Multi Point Testing of Gas Wells

- H · (R)eservoir Flow Rate Eq. (Gas)
- V · (T)ubing Flow — " — (Gas)

} Single Wells

- H · Pipeline Flow — " — (Gas) Multiple Wells

Single Well

Wellhead Deliverability Eq. } (R) & (T)
"Backpressure Eq."

- Annual Health Check-Up of a Gas-Well
  Monitor Gas Well Performance

R:

$$q_{\bar{g}} = q_g = \frac{0.703\, kh \left[\overbrace{p_{pR} - p_{pwf}}^{\Delta p_p} \right]}{T_R \left[\ln \frac{r_e}{r_w} - \frac{3}{4} + s + D q_g \right]}$$

$D q_g$: Rate-Dependent Skin

$q_g = q_{\bar{g}}$ = Surface Gas Rate

PSS (BD) Flow Cond.

$$p_p = 2 \int_{p_{ref}}^{p} \frac{p}{\mu Z} dp$$

Conversion from R → STC

$$\frac{dp}{dx} = \underbrace{\frac{\mu}{k} v}_{\text{Darcy}} + \beta \rho v^2$$

$\beta \rho$ → "D"

Forchheimer: Often to Gas Wells; Sometimes Oil Wells

$$B = \left(\frac{T_R}{0.703\, kh} \right) D$$

B : D

$$B q_g^2 + A q_g - \Delta p_p = 0$$

PSS: $A = \left(\frac{T_R \left[\ln \frac{r_e}{r_w} - \frac{3}{4} + s \right]}{0.703\, kh} \right)$ | A: kh, s; $\underbrace{\ln \frac{r_e}{r_w}}_{8-10}$

IA: $A = \frac{T_R}{0.703\, kh} \cdot \left[p_D(\Delta t_D) + s \right]$

↑ @ Fixed period e.g. 8 hr

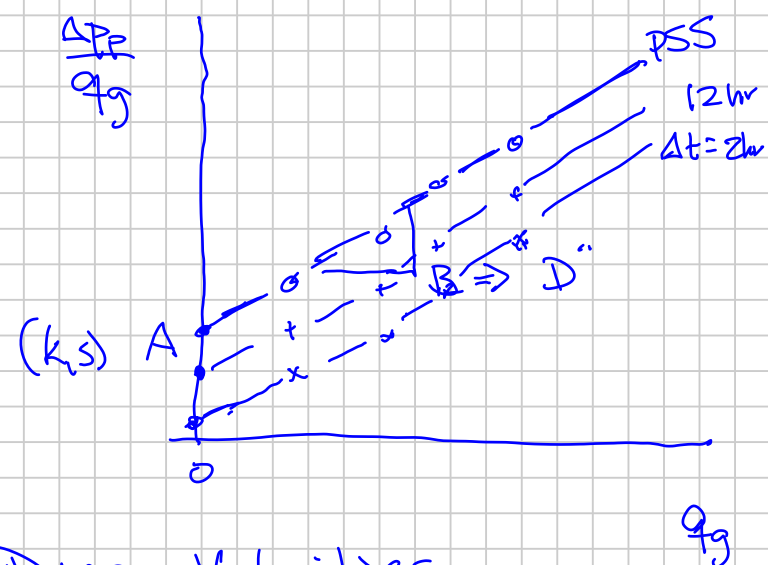
$$\frac{\Delta p_p}{q_g} = A + B q_g$$

Test Rates @ Time $\bar{p}_R \Rightarrow \bar{p}_{pR}$

Δt	Rate	p_{wf}	$\Rightarrow p_{pwf}$	$\left(\frac{\Delta p_p}{q_g}\right)$
8 hr	q_{g1}, BU	p_{wf1}		
8 hr	q_{g2}, BU	p_{wf2}		
8 hr	q_{g3}, BU	p_{wf3}		
8 hr	q_{g4}	p_{wf4}		

3–4

(BU +)



Low μ_g ⇒ "high" Darcy Velocities

$(Re)_{\text{porous media}} \sim 1-8$

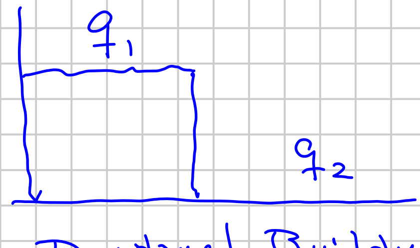
Muskat

Darcy Conventional:

k

s

($\bar{p}_R$)



k | "s", ⇒ $\bar{p}_R$ (p^*)

Forchheimer Conventional

k — Min 2 (3–4) $q>0$ rates

s — + BU

D

($\bar{p}_R$)

Wellhead Deliverability (Backpressure)

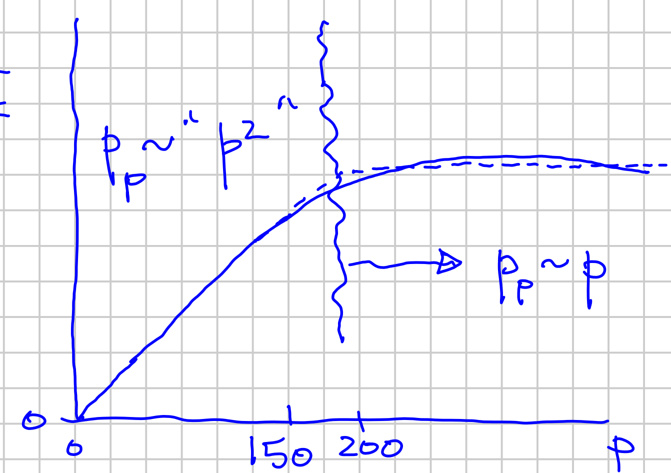
Pressure-Squared Approx.

$$kh\,(p_{pR} - p_{pwf}) \approx \frac{kh}{(\mu Z)^*}\,(p_R^2 - p_{wf}^2)$$

$(\mu Z)^* \cong$ constant

1–150 bar

$\frac{1}{\mu B_o}$ $\frac{p}{\mu Z}$



"R" $$q_g = \frac{0.703\ kh\,(p_R^2 - p_{wf}^2)}{T_R(\mu Z)^* \left[\ln\frac{r_e}{r_w} - \frac{3}{4} + S + Dq_g\right]}$$

$p_R \lesssim 150$ bar

k [md]

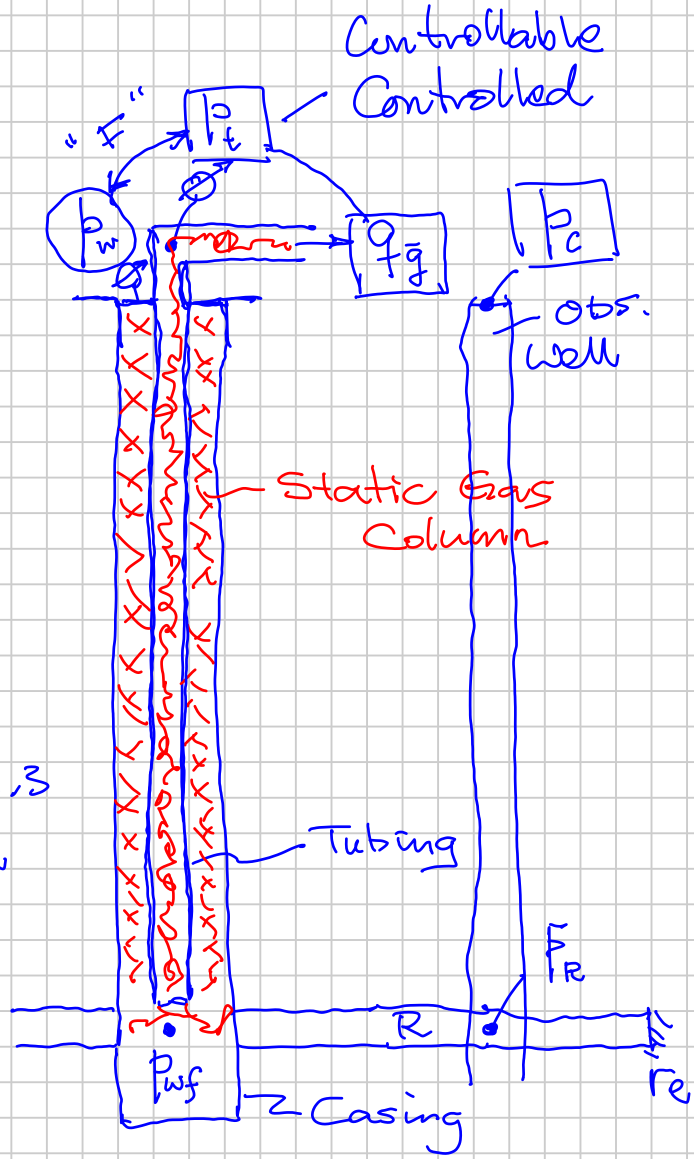
p [psia]

q_g [scf/D]

h [ft]

μ [cp]

T_R [°R]



"T" Tubing Rate Eq.

Static Gas Column:

$$\frac{dp}{dD} = \rho g$$

$$\rho = \frac{pM}{RTZ}$$

$$\Rightarrow \frac{p_{Bottom}}{p_{Top}} = \text{constant} = e^{S/2}$$

1,1–1,3

$$S/2 = \left(\frac{M_g}{R\bar{T}\bar{Z}}\right) g \cdot TVD$$

$$a_0 \left(\frac{\gamma_g}{\bar{T}\bar{Z}_g}\right) TVD$$

$$\frac{\bar{p}_R}{p_c} \simeq \frac{p_{wf}}{p_w} = e^{S/2} = \text{const.}$$

$$\bar{p}_R \simeq p\left(r = \tfrac{1}{2} r_e\right)$$

q_g (p_t @ p_R) time : Δp_R + Δp_T

$p_R \downarrow p_c$

T: $q_g = C_T (p_w^2 - p_t^2)^{0.5}$

Friction Only

~~Gravity~~

$C_T \propto d_T^{2.7}$

$\dfrac{p_c}{p_R} = e^{-S/2} = \dfrac{p_w}{p_{wf}}$ ϵ, L_t Fetkovich ($\neq$ TVD)

$\dfrac{p_c^2}{p_R^2} = e^{-S} = \dfrac{p_w^2}{p_{wf}^2}$

$p_R^2 \cdot e^{-S} = p_c^2$

$p_{wf}^2 \cdot e^{-S} = p_w^2$

R: $(p_R^2 - p_{wf}^2) = (B_R q_g^2 + A_R q_g)$

$\times e^{-S}$ $\times e^{-S}$

$(p_c^2 - p_w^2) = B_R e^{-S} q_g^2 + A_R e^{-S} q_g$

T: $p_w^2 - p_t^2 = \dfrac{1}{C_T^2} q_g^2$

$$(p_c^2 - p_t^2) = \underbrace{\left(B_R e^{-S} + \frac{1}{C_T^2}\right)}_{B_{w+1}} q_g^2 + A_R e^{-S} q_g$$

$$\left(p_c^2 - p_t^2\right) = B_{WH}\, q_g^2 + A_{WH}\, q_g$$

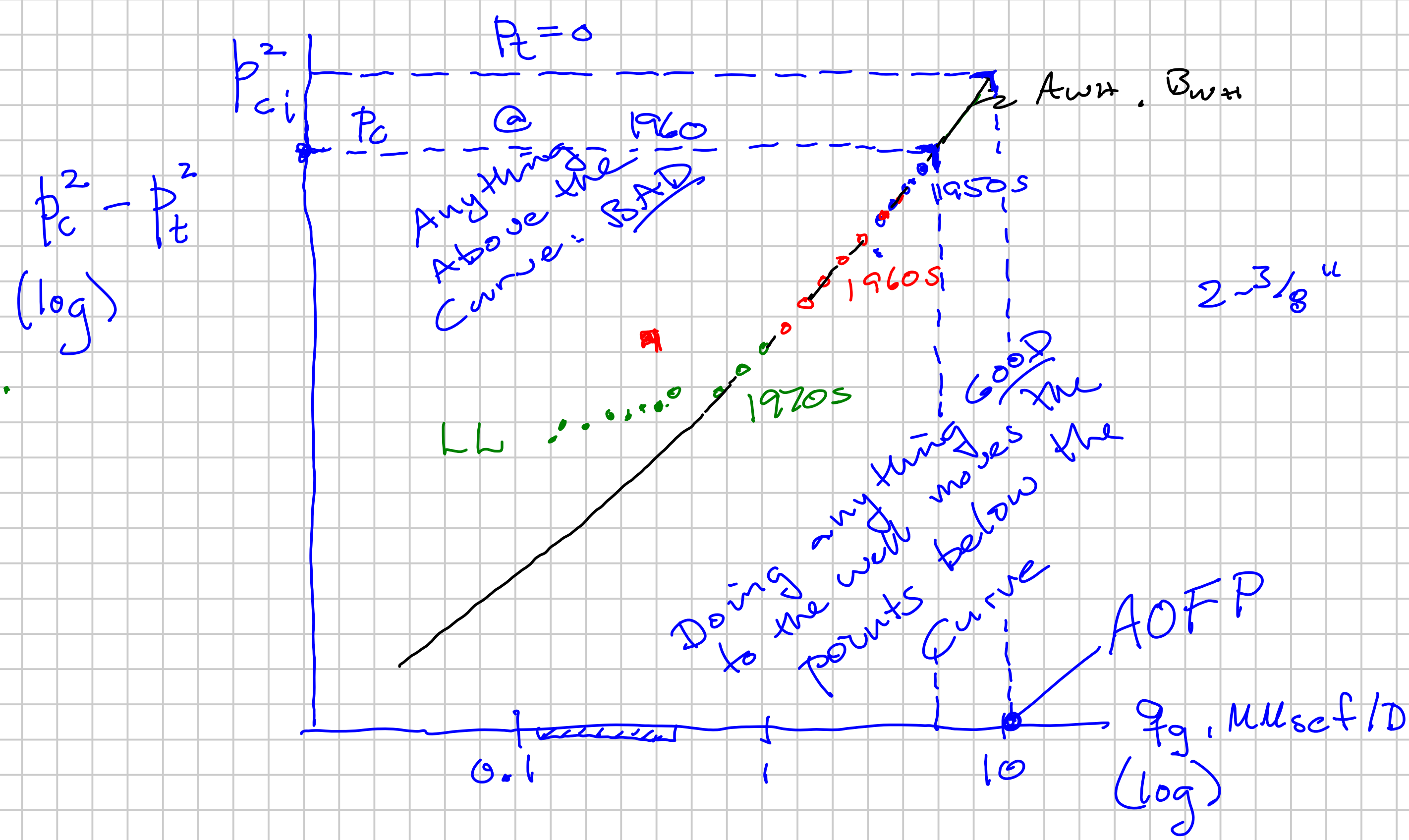
WELLHEAD DELIVERABILITY EQ.

Should NEVER change unless something is wrong

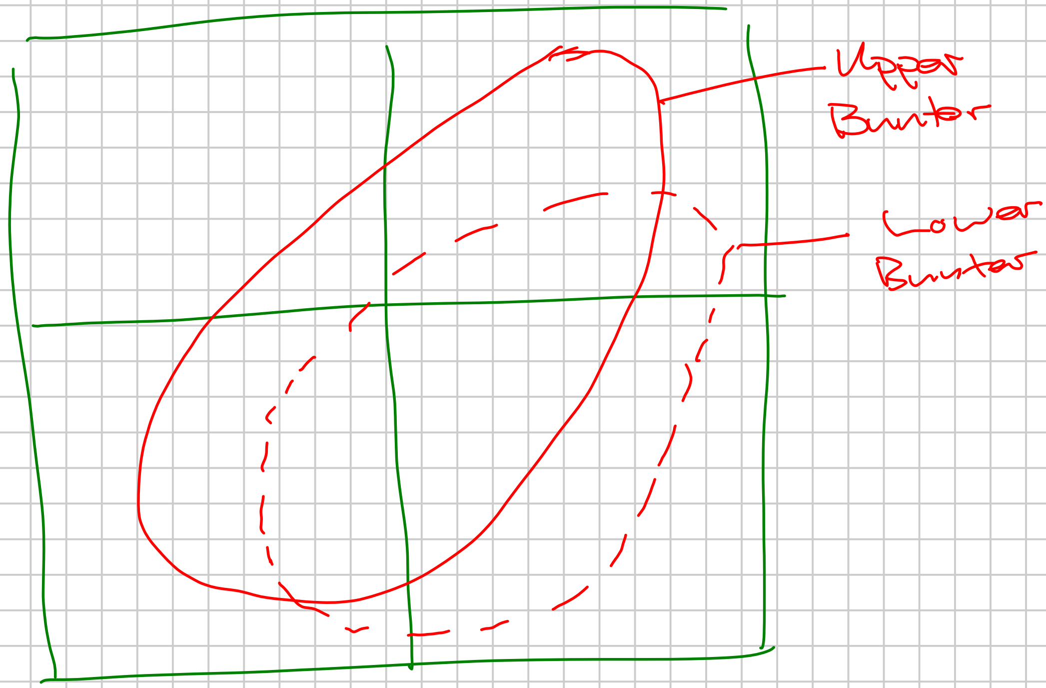
$$B_{WH} = \left(B_R\, e^{-S}\right) + \frac{1}{C_T^2}$$

$$A_{WH} = A_R \cdot e^{-S}$$

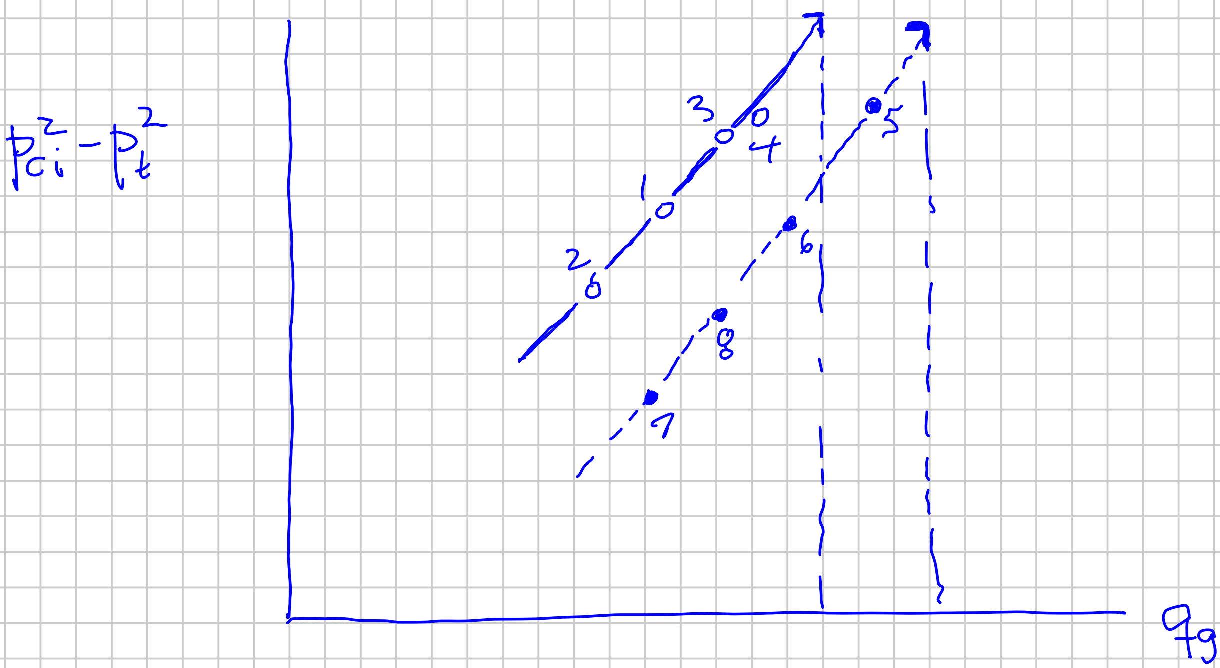
At time (know p_c (p_R)) q_g (p_t)



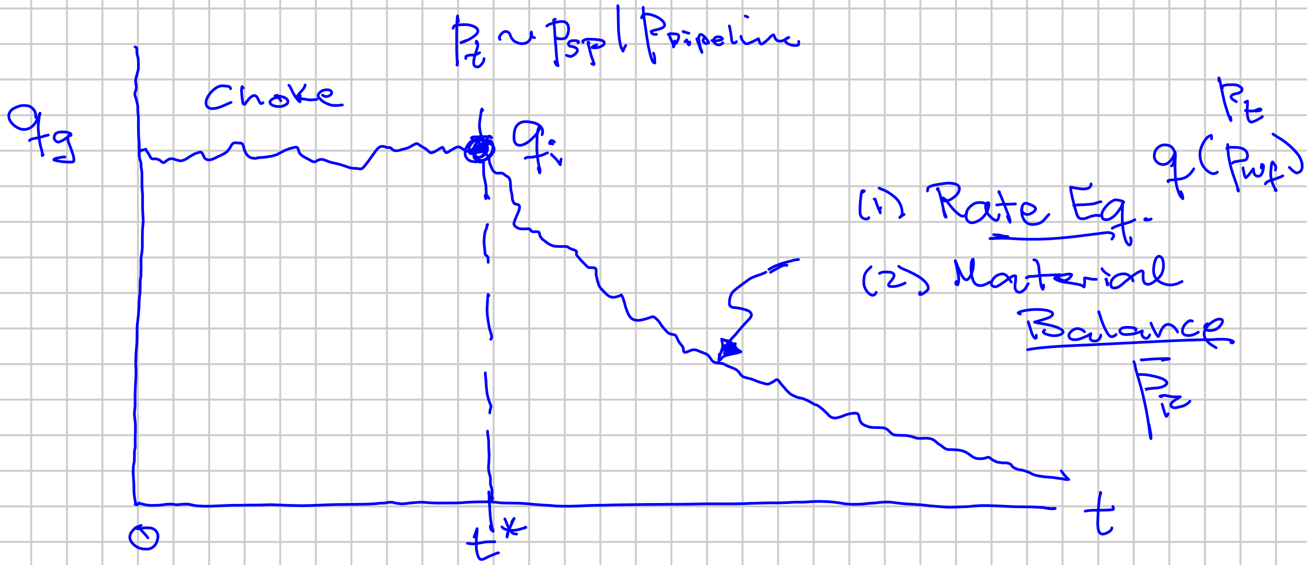
	p_c	p_t	q_g	Engineer	Status
1956				MJF	✓
1957				MJF	✓
58				⋮	⋮
⋮					
72					
74					Red Flag
75					Workover



Deliverability Performance of U. & L Bunter Formations.



DECLINE CURVE ANALYSIS (Thursday)
(DCA) (RTA)



Decline 0

Arps: $$q = \frac{q_i}{[1 + bDt]^{1/b}}$$

$$0 \le b < 0.5$$

Fetkovich $\{D, b, q_i\}$ ① $\sim$ Reservoir & Well Properties

② RTA

$$\ln\frac{r_e}{r_w} - \frac{3}{4} \sim P_D(t_D)$$

for years

Tied $q(t)$ Infinite Acting to PSS Arps Eq.