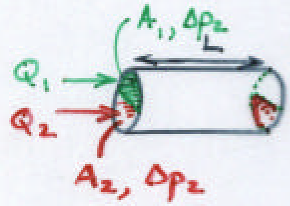
3.1 MOTION EQUATIONS

Apply Darcy's Law



Establish steady flow at volumetric flow rates, Q_1 and Q_2.

□ $q_1 = \left(\frac{k_1}{\mu_1}\right) \frac{\Delta p_1}{L}$

□ $q_2 = \left(\frac{k_2}{\mu_2}\right) \frac{\Delta p_2}{L}$

$$q_\alpha = \left(\frac{k_\alpha}{\mu_\alpha}\right) \frac{\Delta p_\alpha}{L} \quad ; \quad q_\alpha = \frac{Q_\alpha}{A_\alpha}$$

Δp_α = effective pressure drop of α^{th} fluid

k_α = "effective" permeability of medium to fluid α.

k_α depends on: a) Porous medium (pore size & distribution and fractures).

b) Saturation, S_w and S_{nw}.

"Relative" permeabilities

$$k_{r_1} = \frac{k_1}{k}(S_1) \quad ; \quad k_{r_2} = \frac{k_2}{k}(S_2)$$

□ Relative to single phase permeability of a fully saturating fluid

□ Determine from "equilibrium" laboratory flow tests under different saturations.

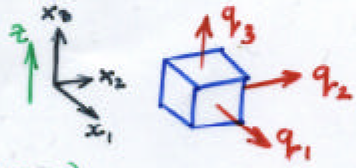
$$k_1 = k_{r_1} k$$

Effective permeability → k_1

Relative permeability → k_{r_1}

True permeability (L^2) → k

FLUID MOTION EQUATION (DARCY'S LAW)



i = flow direction, x_1, x_2, x_3. ("z" is // to x_3)

$$q_{i_1} = -\frac{k_1}{\mu_1}\left(\frac{\partial p_1}{\partial x_j} + \rho_1 g \frac{\partial z}{\partial x_j}\right) = -k\frac{k_{r1}}{\mu_1}\left(\frac{\partial p_1}{\partial x_j} + \rho_1 g \frac{\partial z}{\partial x_j}\right)$$

$\frac{K_2}{\rho_2 g}$

$$q_{i_2} = -\frac{k_2}{\mu_2}\left(\frac{\partial p_2}{\partial x_j} + \rho_2 g \frac{\partial z}{\partial x_j}\right) = -k\frac{k_{r2}}{\mu_2}\left(\frac{\partial p_2}{\partial x_j} + \rho_2 g \frac{\partial z}{\partial x_j}\right)$$

May also use piezometric head, h, for constant ρ_1 and ρ_2, but must be defined separately for each fluid, h_α

$$h_\alpha = \frac{p_\alpha}{\rho_\alpha g} + z \quad ; \qquad \alpha = 1, 2$$

$$q_{i_1} = -k\frac{k_{r_1}}{\mu_1}\rho_1 g \frac{\partial h_1}{\partial x_j}$$

$$q_{i_2} = -k\frac{k_{r_2}}{\mu_2}\rho_2 g \frac{\partial h_2}{\partial x_j}$$

Similarity between:

$$q = -k\frac{\rho g}{\mu}\frac{dh}{dx_j}$$

k: permeability (L^2)

$$= -K\frac{dh}{dx_j}$$

K: Hydraulic Conductivity (L/T)

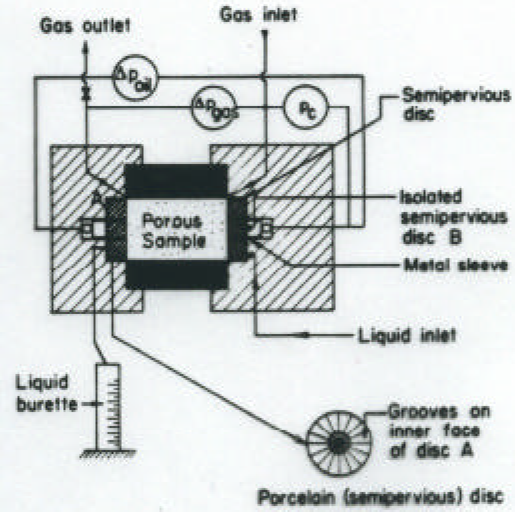


FIG. 9.2.15. Hassler's apparatus for relative permeability determination (after Osoba et al., 1951).

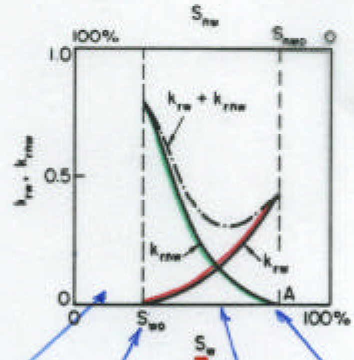


FIG. 9.3.1. Typical relative permeability curves (e.g., wetting fluid = water, nonwetting fluid = oil).