

Comments to gas IPR derivations

$$\text{LP} \quad \int a p \, dp \quad \approx \quad \int x \, dx = \frac{x^2}{2}$$

$\underbrace{\hspace{10em}}_{\frac{p^2}{2}}$

$$\text{HP} \quad \int a \, dp \quad \approx \quad \int dx = x$$

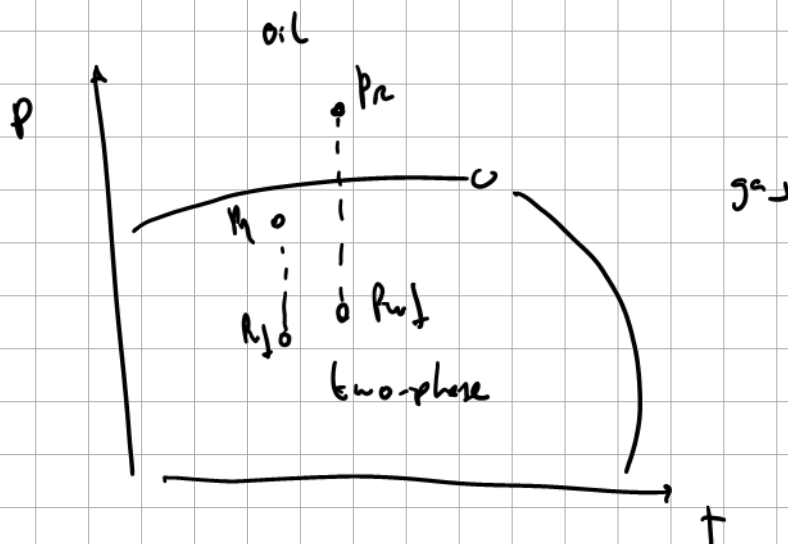
High velocity flow (Forchheimer)

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

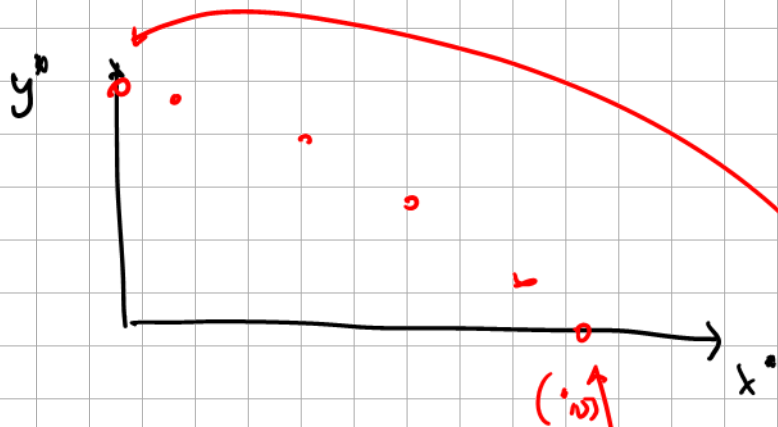
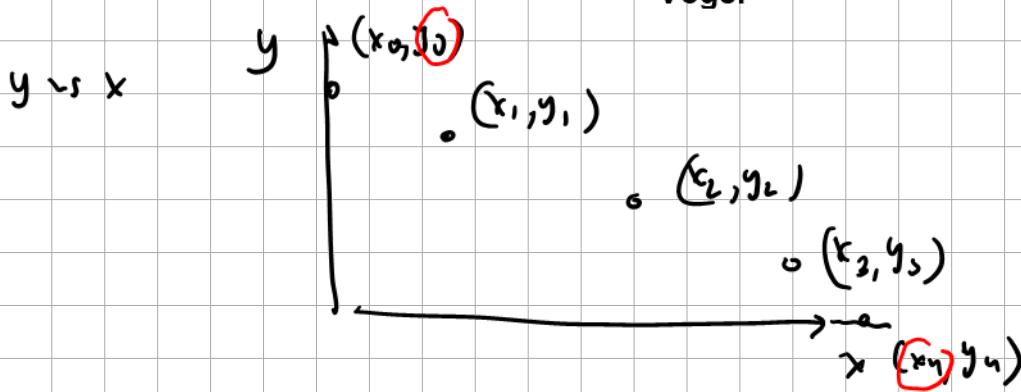
$$(1) q_g^2 + (1) q_g + (P_R^2 - P_{wf}^2) = 0$$

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

$$(P_R^2 - P_{wf}^2) \frac{7.63 \times 10^{-4}}{T_R h_g z} = \left(\ln \frac{r_e}{r_w} - 0.75 + S \right) q_g + D q_g^2$$



Vogel



$$\max(y) = y_0$$

$$\max(x) = x_4$$

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

$$q_{fs} = C (p_e^2 - p_{wf}^2)^{n=1}$$

$\rightarrow$

$$q_o = C (p_e^2 - p_{wf}^2) \quad \text{at } p_{wf} = 0 \quad q_{o,max} = C p_e^2$$

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

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

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

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

$$q_g = C (p_a^2 - p_w^2)^n$$

n is unitless

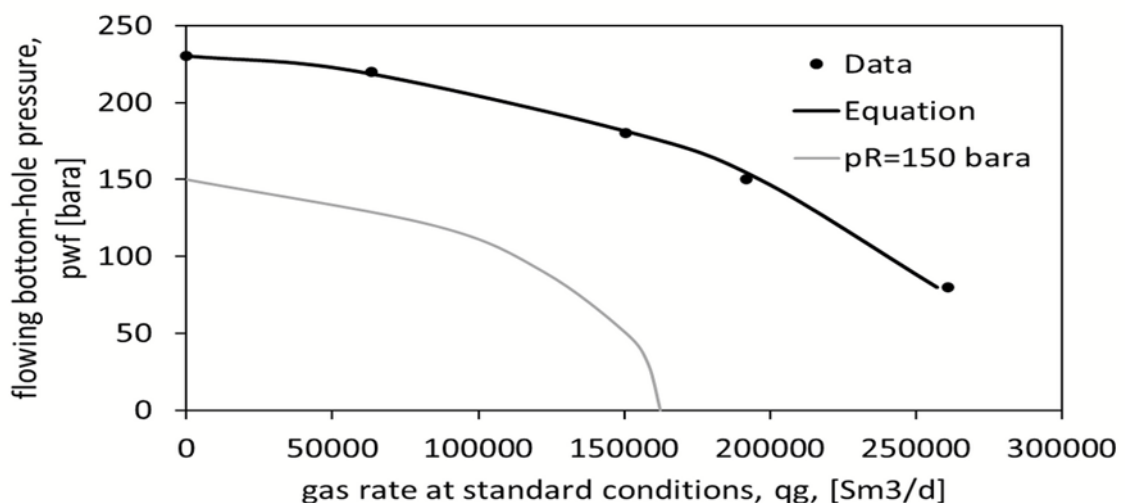
$$C = \frac{q_g}{(p_a^2 - p_w^2)^n} = \frac{(\text{Sm}^3/\text{d})}{(\text{bar}^2)^n} = \left[\frac{\text{Sm}^3/\text{d}}{\text{bar}^{2n}} \right]$$

0.5 ≤ n ≤ 1
turbulent Darcy

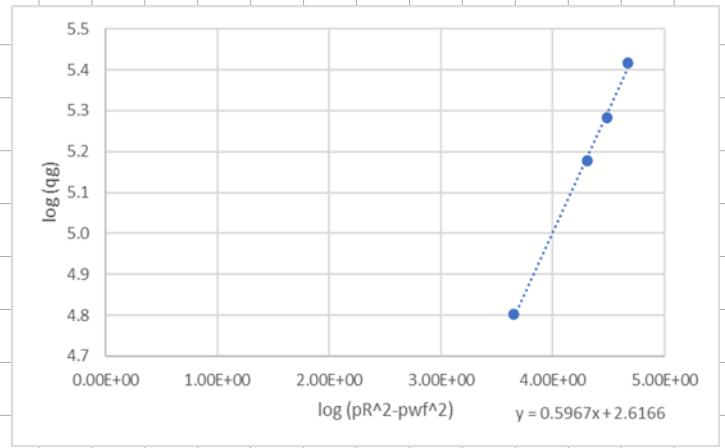
$\frac{S_{cf}/d}{p_{ria}^{2n}}$

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

C	[Sm ³ /d/bar ²ⁿ]	281.3		
n	[-]	0.63		
Test nr.	q [sm ³ /d]	pwf [bara]	q_calc [sm ³ /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	[Sm ³ /d/bar ²ⁿ]	281.3				
n	[-]	0.63				
Test nr.	q	pwf	q_calc	q_diff^2	log(qg)	log(pR^2-pwf^2)
	[sm ³ /d]	[bara]	[sm ³ /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			



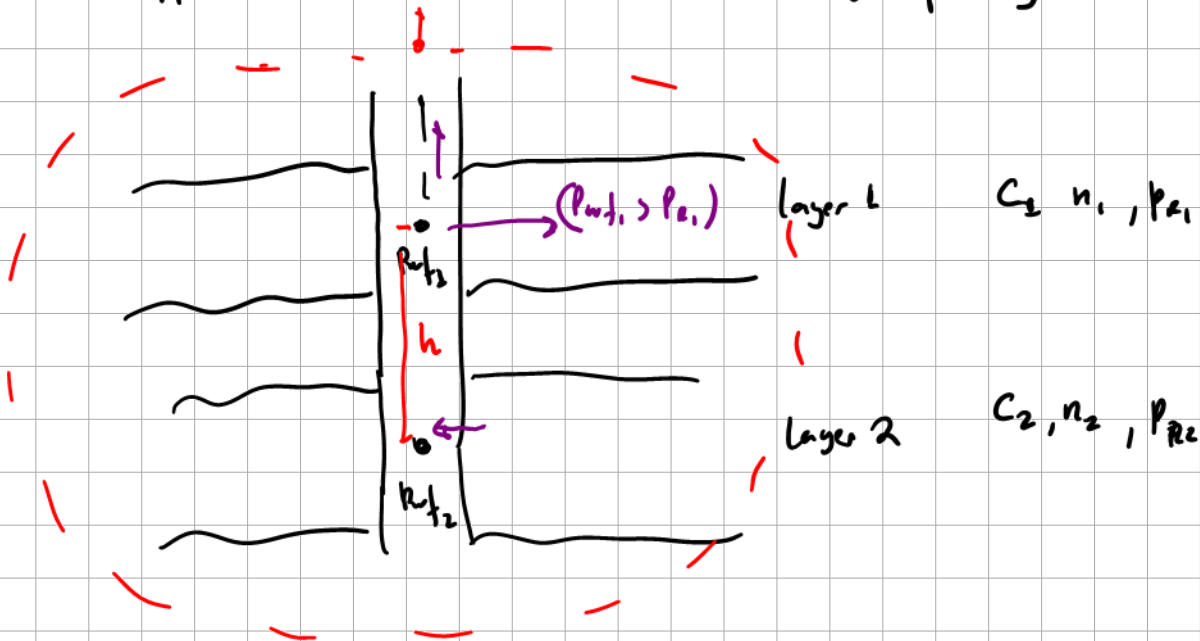
$$\log_{10}(C) = 2.6166$$

$$C = 10^{2.6166} = 458 \frac{\text{Sm}^3/\text{d}}{\text{bara}^{0.63}}$$

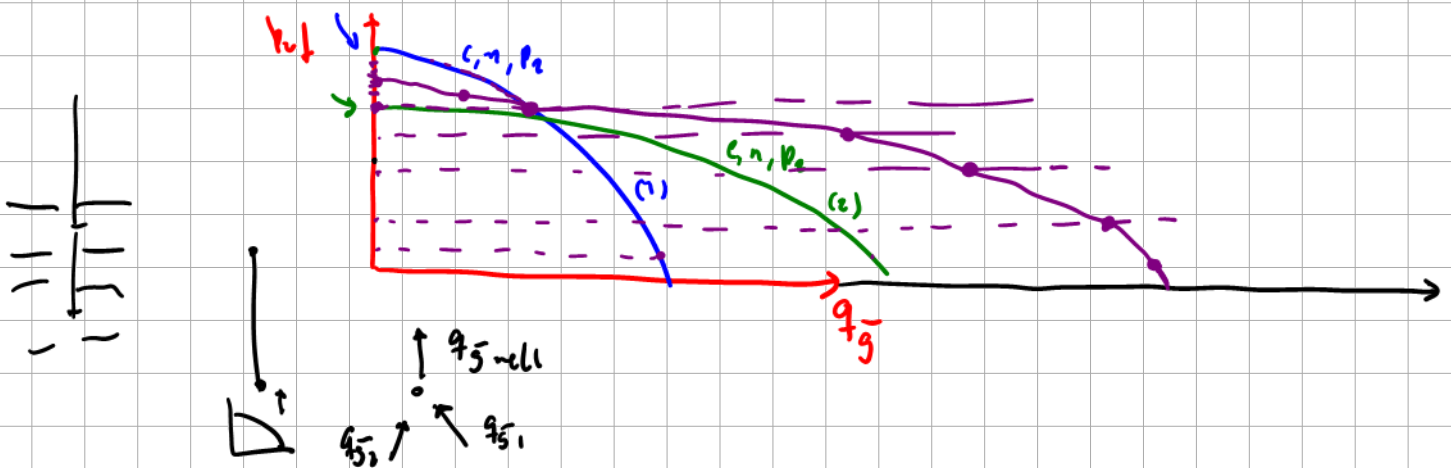
$$n = 0.59$$

Similar to the values obtained with tuning, but poorer fit

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



h is small, such that $\underline{p_{wf1} = p_{wf2}}$



$$p_{wf} = 80 \text{ bara}$$

two layers

(1)

$$C = 880 \text{ Sm}^3/d/\text{bara}^{2n}$$

$$n = 0.6$$

$$p_R = 230 \text{ bara}$$

$$p_{wf1} = p_{wf2}$$

(2)

$$C = 200 \text{ Sm}^3/d/\text{bara}^{2n}$$

$$n = 0.8$$

$$p_R = 250 \text{ bara}$$

Calculate production from the well

The graph plots pressure drop (pwf [bara]) on the y-axis against gas flow rate (qg [Sm3/d]) on the x-axis. The y-axis ranges from 0 to 250 in increments of 50. The x-axis ranges from 0 to 400,000 in increments of 50,000. Three curves are shown: a blue curve for 'IPR layer 1', an orange curve for 'IPR layer 2', and a grey curve for 'IPR compound'. All three curves start at approximately 230 bara at a flow rate of 50,000 Sm3/d. The 'IPR compound' curve decreases most gradually, reaching about 30 bara at 350,000 Sm3/d. The 'IPR layer 1' curve reaches about 30 bara at 190,000 Sm3/d. The 'IPR layer 2' curve is the steepest, reaching about 30 bara at 150,000 Sm3/d.

qg [Sm3/d]	pwf [bara] (IPR layer 1)	pwf [bara] (IPR layer 2)	pwf [bara] (IPR compound)
50,000	230	230	230
100,000	190	170	215
150,000	140	30	200
200,000	80	-	185
250,000	-	-	160
300,000	-	-	110
350,000	-	-	30

A hand-drawn graph on a grid. The vertical axis is labeled f_1 and the horizontal axis is labeled f_2 . A blue curve starts at a high point on the f_1 axis and decreases as it moves to the right, approaching the f_2 axis. A horizontal dashed line is drawn at the level of the f_1 intercept, extending to the left. There are blue dots marking the intercepts of the curve on both axes.