* DARCY'S LAW (liquid & gas) Velocities

* RATE EQUATIONS +PVT Volumetric Rates

↑

Sellable surface volumetric rates

Control Indirectly

$$\left.\begin{array}{l} q_{\bar{g}} \\ q_{\bar{o}} \end{array}\right. = f(p_{wf})$$ Reservoir Rate Eq.

↑

Flowing Bottomhole pressure (FBHP)

Production Engineering

p_t : surface flowing pressure (FTP)

Control Directly

- Assume "Steady State" flowing conditions

$\underbrace{\text{Pseudo-SS (PSS)}}_{\text{Boundary Dominated}}$

Good assumption when k "higher" ($\gtrsim$10-100 md)

$\left(\frac{dp}{dt}\right) \simeq$ same everywhere in the volume being drained

$\frac{\text{mbar}}{\text{d}}$ $\frac{\text{psi}}{\text{mo}}$

0.0256

0.0254

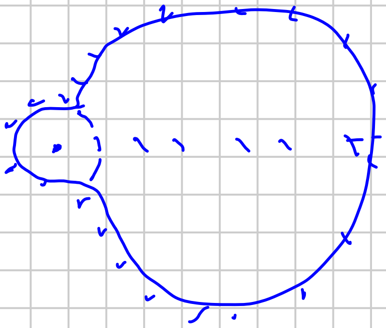
⋮

* Time transition to reach PSS (BD)

hrs days wks months years decades

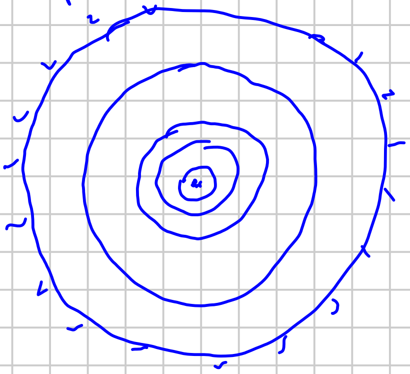
$$t^* = f(k,\ \mu,\ A,\ \text{shape},\ \underset{\uparrow}{c},\ \phi)$$

rock (pore) + fluid



t_{end} IA = 1 hr

t_{start} BD ~ $\frac{1^+}{2}$ day



t_{end} IA = 1 day

t_{start} BD = 1^+

Early-on the system behaves as if there are <u>NO</u> outer boundaries.

"Infinite-Acting"

$\boxed{0 < t < \underset{\underset{\text{start}}{\uparrow}}{t_{BD}}}$: "Transient" Flow (Rate) Analysis :

"Well Testing"

- PTA (Pressure Transient Analysis)
  Assume q = const, $\underset{\uparrow}{\Delta p}(t)$
  Dimensionless Pressure (Drop) : $p_D(t_D) \mid p_i - \underline{p_{wf}(t)}$

- RTA (Rate Transient Analysis)
  Assume p_{wf} = constant, $\underset{\uparrow}{q}(t)$
  Dimensionless Rate : $q_D(t_D)$

$$p_D(t_D) \simeq \frac{1}{q_D(t_D)}$$

In reality $p_{wf}(t)$ $q(t)$ both.

Use superposition (convolution)

* Volumetric Material Balance (used only in BD)

$$\bar{p}_R = f(Q_p) \qquad Q_p = \int_0^t q\,dt$$

$\bar{p}_R$: Volumetric Average Pressure

Q_p: Cumulative Volumetric Production ($\bar{g}$ or $\bar{o}$)

q: surface rate

⊛ $\bar{g}$: $Q_p = G_p$

$\bar{o}$: $Q_p = N_p$

- Gas Expansion
  $pV = nRTZ$!
- c_w
- c_f (formation = rock ⇒ pore)
  $c_f = c_r = c_p$

$$q_g = \frac{kh\,\Delta p}{\quad}$$

$$\Delta p = \bar{p}_R - p_{wf}$$

* Combine $\underbrace{\left[\, q_g\left(p_{wf}, \boxed{\bar{p}_R}\right) \right]}_{\text{Reservoir Rate Eq}}$ with Mat Bal $\underbrace{\bar{p}_R(G_p)}$

$$\boxed{\bar{p}_R} \longleftrightarrow \bar{p}_R\left(\int q_g\,dt\right)$$

$$\boxed{q_g(t)}$$

$\$$

NOK

$=$

$\sum q_g(t) \, P_g(t)$

$\frac{Mscf}{D}$ $\$/Mscf$

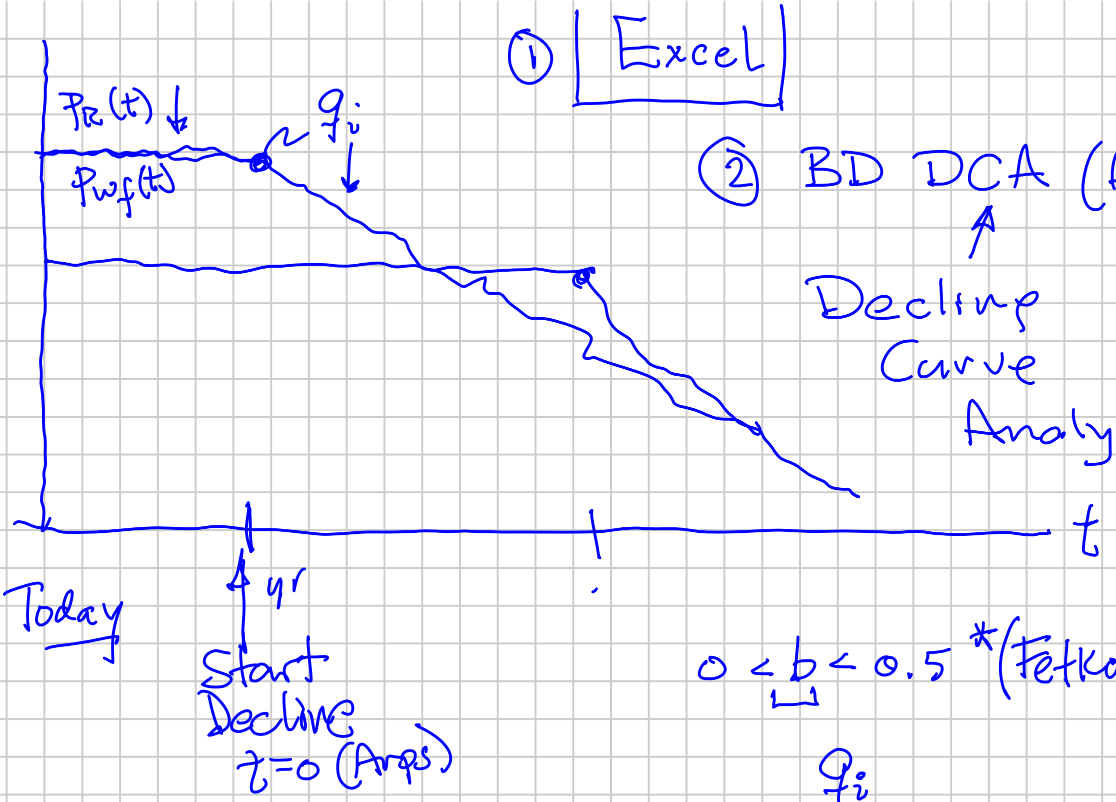
1.5 - 6

① $\boxed{\text{Excel}}$

② BD DCA (Arps)

↑

Decline Curve Analysis



$0 < \underbrace{b} < 0.5$ *(Fetkovich)

Hyperbolic Decline

$$\text{Arps}: \quad q = \frac{q_i}{\left[1 + bD\tau\right]^{1/b}}$$

* Draining a single "Reservoir Unit"

$b = 0$

Exponential Decline

$$q = q_i \cdot e^{-D\tau}$$

$$D = \text{"rate of decline" constant} = \frac{1}{1-b} \cdot \frac{q_i}{Q_{p\infty}}$$

↑

Ultimate Final Cum. Prod.

$q \to 0$

$G = IGIP$

$N = IOIP$

$Q_{p\infty} = RF_{\infty} \cdot IFIP$

Q

↑

Ultimate Recovery Factor

$RF_{\underset{g}{\infty}} \sim 0.5 - 0.98$

$RF_{o\infty} \sim 0.05 \sim 0,5$

Bakken