Comments to gas IPR derivations

LP

$$\int a\,p\,dp \simeq \int x\,dx = \frac{x^2}{2}$$

$$\frac{p^2}{2}$$

HP

$$\int a\,dp \simeq \int dx = x$$

High velocity flow (Forchheimer)

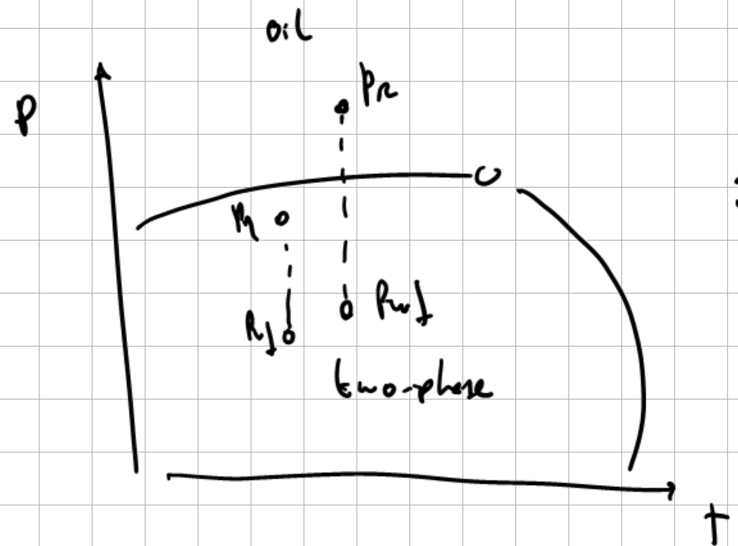
$$a x^2 + b \cdot x + c = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$(\ )\, q_g^2 + (\ )\, q_g + (p_R^2 - p_{wf}^2) = 0$$

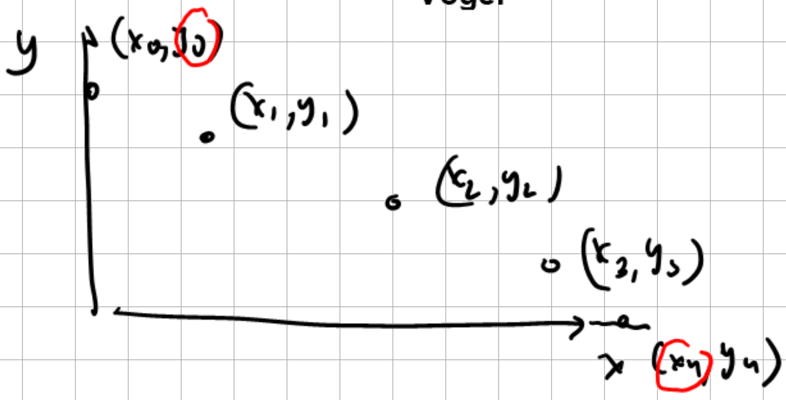
$7.63 \cdot k\,h$

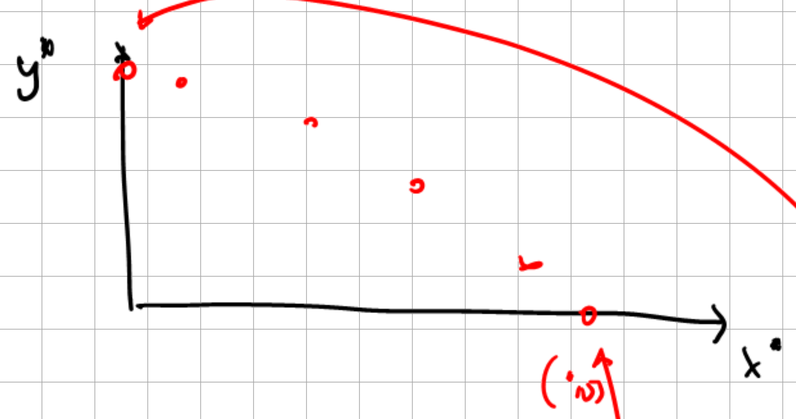
$$(p_R^2 - p_{wf}^2)\,\frac{7.63\,kh}{T_R\,\mu_g\,Z} = \left(\ln\frac{r_e}{r_w} - 0.75 + S\right) q_g + D\,q_g^2$$



Vogel

y vs x





$\max(y) = y_0$

$\max(x) = x_4$

x^*	y^*
$\frac{x_0}{x_4} = 0$	$\frac{y_0}{y_0} = 1$
$\frac{x_1}{x_4}$	$\frac{y_1}{y_0}$
$\frac{x_2}{x_4}$	$\frac{y_2}{y_0}$
$\frac{x_3}{x_4}$	$\frac{y_3}{y_0}$
$1 = \frac{x_4}{x_4}$	$\frac{y_4}{y_0} = 0$

Fetkovich IPR for saturated oil = gas IPR

$$q_g = C\left(p_r^2 - p_{wf}^2\right)^n \quad n = 1 \longrightarrow q_o = C\left(p_r^2 - p_{wf}^2\right)$$

$p_{wf} = 0 \rightarrow q_{o\,max} = C p_r^2$

$$q_o = \frac{C}{p_r^2}\left(1 - \left(\frac{p_{wf}}{p_r}\right)^2\right)$$

$$\frac{q_o}{q_{o\,max}} = 1 - \frac{p_{wf}^2}{p_r^2}$$

$$q_o = \frac{C}{p_r^2}\left(1 - V\frac{p_{wf}}{p_r} - (1-V)\left(\frac{p_{wf}}{p_r}\right)^2\right)$$

Quiz 2 - OG621, 2021

1. What are the units of C and n in the backpressure equation?

$$q_{\bar{g}} = C\left(p_R^2 - p_{wf}^2\right)^{n \le 1\,?}$$

n is unitless

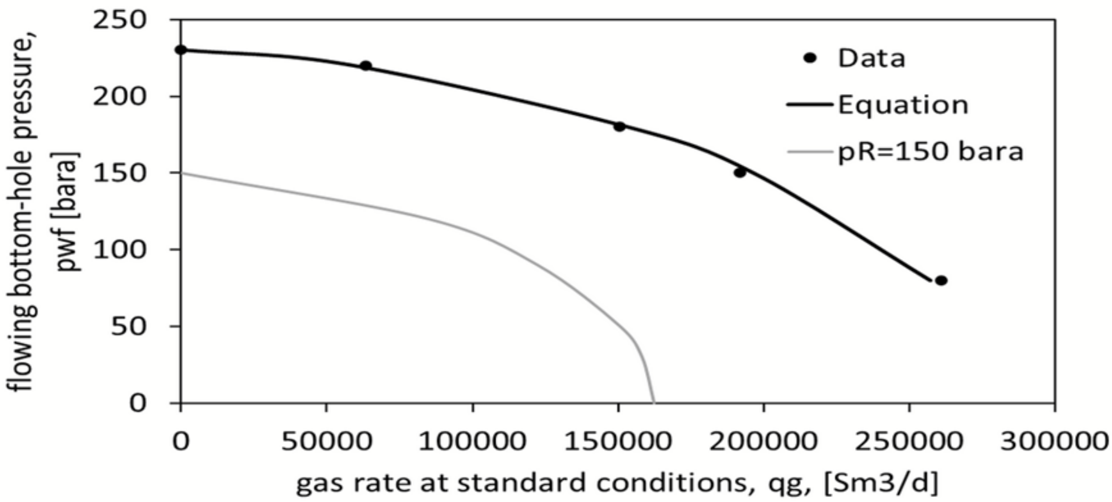
$$C = \frac{q_{\bar{g}}}{(\underbrace{p_R^2 - p_{wf}^2}_{bara^2})^n} \longrightarrow \frac{(Sm^3/d)}{(bara^2)^n} = \left[\frac{Sm^3/d}{bar^{2n}}\right]$$

$$\underset{turbulent}{0.5} \le n \le \underset{Darcy}{1}$$

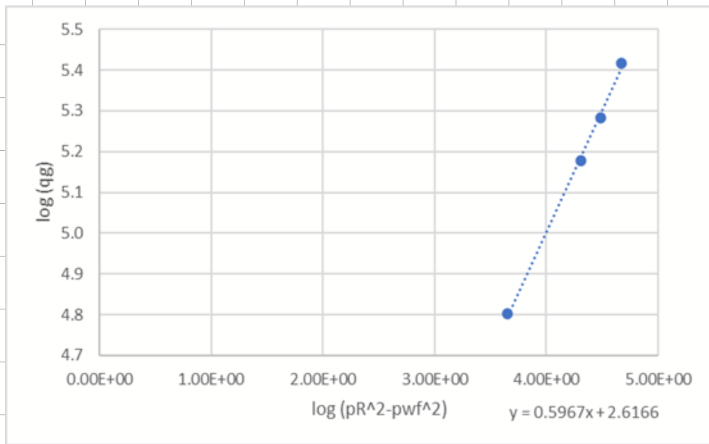
$$\frac{Scf/d}{psia^{2n}}$$

2. Using the backpressure equation, obtain a C and n that match the measured values.

C	[Sm3/d/bar^2n]	281.3		
n	[-]	0.63		
Test nr.	q [sm3/d]	pwf [bara]	q_calc [sm3/d]	q_diff^2
Shut-in	0	230	0	
1	63400	220	58422.97	2.48E+07
2	150413	180	152868.4	6.03E+06
3	191787	150	196274.8	2.01E+07
4	260765	80	257009.6	1.41E+07
			SUM=	6.50E+07



C	[Sm3/d/bar^2n]	281.3				
n	[-]	0.63				
Test nr.	q	pwf	q_calc	q_diff^2	log(qg)	log(pR^2-pwf^2)
	[sm3/d]	[bara]	[sm3/d]			
Shut-in	0	230	0			
1	63400	220	58422.97	2.48E+07	4.8020893	3.65E+00
2	150413	180	152868.4	6.03E+06	5.1772854	4.31E+00
3	191787	150	196274.8	2.01E+07	5.2828192	4.48E+00
4	260765	80	257009.6	1.41E+07	5.4162493	4.67E+00
			SUM=	6.50E+07		



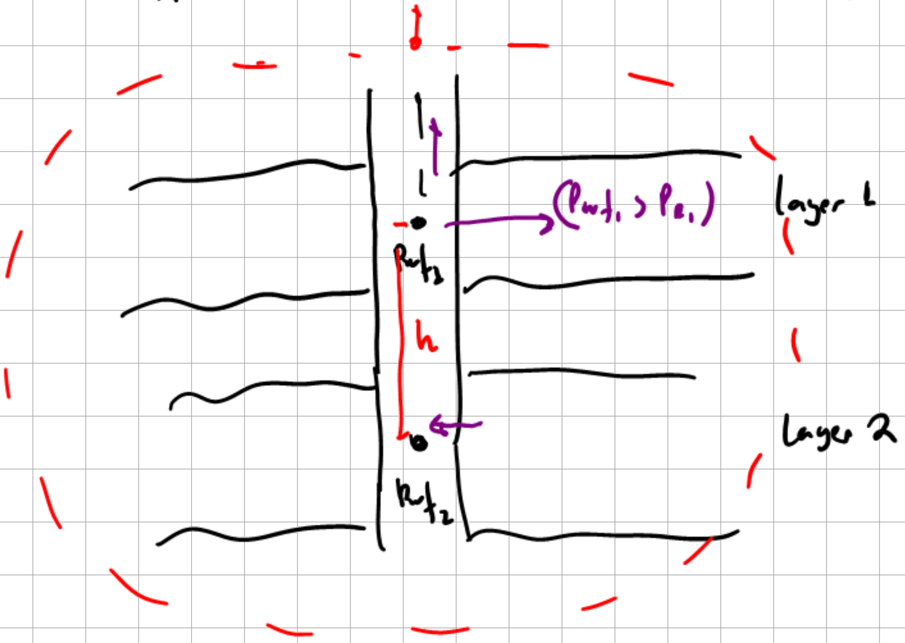
$$\log_{10}(C) = 2.6166$$

$$C = 10^{2.6166} = 458 \ \frac{Sm^3/d}{bara^{2 \cdot n}}$$

$$n = 0.59$$

Similar to the values obtained with tuning, but poorer fit

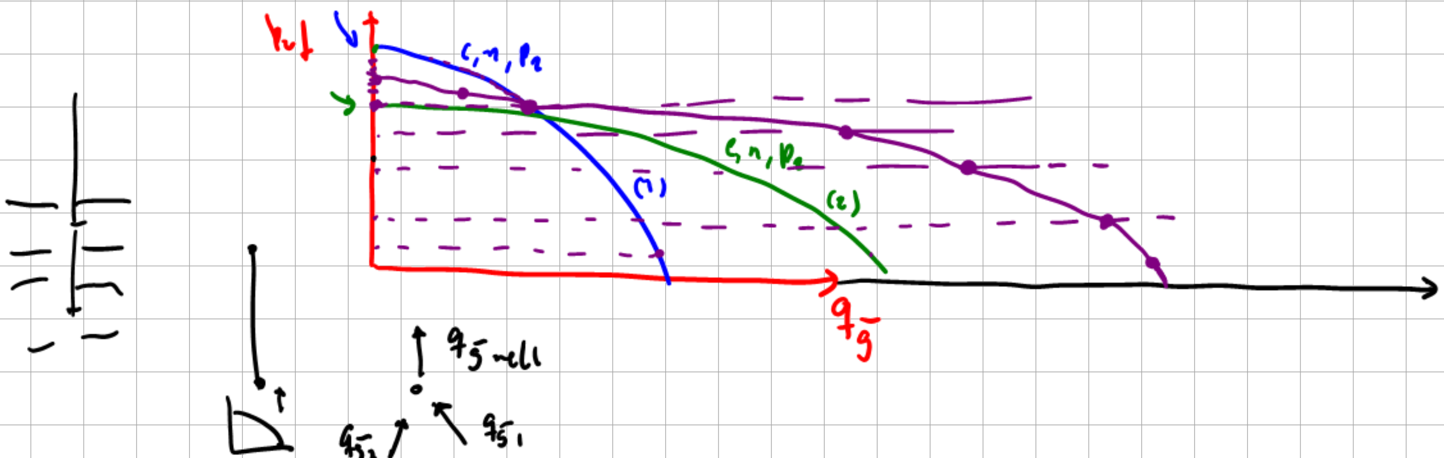
what happens when there is more than 1 layer producing to a well bore



C_1 n_1, P_{R_1}

C_2, n_2, P_{R2}

h is small, such that $P_{wf_1} \simeq P_{wf_2}$



$P_{wf} = 80$ bara

two layers

(1) $C = 880$ $Sm^3/d/bara^{2n}$

$n = 0.6$

$P_R = 130$ bara

$P_{wf_1} = P_{wf_2}$

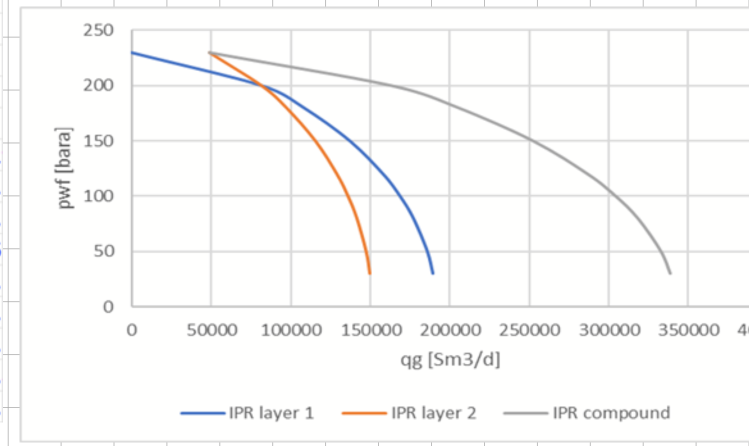
(2) $C = 200$ $Sm^3/d/bara^{2n}$

$n = 0.8$

$P_R = 250$ bara

Calculate production from the well

Layer 1							
pR	[bara]	230					
C	[Sm3/d/bara^2n]	280					
n	[-]	0.6					
				pwf (pwf1 =pwf2)	qg1	qg2	qg well
Layer 2				[bara]	[Sm3/d]	[Sm3/d]	[Sm3/d]
pR	[bara]	250		230	0	49022.19	49022.1
C	[Sm3/d/bara^2n]	200		200	81943	81722.1	163665.
n	[-]	0.6		180	108195.8	97312.78	205508.
				150	137051	115416	25246
				120	157919	128919	286838.
				100	168512.6	135870.6	304383.
				80	176860.1	141386.4	318246.
				50	185616.4	147204.4	332820.
				30	189129.8	149547.2	338677.



Comment about well Injection performance