$\frac{g}{l}$

$l \begin{cases} \text{oil} \\ \text{water} \end{cases} \} \rightarrow$

$\frac{q_w}{q_o + q_w}$

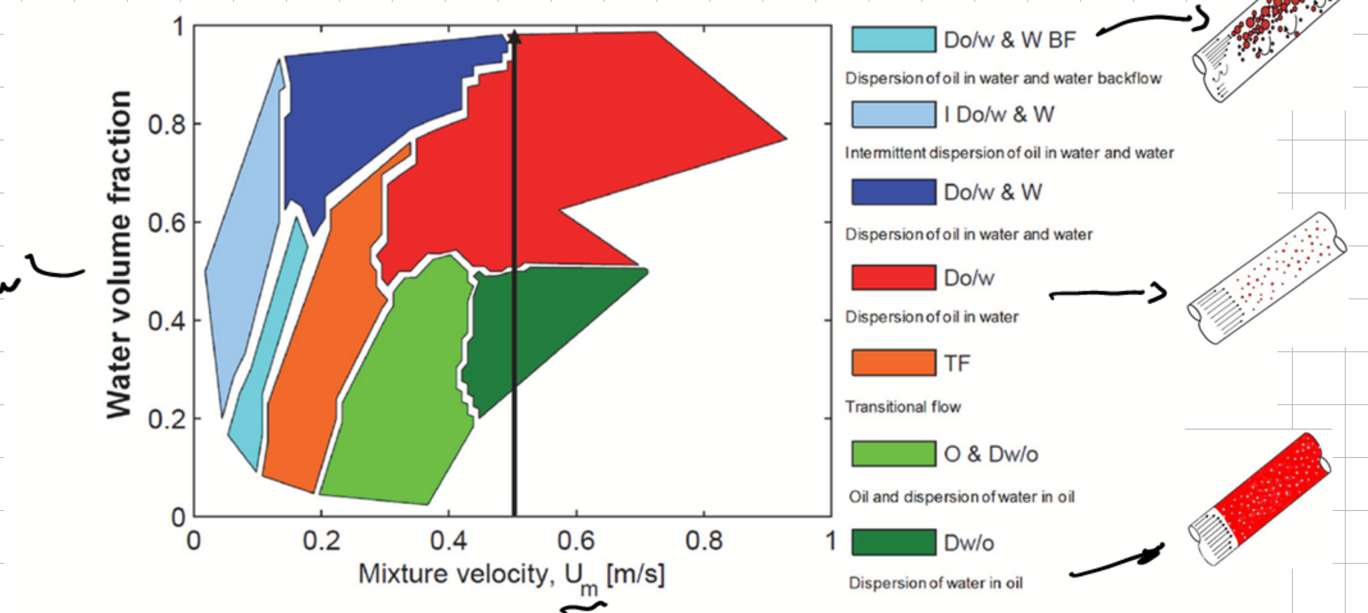


FIGURE 7-24. OIL-WATER FLOW PATTERN MAP OF WATER VOLUME FRACTION VERSUS MIXTURE VELOCITY FOR AN UPWARD PIPE INCLINATION OF 45°. FIGURE ADAPTED FROM RIVERA[7-5] [7-1].

$u_{so} + u_{sw}$

$$\left.\begin{matrix} g \\ o \\ w \end{matrix}\right\} \begin{matrix} u_{sg} & \lambda_g & H_g & V_g \\ u_{so} & \lambda_o & H_o & V_o \\ u_{sw} & \lambda_w & H_w & V_w \end{matrix}$$

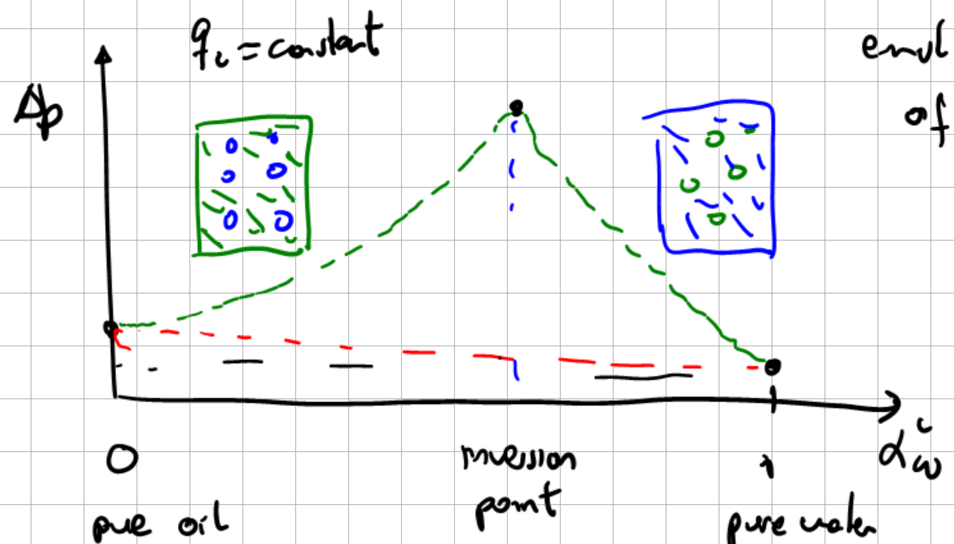
$V_o \approx V_w$ little slip

assume both travel at the same speed V_L

$$\rho_L = \rho_o \alpha_o^L + \rho_w \alpha_w^L \qquad \mu_L = \mu_o \alpha_o^L + \mu_w \cdot \alpha_w^L$$

$$\alpha_o^L = \frac{q_o}{q_o + q_w} \qquad \alpha_w^L = \frac{q_w}{q_o + q_w} = 1 - \alpha_o^L$$

$\frac{q_L}{q_o + q_w} \rightarrow$



emulsion behavior of oil + water mixture

$$\mu_L = \mu_o \cdot e^{c_1(\alpha_w^L)} \qquad \mu_L = \mu_w \cdot e^{c_2(1-\alpha_w^L)}$$

$$wc = \frac{q_{\bar{w}}}{q_{\bar{o}} + q_{\bar{w}}} \qquad \alpha_w^L = \frac{q_w}{q_o + q_w}$$

sometimes in the literature, if $q_{\bar{o}} = q_o$

$wc \approx \alpha_w^L$

Pressure integration method

p_3

p_2 } ΔL

p_1

$$p_2 = p_1 + \left.\frac{dp}{dx}\right|_{@p_1} \cdot \Delta L$$ } not so accurate for large ΔL

$$p_2 = p_1 + \left.\frac{dp}{dx}\right|_{@p_{av}} \Delta L$$

$$p_{av} = \frac{p_1 + p_2}{2}$$

implicit calculation

- assume a value of p_2^*
- compute $\left.\frac{dp}{dx}\right|_{p_{av}}$
- compute $p_2^{calc} = p_1 + \left.\frac{dp}{dx}\right|_{@p_{av}} \Delta L$
- check $p_2^{calc} = p_2^*$

not → (back to assume a value of p_2^*)

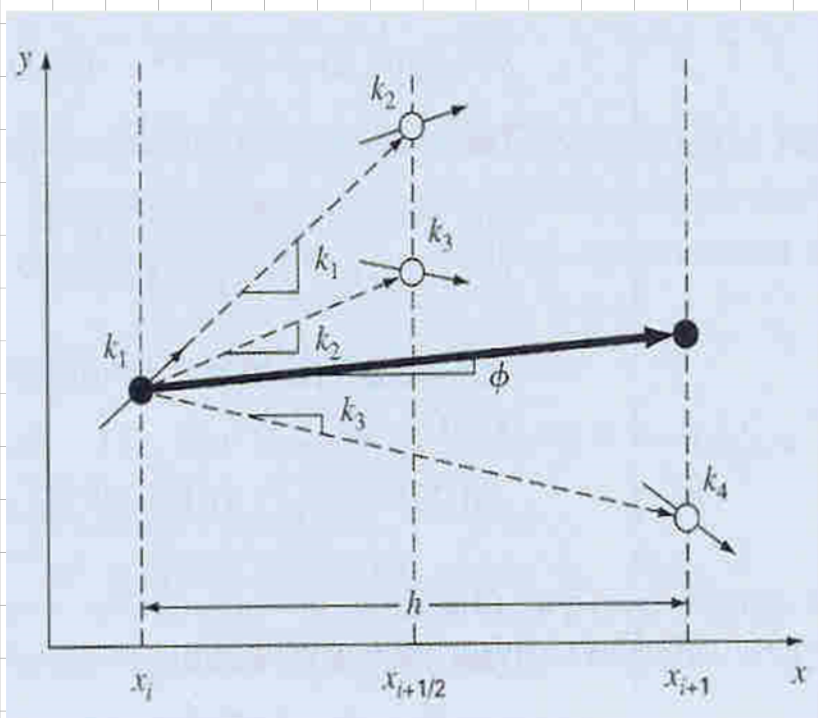
yes ↓

proceed to next step

explicit approach (higher order)

Runge-Kutta 4th

$$y_{n+1} = y_n + \frac{1}{6} \cdot h \cdot (k_1 + 2 \cdot k_2 + 2 \cdot k_3 + k_4)$$



p_1 $\quad$ p^* $\quad$ p_2

$$p_2 = p_1 + \frac{1}{6} \Delta L (k_1 + 2k_2 + 2k_3 + k_4)$$

$$k_1 = \left.\frac{dp}{dx}\right|_{@p_1}$$

$$p^* = p_1 + \left.\frac{dp}{dx}\right|_{@p_1} \cdot \frac{\Delta L}{2}$$

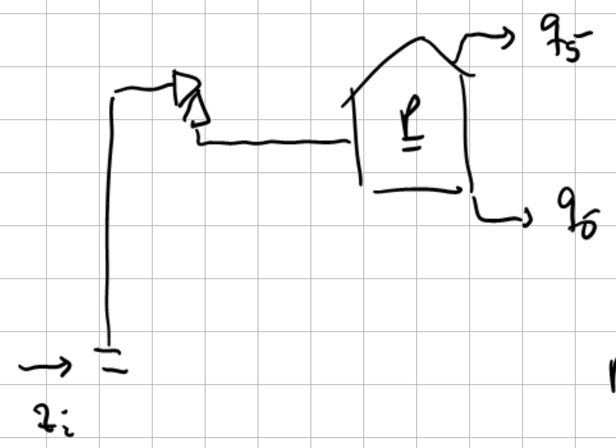
$$k_2 = \left.\frac{dp}{dx}\right|_{@p^*}$$

$$p^{**} = p_1 + k_2 \frac{\Delta L}{2}$$

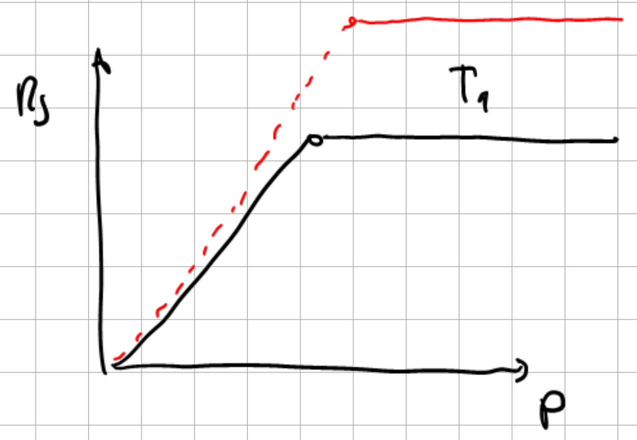
$$k_3 = \left.\frac{dp}{dx}\right|_{@p^{**}}$$

$$p^{***} = p_1 + k_3 \Delta L$$

$$k_4 = \left.\frac{dp}{dx}\right|_{@p^{***}}$$



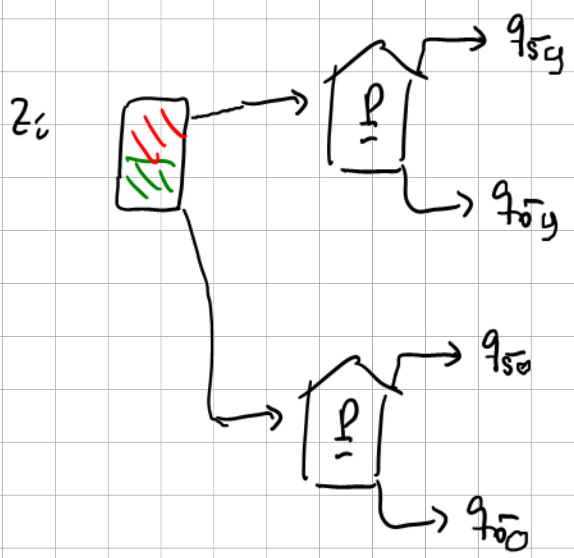
$R_p = \frac{q_{\bar g}}{q_{\bar o}}$ If z_i changes then R_p should also change



If z_i changes

z_i^*

If z_i changes (or R_p) it is usually necessary to generate a new black oil table



$T_3 > T_1 > T_2$