Two Phase Flows

(Section 6)

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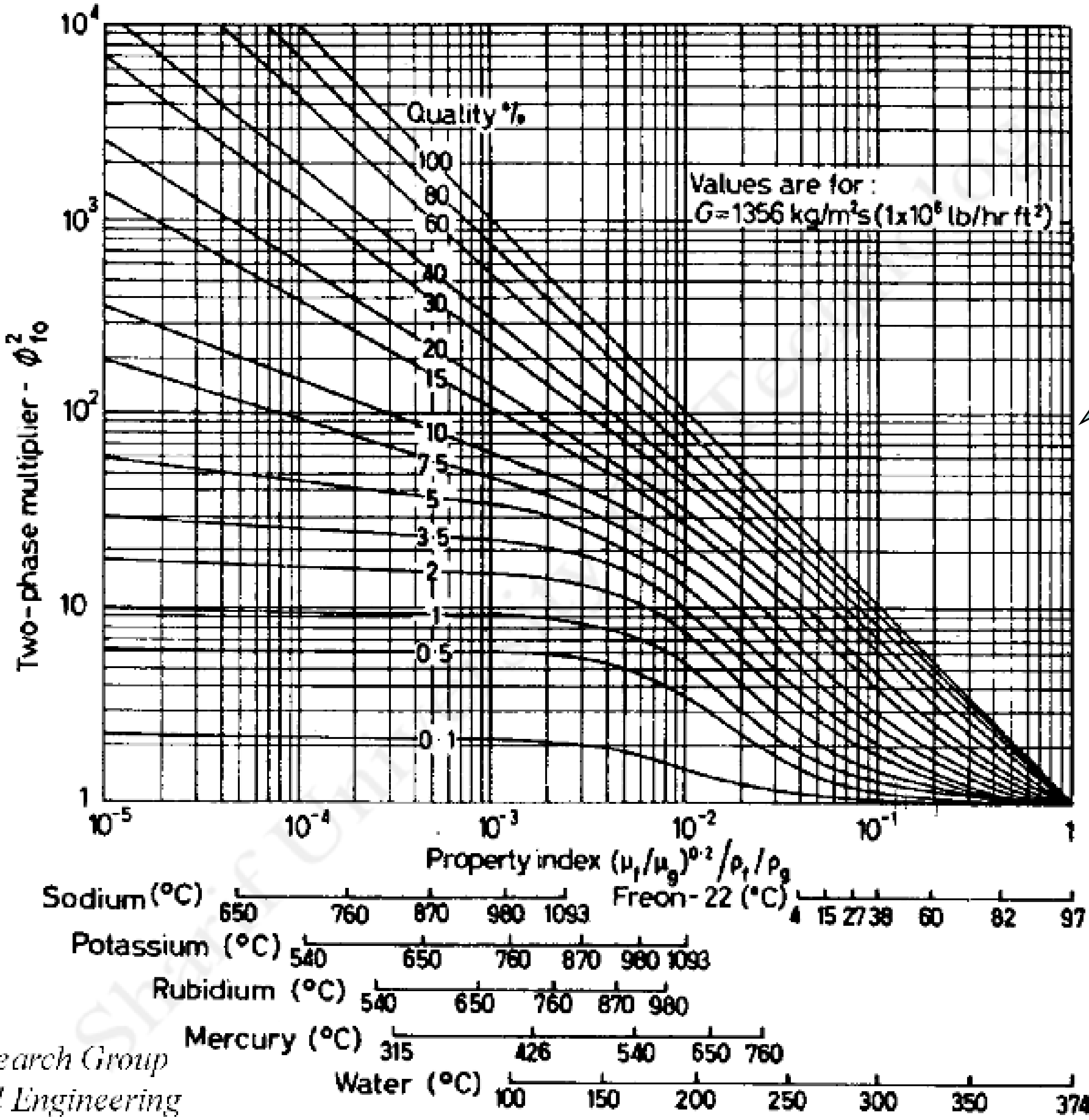
Two Phase Flows

Homework set#2

Problems 5-9; Chapter 1, Collier and Thome.

Due to next Tuesday

Methods Used with HM and SFM



Baroczy (1965)

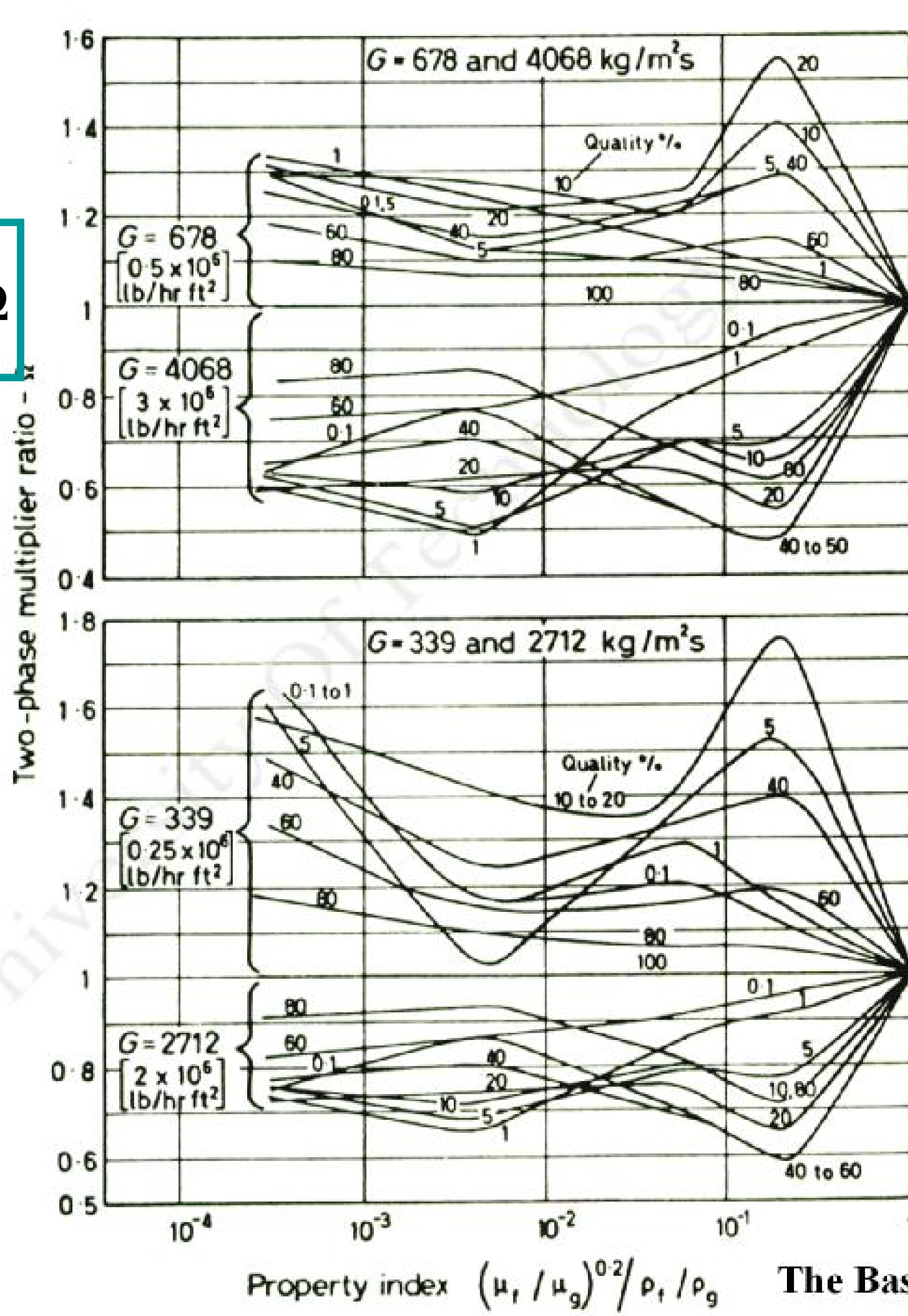
Baroczy Method

Baroczy (for flux of mass flow rate 1365 kg/m².s)

Physical property index $\left(\frac{\mu_f}{\mu_g}\right)^{0.2} \Big/ \left(\frac{\rho_f}{\rho_g}\right)$	Vapour quality % by wt.														
	0.1	0.5	1	2	3.5	5	7.5	10	15	20	30	40	60	80	100
0.0001	2.20	5.80	9.20	16.0	26.5	47.0	99.0	163	376	630	1300	2050	4300	6600	10,000
0.001	2.15	5.60	8.80	14.8	22.8	34.2	48.2	70.0	108	148	240	330	538	760	1,000
0.004	2.08	4.90	7.80	11.9	16.3	22.8	29.0	36.0	49.5	63.0	86.0	110	155	203	250
0.01	1.59	3.30	4.80	7.00	9.60	12.4	16.0	20.0	27.0	33.5	43.5	53.0	69.0	85.0	100
0.03	1.12	1.55	1.81	2.57	3.45	4.7	6.10	7.90	11.0	13.2	17.3	21.2	26.0	30.0	33.3
0.1	1.04	1.12	1.22	1.48	1.78	2.05	2.50	2.80	3.60	4.20	5.50	6.50	8.00	9.10	10.0
0.3	1.01	1.02	1.06	1.13	1.26	1.36	1.50	1.59	1.77	1.93	2.25	2.48	2.86	3.20	3.33
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

$$\left(\frac{dp}{dz}F\right) = \frac{2 f_{fo} G^2 n_f}{D} \Phi^2_{fo(G=1356)} \Omega$$

Baroczy method has the satisfaction results for liquid metals and refrigerants.



Chisholm method

$$f_f^2 = 1 + \frac{C}{X} + \frac{1}{X^2}$$

$$C = \left[l + (C_2 - l)\left(\frac{v_{fg}}{v_g}\right)^{0.5} \right] \left[\left(\frac{v_g}{v_f}\right)^{0.5} + \left(\frac{v_f}{v_g}\right)^{0.5} \right]$$ **A**

$$l = 0.5(2^{(2-n)} - 2)$$

$$f_f = K_f \left[\frac{r_f u_f D_f}{m_f} \right]^{-n}$$

For rough pipe: n=0 and λ=1

For smooth pipe: n=0.25 and λ=0.68

at critical pressure → **$v_f = v_g$ and $v_{fg} = 0$** →

For rough pipe: C=2

For smooth pipe: C=1.36

Chisholm method

Chisholm proposed this method for water-steam flow in the pipe at high pressure

$for \quad G \le G^*$ → **for smooth pipe:** → $$G^* = 2000 \frac{kg}{m^2.s} \; or \; 1.47\times10^6 \frac{lb}{h.ft^2}$$

C is calculated by equation A with λ=0.75 and C_2=G^*/G

for rough pipe: → $$G^* = 1500 \frac{kg}{m^2.s} \; or \; 1.1\times10^6 \frac{lb}{h.ft^2}$$

C is calculated by equation A with λ=1 and C_2=G^*/G

Chisholm method

$for \quad G^* \le G$

for smooth and rough pipe

$$f_f^2 = (1 + \frac{\bar{C}}{X} + \frac{1}{X^2})y$$

$$y = (1 + \frac{C}{T} + \frac{1}{T^2}) / (1 + \frac{\bar{C}}{T} + \frac{1}{T^2})$$

$$\bar{C} = (\frac{v_g}{v_f})^{0.5} + (\frac{v_f}{v_g})^{0.5}$$

$$T = (\frac{x}{1-x})^{1-\frac{n}{2}} (\frac{m_f}{m_g})^{\frac{n}{2}} (\frac{v_f}{v_g})^{0.5}$$

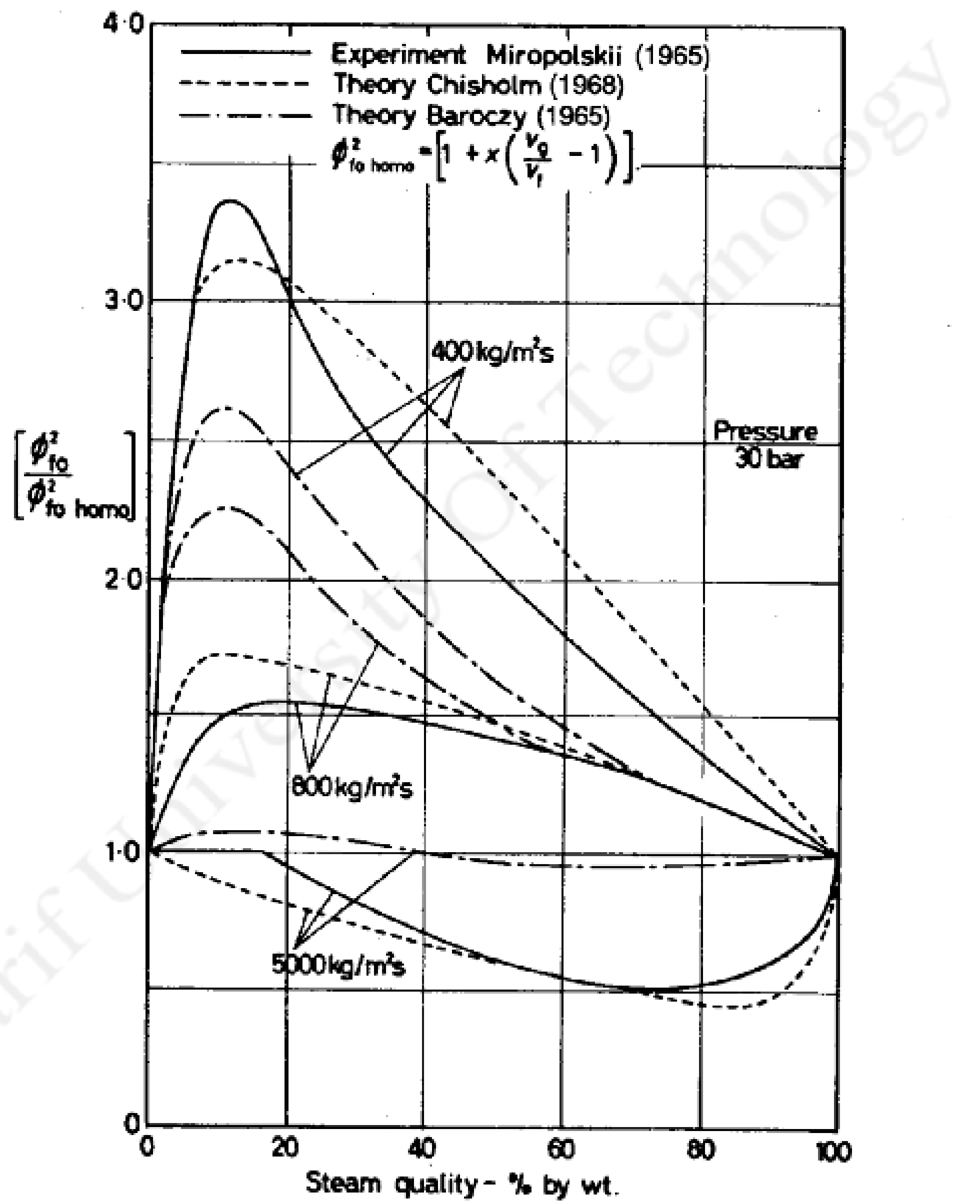
for smooth pipe C is calculated by equation A with λ=0.75 and C_2=G^*/G

For rough pipe C is calculated by equation A with λ=1 and C_2=G^*/G

Comparison of experiment with Chisholm and Baroczy theory

Baroczy theory can be used directly for the other systems

Chisholm theory must be corrected with property index when it used for the other systems



Index of property

$$\left[\left(\frac{v_f}{v_g}\right)\left(\frac{m_f}{m_g}\right)^{0.2} \right]$$

Friedel Theory

$$(f_{fo}^2)_{heated\,Tube} = A_1 + \frac{3.24 A_2 A_3}{Fr^{0.045} We^{0.035}}$$

Friedel (1979) is one of the exactest relation for two phase flow

$$A_1 = (1-x)^2 + x^2 \left(\frac{r_f f_{go}}{r_g f_{fo}}\right)$$

$$A_2 = x^{0.78} (1-x)^{0.224}$$

$$A_3 = \left(\frac{r_f}{r_g}\right)^{0.91} \left(\frac{m_g}{m_f}\right)^{0.19} \left(1-\frac{m_g}{m_f}\right)^{0.7}$$

$$Fr = \frac{G^2}{gD\bar{r}^2}$$

$$We = \frac{G^2 D}{\bar{r} s}$$

Whalley (1980) recommendation for separated flow

- **For μ_f/μ_g<1000:**

  Friedel theory (1979)

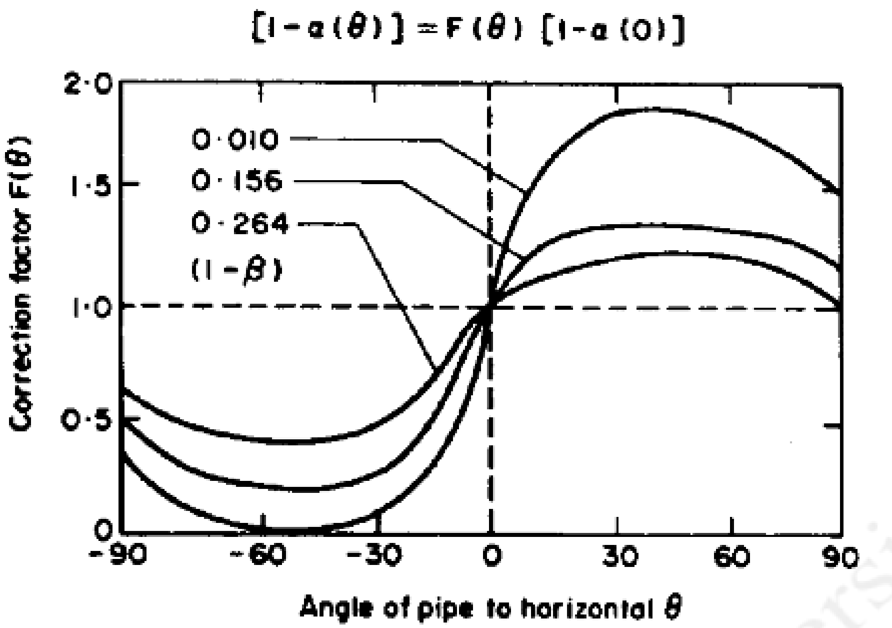
- **For μ_f/μ_g>1000 and G>100 kg/m²**.**s: corrected theory of Chisholm (1973)**

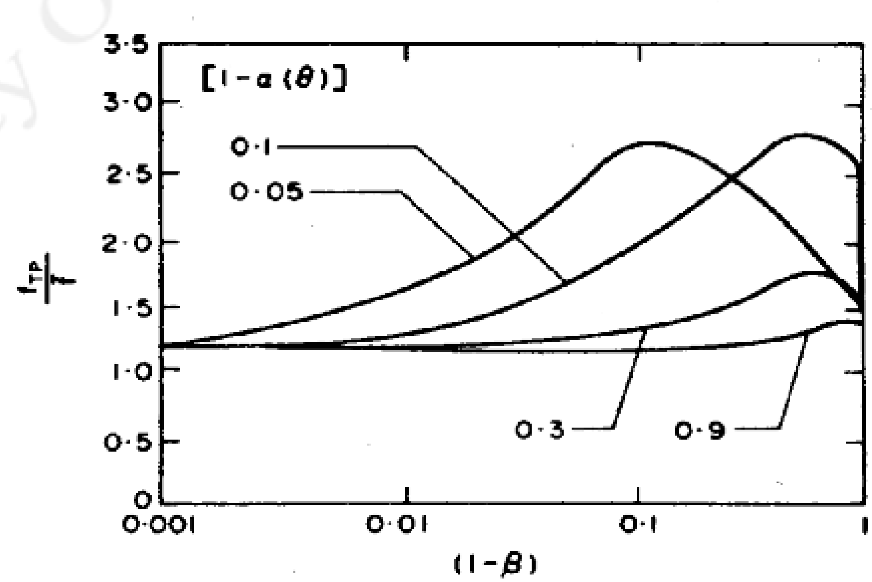
- **For μ_f/μ_g>1000 and G<100 kg/m2.s:**

  theory of Lockhart- Martinelli(1949) and Martinelli- Nelson(1948)

Two phase flow in inclined pipes

Beggs and Brill
1973





Multiphase Flow Research Group
School of Mechanical Engineering

The Basic Model

Effect of heat flux on the void fraction and pressure gradient

Tarasova (1966) and Leont'ev (1965) find a relationship between heat flux and pressure gradient

Tarasova and Leont'ev proposed a empirical equation for friction multiplayer in the isolation pipe for water-steam system

$$(f_{fo}^{2})_{heated\,Tube} = (f_{fo}^{2})_{Unheated\,Tube}[1+4.4*10^{-3}(\frac{f}{G})^{0.7}]$$