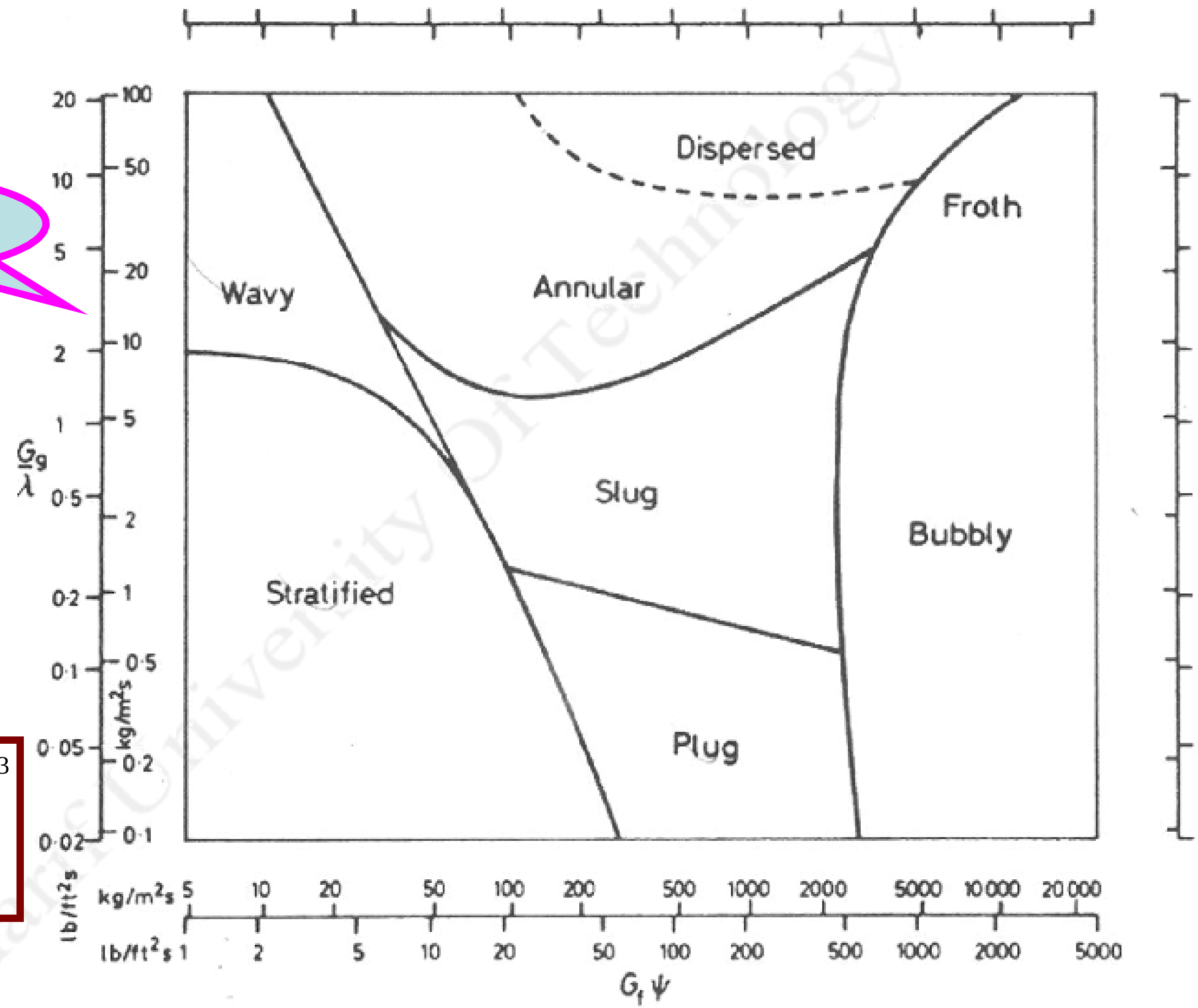
Vapor Superficial Momentum Flux



Liquid Superficial Momentum Flux

Horizontal Flow Pattern Map

Baker 1954

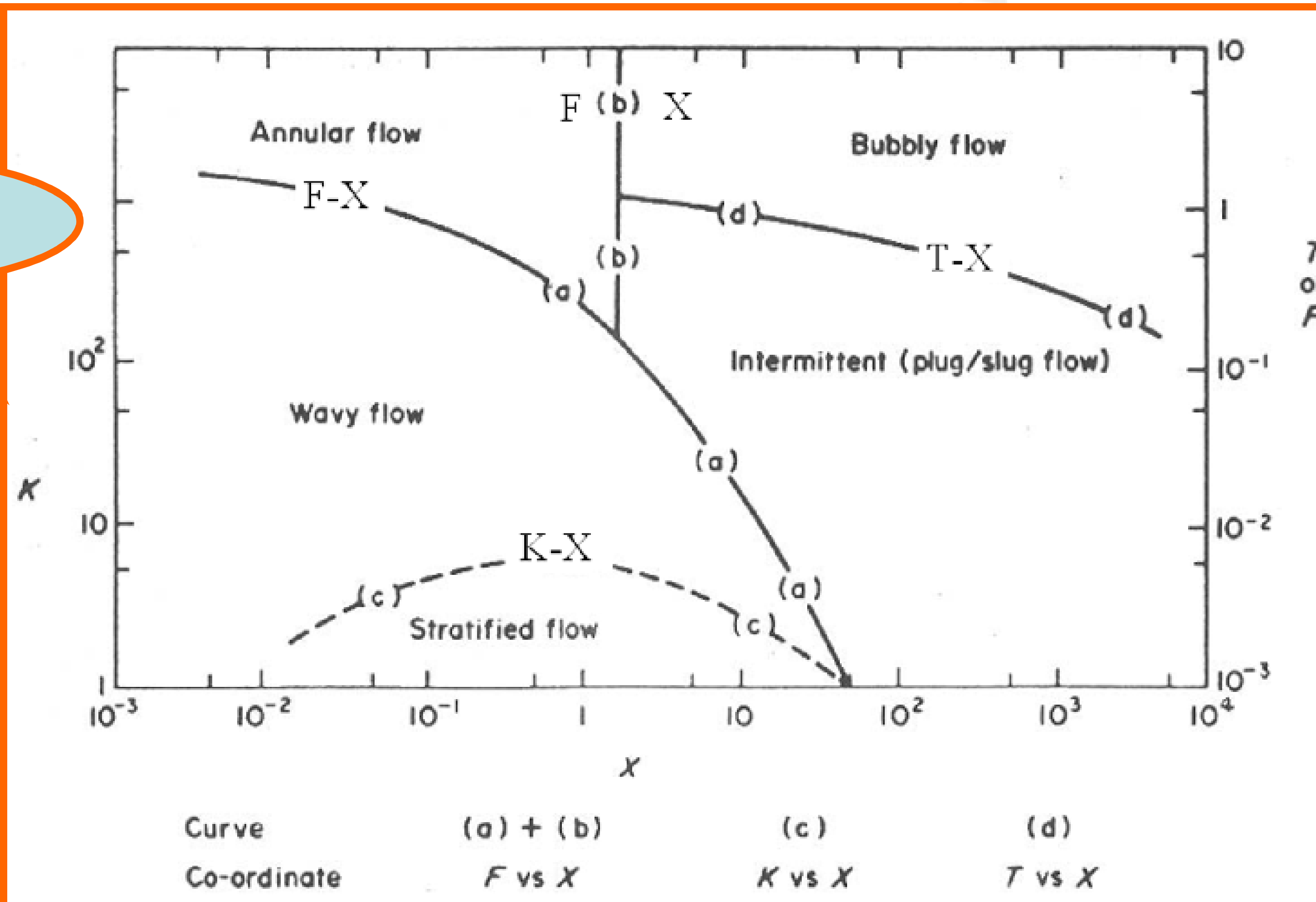


$$l = \left[\left(\frac{r_g}{r_A}\right)\left(\frac{r_f}{r_W}\right)\right]^{1/2}$$

$$y = \left(\frac{s_w}{s}\right)\left[\left(\frac{m_f}{m_W}\right)\left(\frac{r_w}{r_f}\right)^2\right]^{1/3}$$

Horizontal Flow Pattern Map and Transition

Taitel & Duckler 1976



Transition for Horizontal Flow

a. Stratified to non- stratified

b. Bubbly flow transition

- Little bubble coalescence and formation of large bubble
- Turbulence fluctuation break the bubbles
- Gravitational force lift bubbles

c. Transition to annular flow

d. Annular flow to wispy-annular flow transition