# MULTI-POINT WELL TEST FOR GAS WELLS

Note Title 2014-11-06

$$q_g = \frac{kh\,(p_{pR} - p_{pwf})}{T_R \left[ \underbrace{\left( \ln \frac{r_e}{r_w} - \frac{3}{4} \right)}_{7-10} + \underbrace{s + Dq_g}_{\text{Total Skin}} \right]}$$

$$\underbrace{B q_g^2 + A q_g}_{\text{Unknown}} - (p_{pR} - p_{pwf}) = 0$$

$B \; (D \,;\, \beta)$ : $\boxed{Re = \frac{\rho v d}{\mu} \gtrsim 1 \Rightarrow B}$ rvlm

$v \propto \frac{1}{r}$ Radial flow near the wellbore BUT need "high"

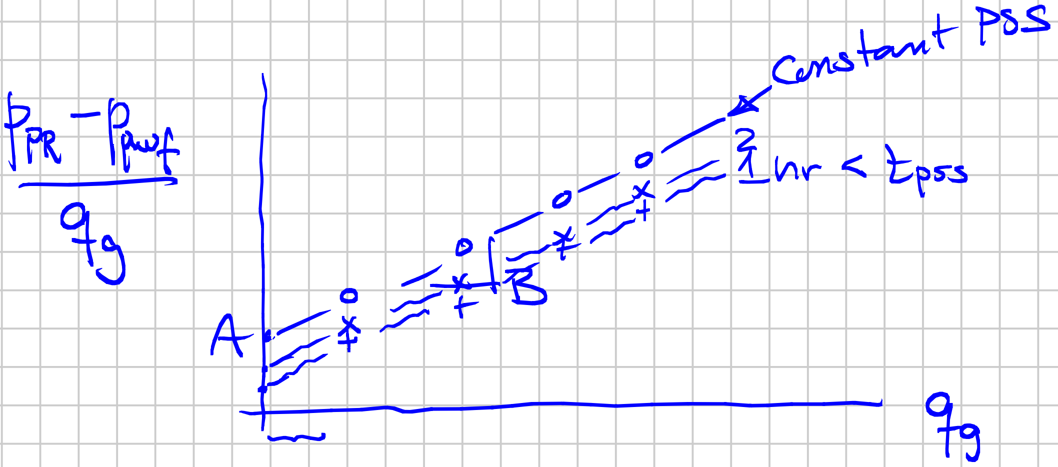
$Dq_g \sim 1-100$

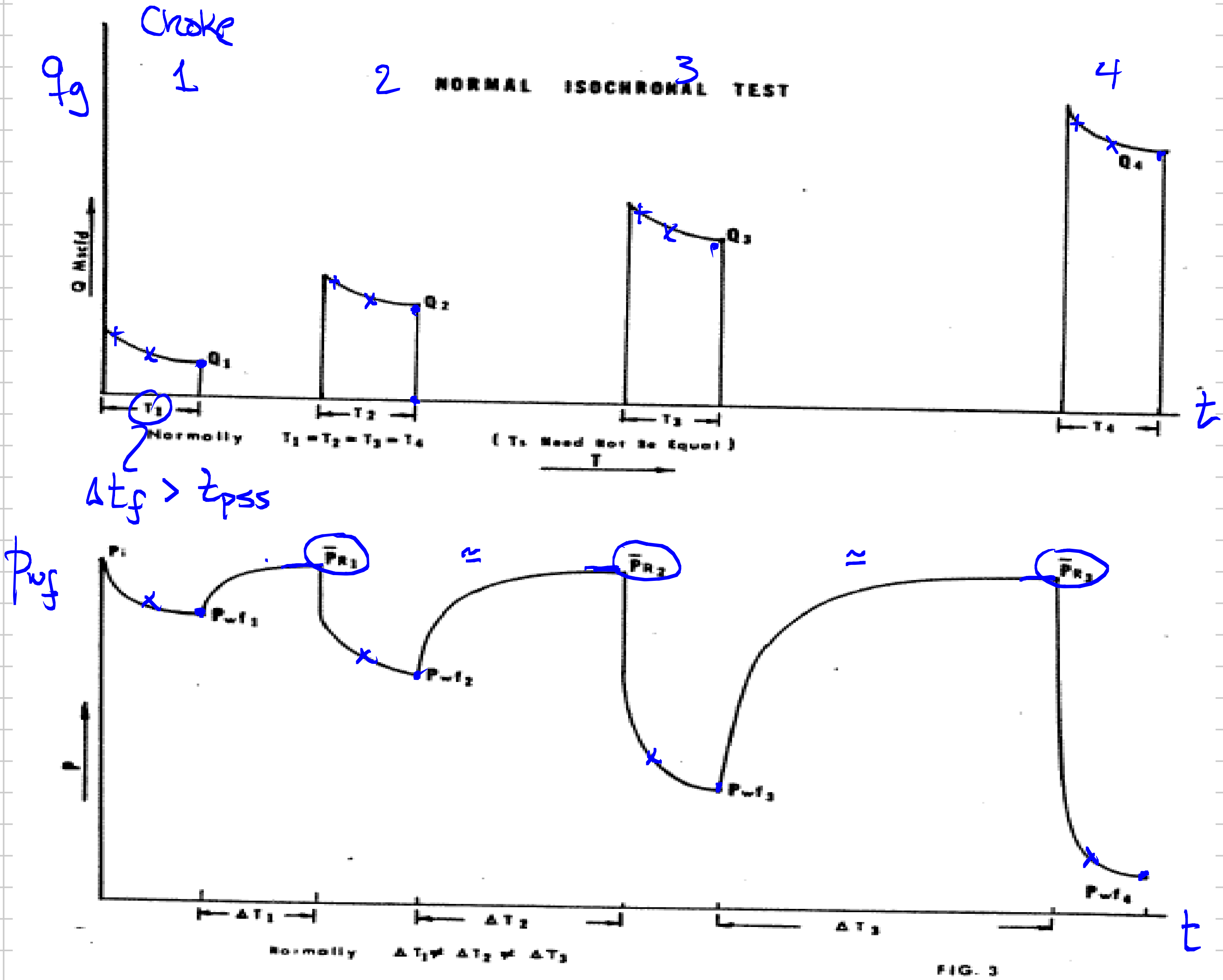
$q_g = 5-50$ MMscf/D

$v = \frac{q_g \cdot B_g}{A_\perp}$

$\simeq 0.1 - 1 \cdot 10^6$ Sm³/d

$A_\perp = 2\pi r h$



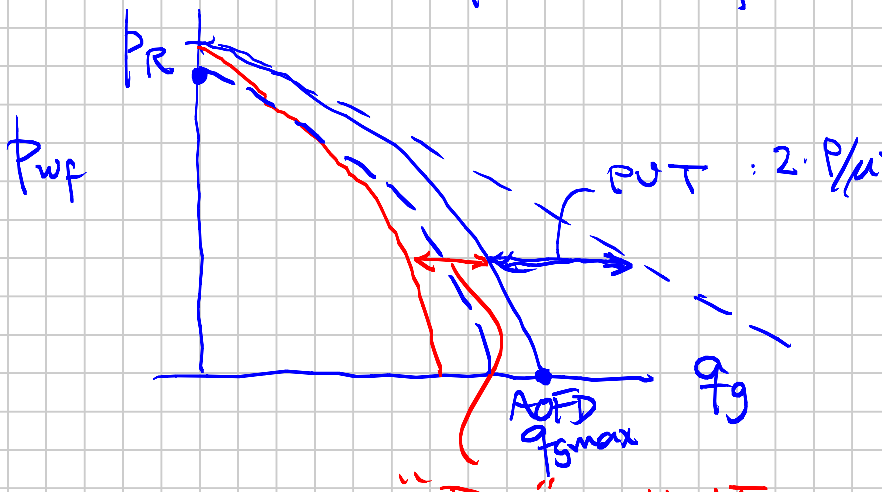


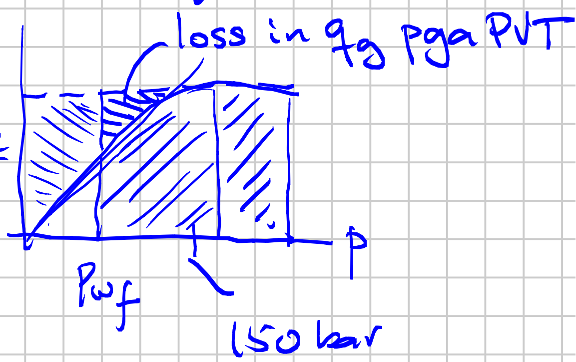

$$A(t) = \frac{T_R}{kh}\Big[\underbrace{p_D(t_D)}_{\frac{1}{2}\left[\ln t_D + 0.809\right]} + s\Big] \qquad t < t_{pss}$$

If $Bq_g << Aq_g$ : Darcy

# Alternative Graphical Representation of IPR

I.




"$Dq_g$" : HVF : non-Darcy

II.

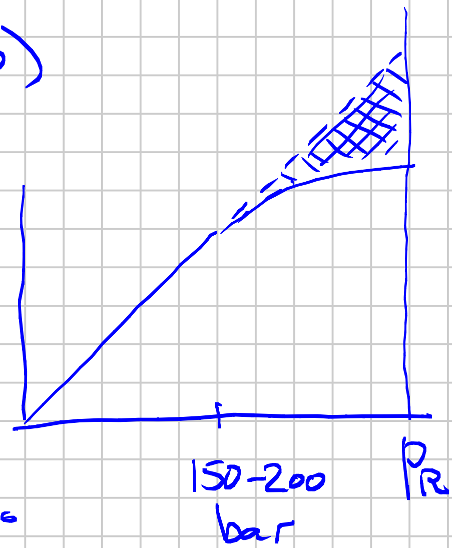

1940s →

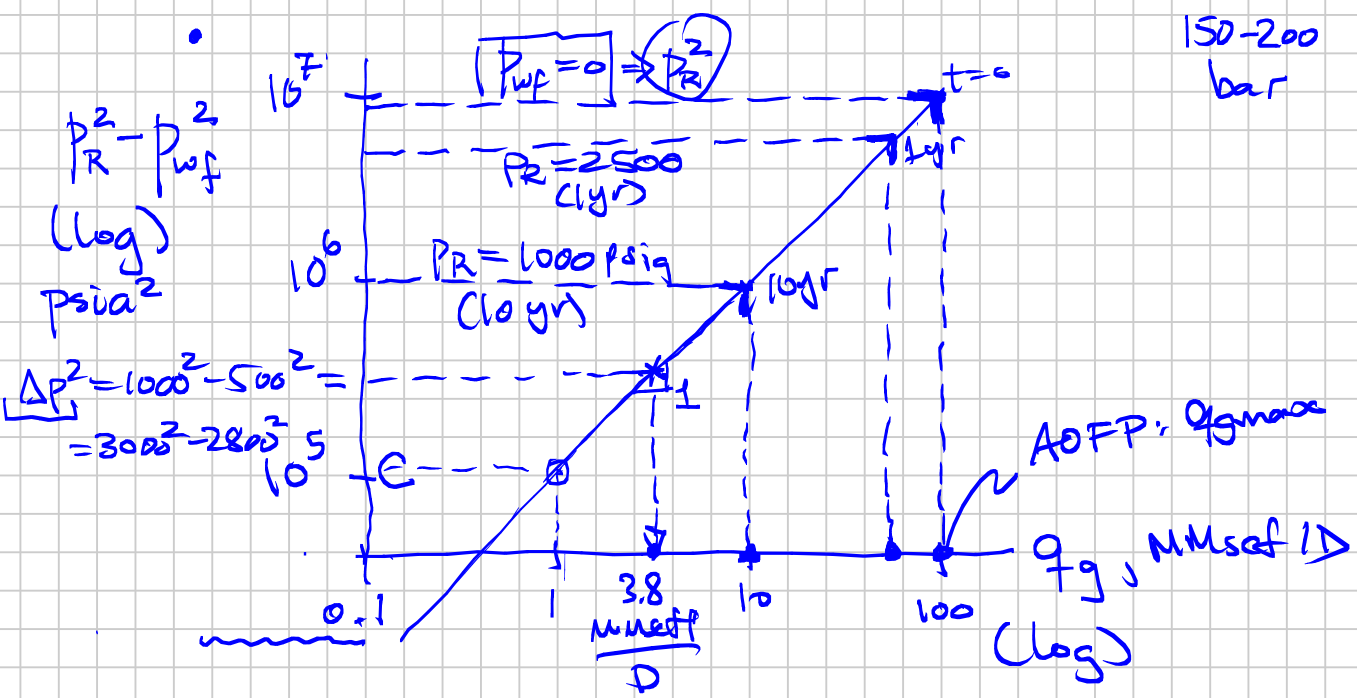
III. (Fetkovich +++ before 1990)

(Log–Log)

Backpressure Plot

- $p_p$ : $p^2$ ; $p_R \lesssim 200$ bar




- 

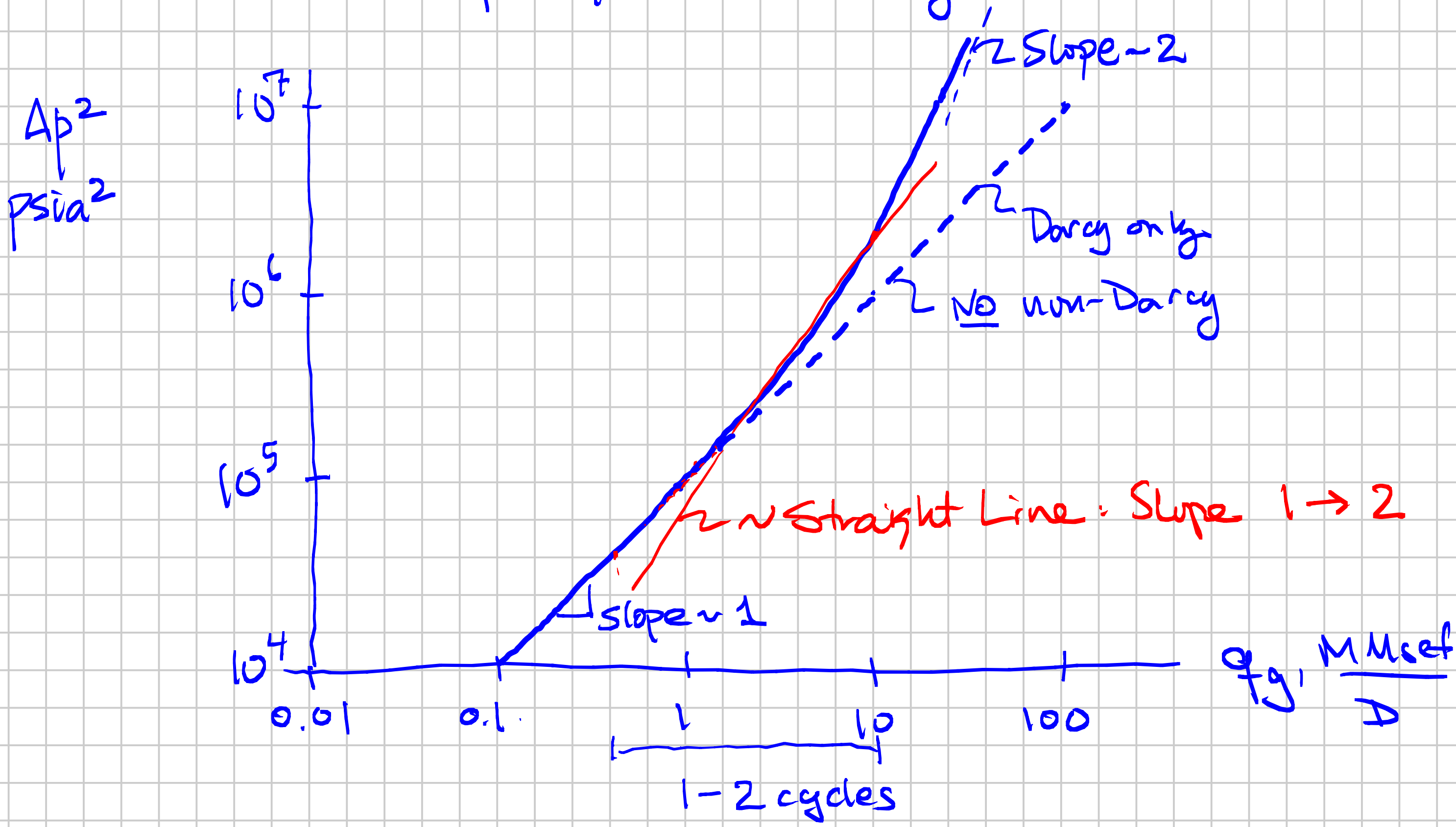
Darcy:
$$q_g = \underbrace{\frac{kh}{T\mu\left[\ln\frac{r_e}{r_w}+s\right]}}_{\text{Constant}} \cdot \left(p_R^2 - p_{wf}^2\right)$$

slope = 1

$$\log q_g = \log C + \log(\Delta p^2)$$

$$\log \Delta p^2 = \log q_g + \log C$$

General Rate Eq. w/ non-Darcy Term




$$\Delta p^2 = p_R^2 - p_{wf}^2 = B q_g^2 + A q_g$$

$$\lim_{q_g \to 0} \to A q_g \qquad \text{Slope} = 1$$

$$\lim_{q_g \to \text{large}} \to B q_g^2 \qquad \text{Slope} = 2$$

Approximate log-log straight line "model"

$$q_g = \underbrace{C_R}_{\text{"Reservoir"}} (p_R^2 - p_{wf}^2)^n$$

"Reservoir" $\sim \dfrac{kh}{(\mu z) T_R \left[ \ln \frac{r_e}{r_w} - \frac{3}{4} + s \right]}$

only → to this if $n = 1$

$$\text{Slope} = \frac{1}{n}$$

$$0.5 \le n \le 1$$

$\left\{ \begin{array}{c} \text{Highly non-Darcy} \\ B q_g^2 \ ! \end{array} \right\}$ $\left\{ \begin{array}{c} \text{Darcy} \\ A q_g \ ! \end{array} \right\}$

If $n = 0.5$

$$C_R = \frac{1}{\sqrt{B}}$$

$$D \propto \beta \propto \frac{1}{k}$$

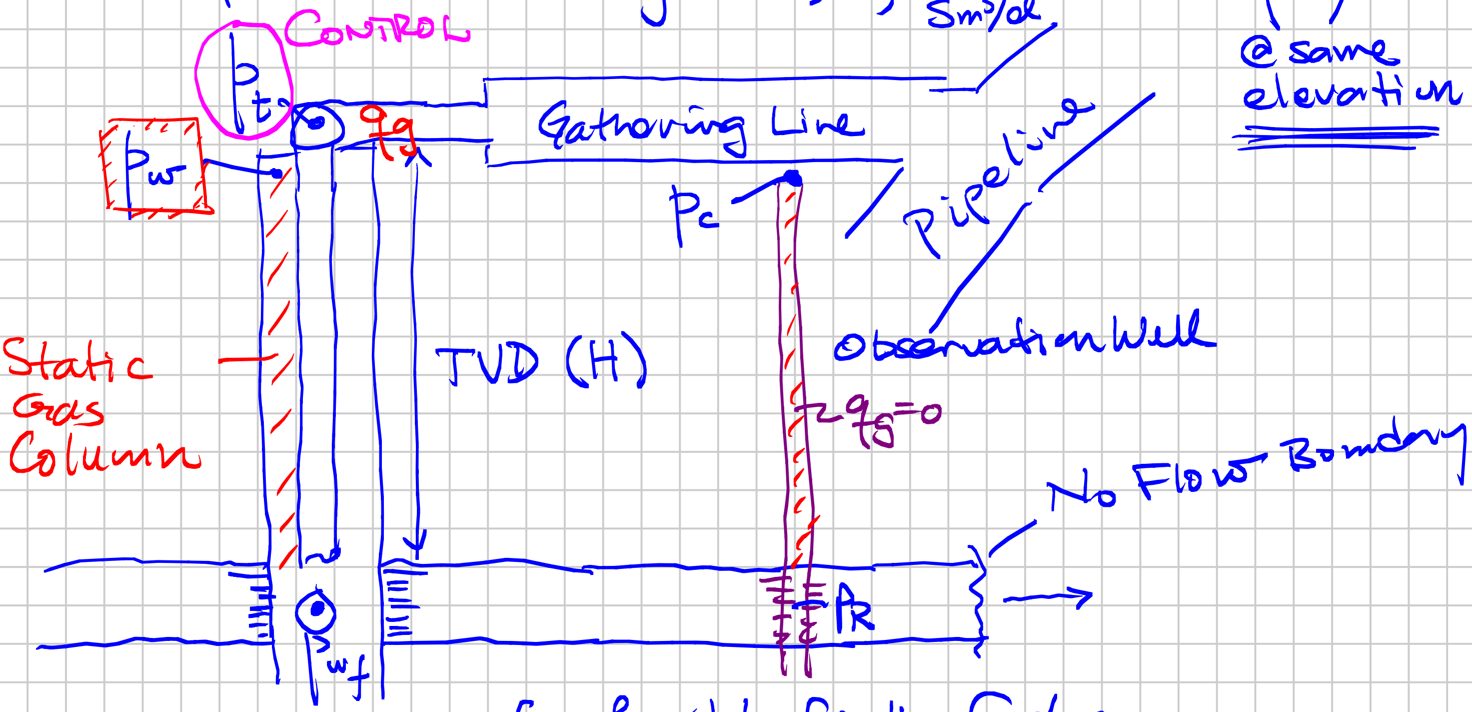
Pipe Flow:

1. Tubing
2. Pipeline (Gathering Line)

Ignore Gravity (only consider friction)

$$\underset{Sm^3/d}{q_{fg}} = C\left(p_{in}^2 - p_{out}^2\right)^{0.5}$$

@ same elevation



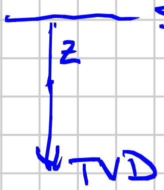

$$C(d, L, \overbrace{\epsilon, \mu}^{f_R\,:\ \text{Reynolds friction factor}})$$

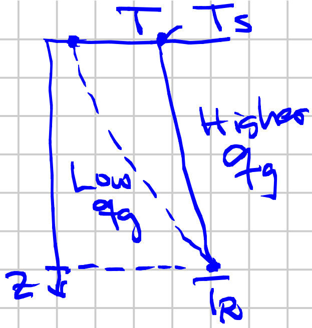
$\epsilon$: roughness of the pipe

Correcting for gravity to bring $p_{wf}$ and $p_R$ @ TVD depth datum to SURFACE depth datum where $p_t$ (that we control) is measured.

| PRESSURE | Datum | Datum | PRESSURE |
|---|---|---|---|
| ⇒ $p_R$ | TVD | Surface | $p_c$ |
| $p_{wf}$ | TVD | Surface | $p_w$ |
| $p_t$ | Surface | Surface | $p_t$ |

$p_{wf} \longleftrightarrow p_w$




Static Fluid Column:

$$\frac{dp}{dz} = \text{constant} = \rho_g g$$

$$\rho_g = \frac{pM}{R\bar{T}\bar{Z}}$$

$$= \left(\frac{M}{R\bar{T}\bar{Z}}\right) \cdot p$$

$$\bar{T} \cong \tfrac{1}{2}(T_s + T_R)$$

$$Z(p,T) : Z(p_s, T_s) \approx \bar{Z}$$

$$\int_{p_T}^{p_B} \frac{1}{p}\,dp = \underbrace{\left(\frac{Mg}{R\bar{T}\bar{Z}}\right)}_{\text{constant}} \int_0^{H(TVD)} dz$$

where $S = 0.0375\, GH/(T_a\, Z_a)$ — H: ft, $T_a$: °R

$$\ln(p_B/p_T) \cong \underbrace{\left(\frac{Mg}{R\bar{T}\bar{Z}}\right) H}_{= S/2}$$

$$S \equiv \underbrace{\quad}_{\text{units}} \frac{\gamma_g H}{\bar{T}\bar{Z}}$$

units: 28.97 $M_{air}$, R, g, 1/2

$$\frac{p_B}{p_T} \cong \exp\cdot(S/2)$$

$$\frac{p_{wf}}{p_w} = e^{S/2}$$

$$\boxed{\frac{p_{wf}^2}{p_w^2} = e^{S}} \sim \text{constant}$$

$$\boxed{\frac{p_R^2}{p_c^2} = e^{S}}$$

Reservoir $\Delta p$

$p_R - p_{wf}$

$$\left(\frac{p_R^2}{e^s}\right) - \left(\frac{p_{wf}^2}{e^s}\right) = \left(\frac{B_R}{e^s}\right) q_g^2 + \left(\frac{A_R}{e^s}\right) q_g$$

$$p_c^2 - p_w^2 = B_R' q_g^2 + A_R' q_g$$

Tubing $\Delta p$

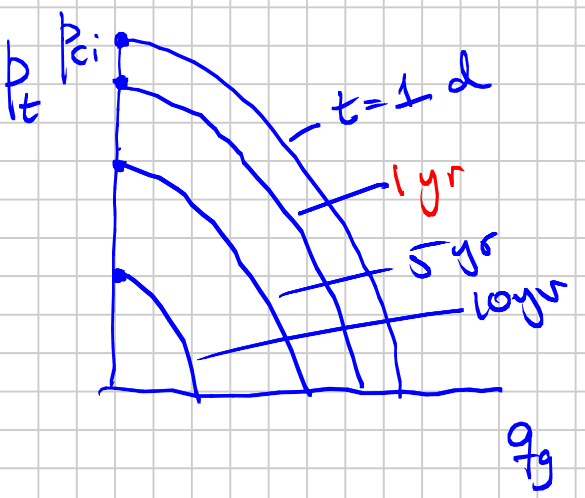
$p_{wf} - p_t$

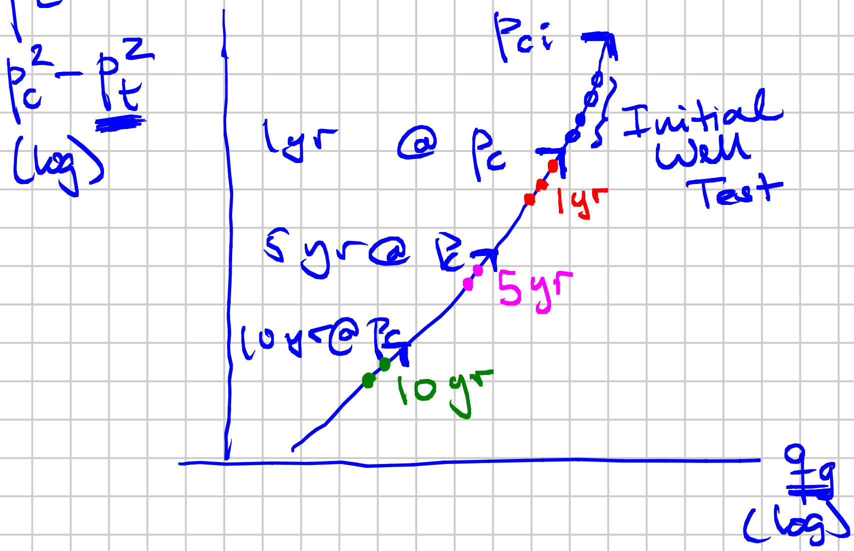
$$p_w^2 - p_t^2 = \frac{1}{C_T^2} q_g^2$$

$$\boxed{p_c^2 - p_t^2 = \Big(\underbrace{B_R' + \frac{1}{C_T^2}}_{\text{non-Darcy + Friction}}\Big) q_g^2 + \underbrace{A_R' q_g}_{\text{Darcy}}}$$

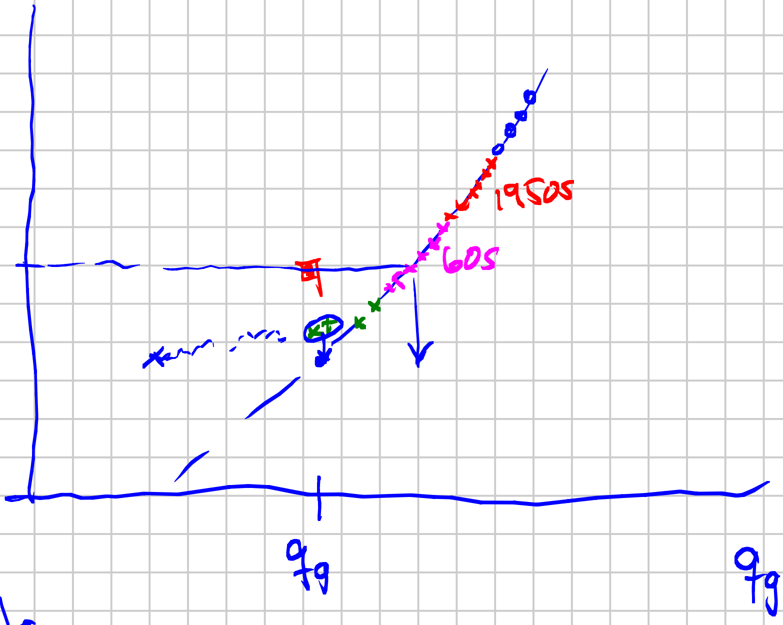
$$\boxed{p_c^2 - p_t^2 = B_{WH} q_g^2 + A_R' q_g}$$

Wellhead Backpressure Eq. @ a particular time in depletion when $p_c$ exists.



$$\underbrace{p_c^2 - p_t^2}_{R + T}$$




$p_R(t(G_p))$

$p_c$

$$G_p = \int_0^t q_g \, dt$$