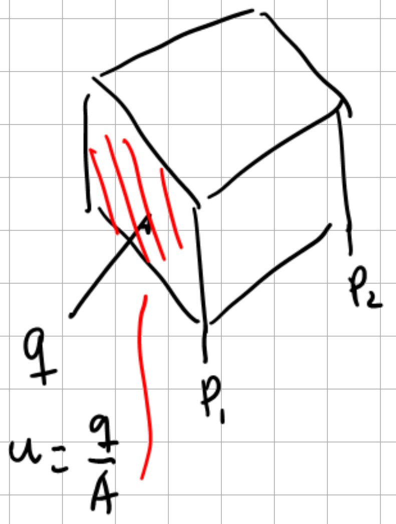
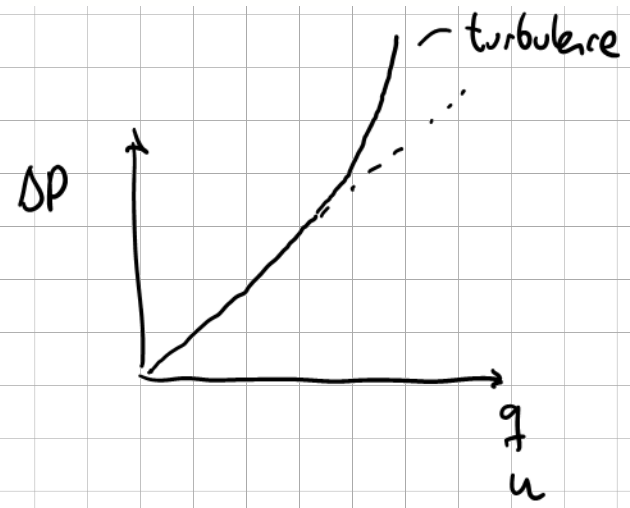
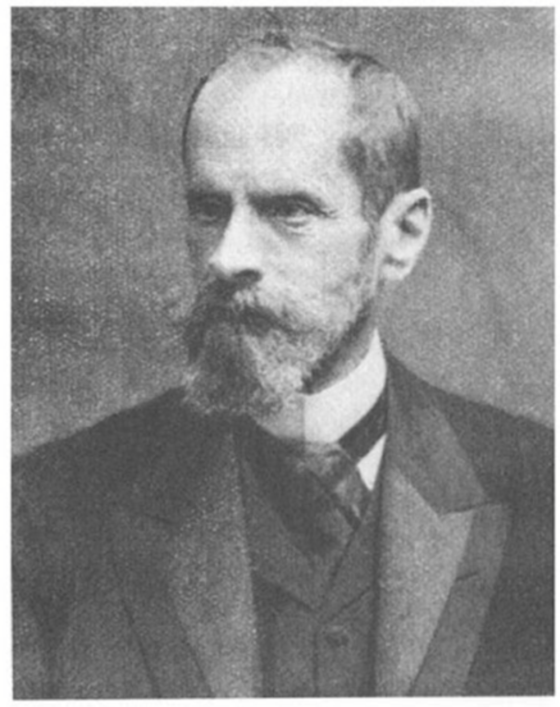
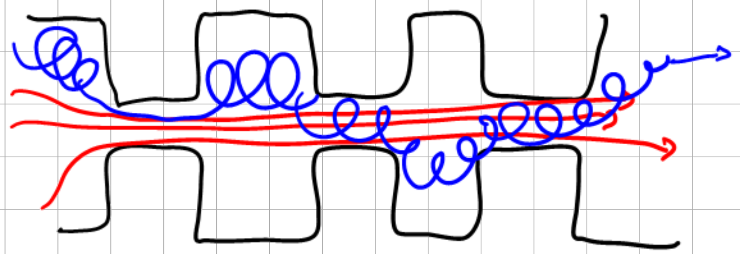
[19] P. Forchheimer. *Wasserbewegung durch Boden.* Zeitschrift des Vereines Deutscher Ingenieuer, 45 edition, 1901.





*Professor Philipp Forchheimer.*

not valid for medium-high rate gas wells
high rate sat oil }



$$\Delta P = A \cdot u + B u^2$$

$$\Delta P = A u \left(1 + \frac{B}{A} u\right)$$

Use of Short Term Multiple Rate Flow Tests To Predict Performance of Wells Having Turbulence

(1976)

Lloyd G. Jones and E. M. Blount, Mobil Research and Development Corp., and O. H. Glaze, Mobil Oil Corp., Members SPE-AIME

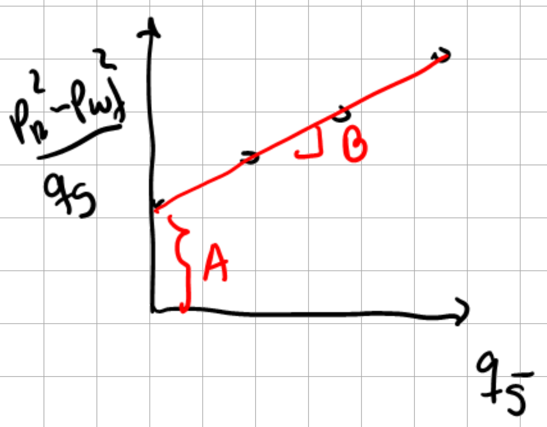
LP dry gas wells

$$(p_R^2 - p_{wf}^2) = A\, q_{sc} + B\, q_{sc}^2$$


$$\frac{(p_R^2 - p_{wf}^2)}{q_{sc}} = A + B\, q_{sc}$$

quadratic equation

$$a x^2 + b x + c = 0$$




$$q_{sc} = \frac{7.63\, k h}{T_R\, \mu_g\, z} \frac{(p_R^2 - p_{wf}^2)}{\left(\ln\left(\frac{r_e}{r_w}\right) - 0.75 + S\right)}$$

$$(p_R^2 - p_{wf}^2) = \frac{T_R\, \mu_g\, z}{7.63\, k h}\left[\left(\ln\left(\frac{r_e}{r_w}\right) - 0.75 + S\right) q_{sc}\right] + B\, q_{sc}^2$$

rate dependent skin

$$B = \frac{D\, z\, \mu_g\, T_R}{7.63 \cdot k h}$$

$$(p_R^2 - p_{wf}^2)\frac{7.63\, k h}{T_R\, \mu_g\, z} = \left(\ln \frac{r_e}{r_w} - 0.75 + S\right) q_{sc} + D\, q_{sc}^2$$

$$\frac{\left(p_R^2 - p_{wf}^2\right)}{\left(\ln\left(\frac{r_e}{r_w}\right) - 0.75 + S + D\,q_{\bar{g}}\right)} \frac{7.63\ kh}{T_R\,\mu_g\,z} = q_{\bar{g}}$$

rate-dependent skin

$$D = \left[\frac{d}{Sm^3}\right]$$

$$\hookrightarrow D = f(?)$$

alternative approach

USBM (1935)

$$q_{\bar{g}} = C\left(p_R^2 - p_{wf}^2\right)^n$$

$n$ ? $\nearrow$ 1 laminar (Darcy flow)

$\searrow$ 0.5 turbulent (HVF)

$$q_{\bar{g}} = C\ \underline{\left(p_R^2 - p_{wf}^2\right)^{n}}$$ accounts for turbulent flow

$$C = \frac{(7.63\ kh)^n}{(T\mu_g Z)^n D^{1-n}[\ln(r_e/r_w) - 0.75 + s]^{2n-1}}.$$

extends to other IPRs

$$q_{\bar{g}} = C\left[m(p_R) - m(p_{wf})\right]^n$$

$$C = \frac{(7.63\ \ kh)^n}{T^n D^{1-n}[\ln(r_e/r_w) - 0.75 + s]^{2n-1}}.$$