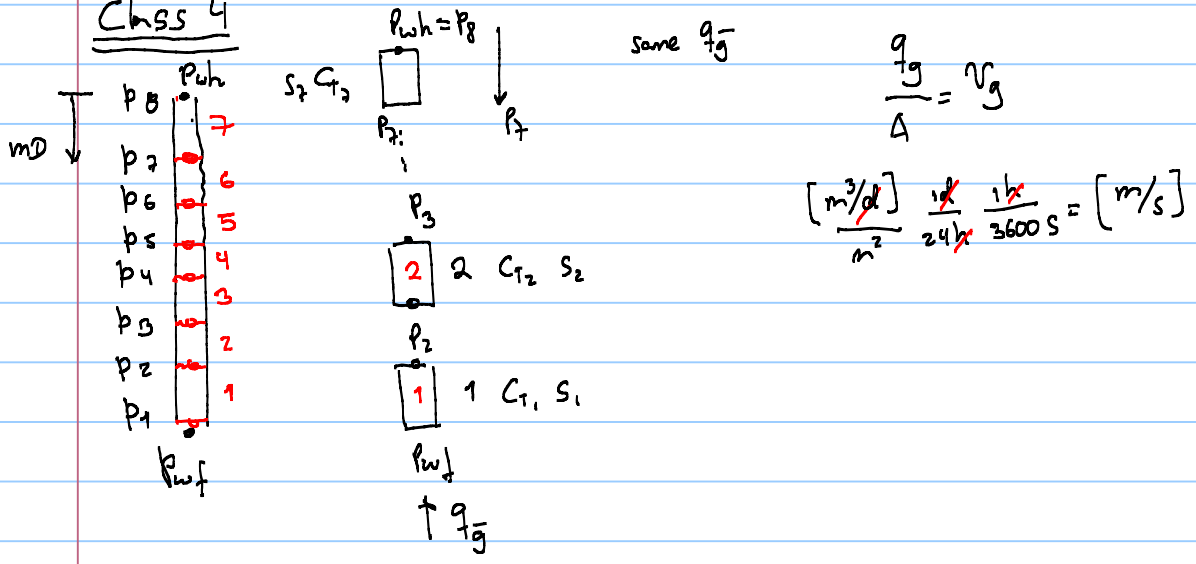
Note Title 01.11.2018

Class 4



same q_g

$$\frac{q_g}{A} = v_g$$

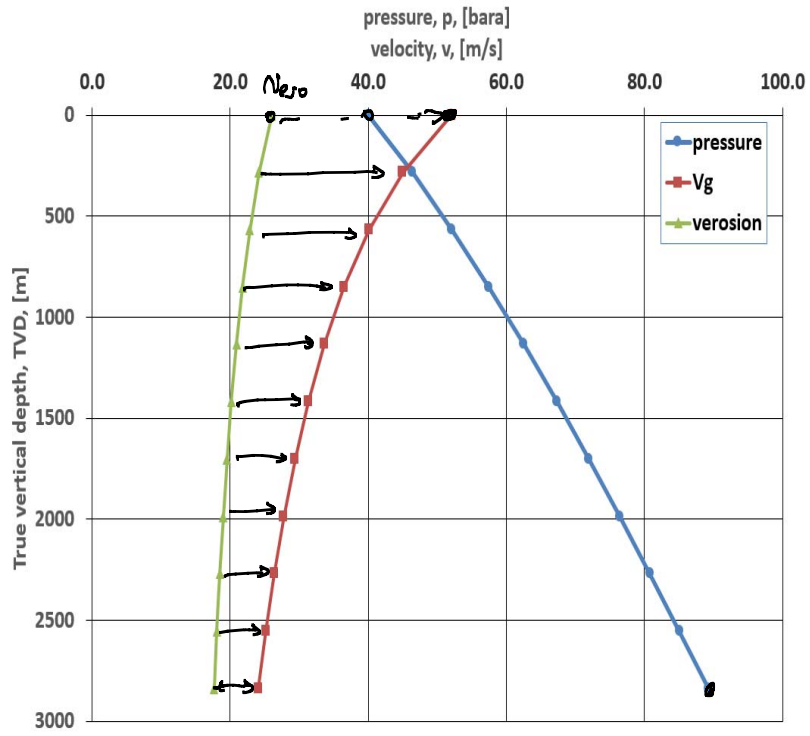
$$\left[\frac{m^3/d}{m^2}\right] \frac{1d}{24h} \frac{1h}{3600\,s} = [m/s]$$

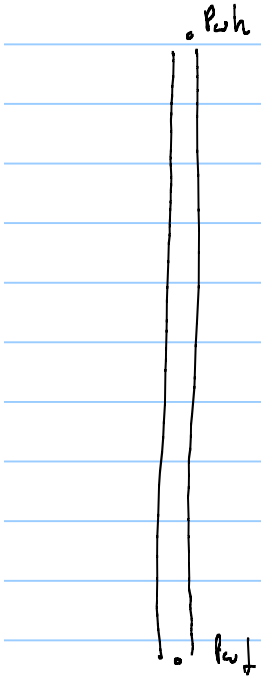
erosion $v_g \leq \frac{C}{\sqrt{\rho_m}}$ API 14E in field units

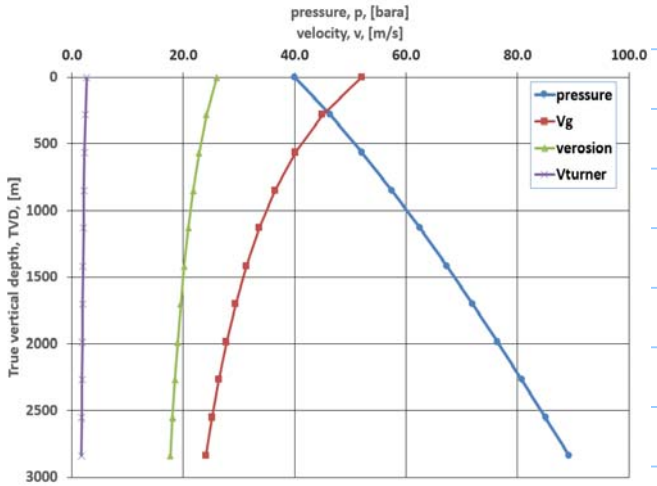
ρ_m → mixture (gas, sand, liquid)

$v_g \leq v_{critерosion}$ $\rho_m \approx \rho_g$ $\rho_g = \frac{p}{RzT}$

$v_{erosional} = \frac{C}{\sqrt{\rho_g}}$ if $\rho_g \uparrow$ $v_{erosional} \downarrow$







- conclusions

① possible erosion in tubing need to:

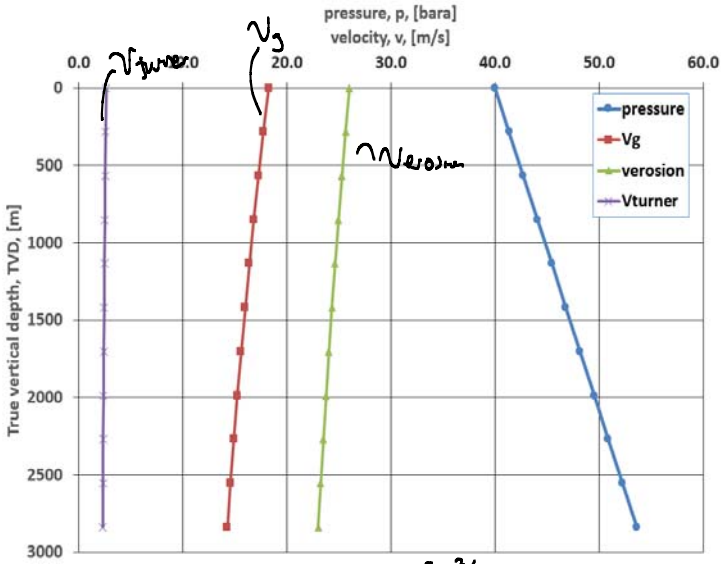
for every TVD
$v_g > v_{erosion}$

- decrease q_{sc} ↓
- change tubing ↑ ϕ

② no liquid loading expected !

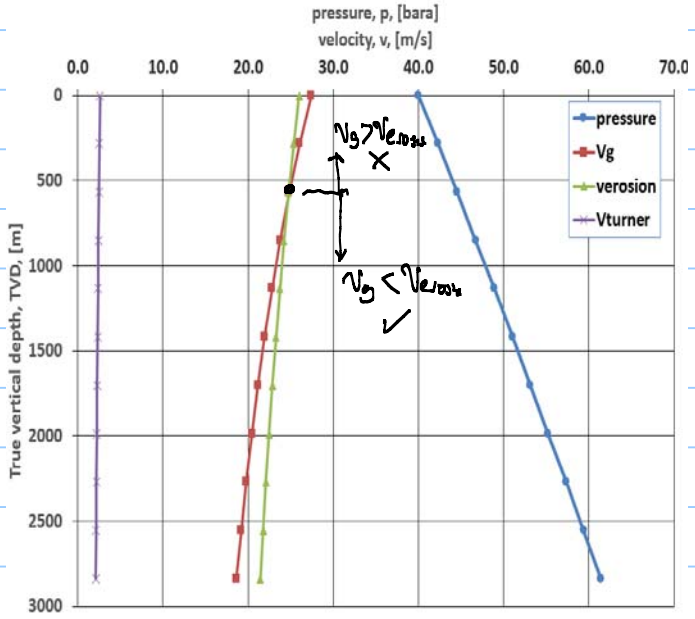
for every TVD in the tubing
always
$v_g > v_{turner}$

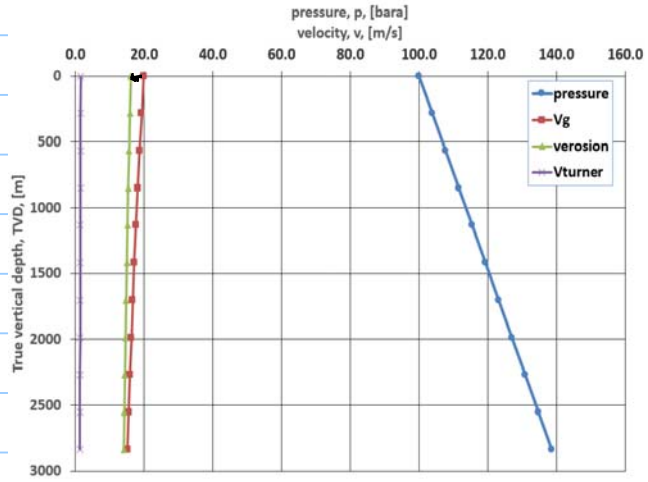
$q_{sc} = 1 \text{ E}06 \ Sm^3/d$



- for all TVDs : $v_g < v_{erosion}$
$v_g > v_{turner}$

$q_{sc} = 1.5 \text{ E}6 \ Sm^3/d$





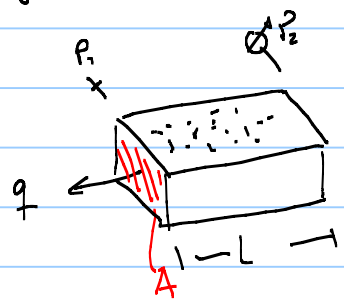
$q_{\bar{g}} = 2836\ Sm^3/d$
but $p_{wh} = 100$ bar (increasing p_{sep} or choking)

IPR

$q_{\bar{g}} = C\left(p_e^2 - p_{wf}^2\right)^n$

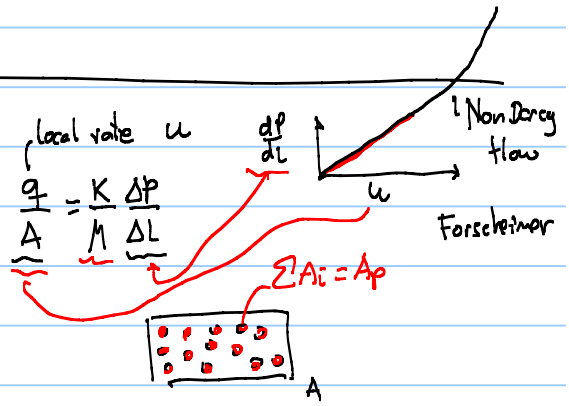
Darcy law

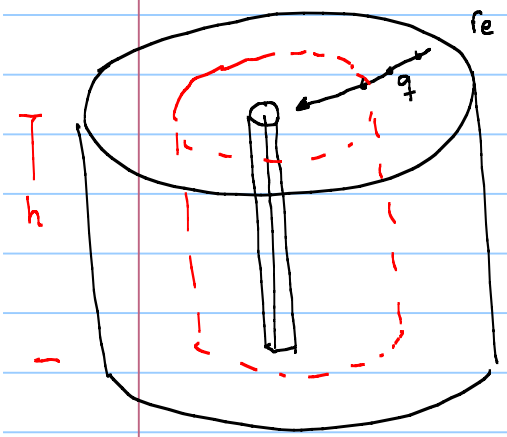
liquid / undersaturated oil



local rate u

$\frac{q}{A} = \frac{K}{\mu}\frac{\Delta p}{\Delta L}$





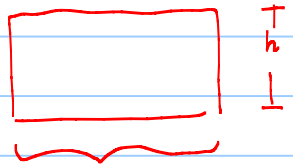
$\frac{q}{A} = \frac{K}{\mu}\frac{dp}{dr}$

$r_w \to r^*$

$p_{wf} \to p^*$

local rate $(f(p))$

$\frac{q}{2\pi r.h} = \frac{K}{\mu}\frac{dp}{dr}$

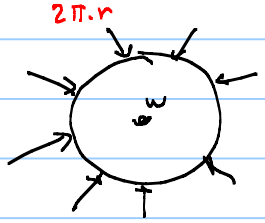


$A = 2\pi r.h$

dead oil 1.0 volatile oil 2.0

$q_o = B_o(p,T) \cdot q_{\bar{o}}$

q at standard conditions



$\frac{B_o\, q_{\bar{o}}}{2\pi r h} = \frac{K}{\mu_o}\frac{dp}{dr}$

$\frac{q_{\bar{o}}}{2\pi K h}\int_{r_w}^{r^*}\frac{1}{r}\,dr = \int_{p_{wf}}^{p}\frac{1}{\mu_o B_o}\,dp$

dead oil or ideal $\mu_o B_o \neq f(p)$

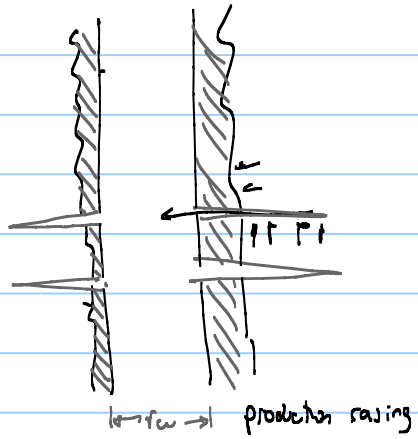
$\frac{q_{\bar{o}}}{2\pi K h}\ln\left(\frac{r^*}{r_w}\right) = \frac{1}{\mu_o B_o}\left(p - p_{wf}\right)$

$$p = p_{wf} + \frac{q_{\bar{o}}\,\mu_o B_o}{2\pi K h}\ln\left(\frac{r^*}{r_w}\right)$$

pure SI units

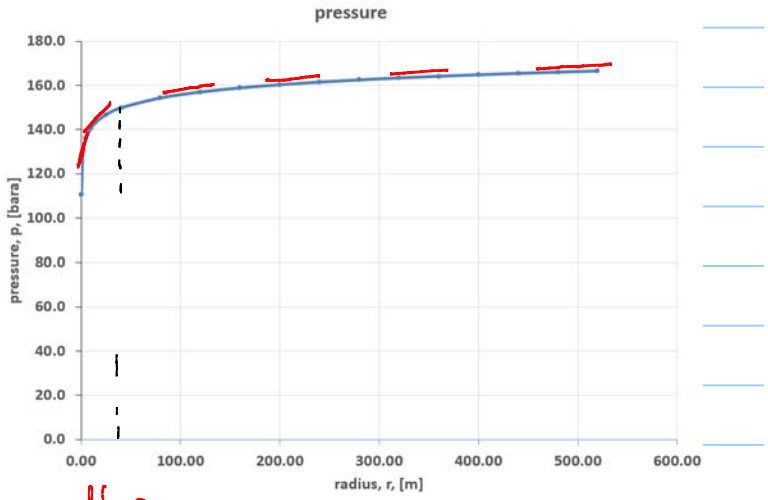
for
$\mu = c_p$
p [bara]
q_{to} [Sm^3/d]
K [md]
h [m]
r [m]

$$p = p_{wf} + \frac{18.42\,\mu_o B_o q_{to}}{2\pi K h} \ln\left(\frac{r}{r_w}\right)$$

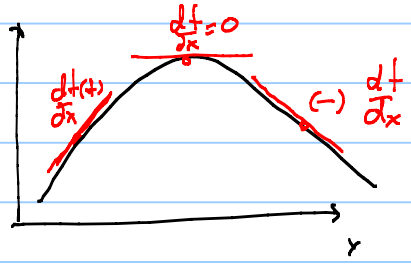


Pressure distribution around the wellbore (part-1)				
kh	1194.23	md*m	h	
u	1.62	cp	K	
B	1.24	m^3/Sm^3		
r_w	0.10	m		
P_{wf}	110.34	bara		
q	210.53	Sm^3/d		
pR	164.00	bara		
S	0.00			
S	18.00			
S	-3.00			

r [m]	p [bara]
0.10	110.3
1	125.7
2	130.2
5	136.2
10	140.7
15	143.4
25	146.7
40	149.8
80	154.3



$$\frac{q}{A} = \frac{K}{\mu}\frac{\partial p}{\partial r}$$



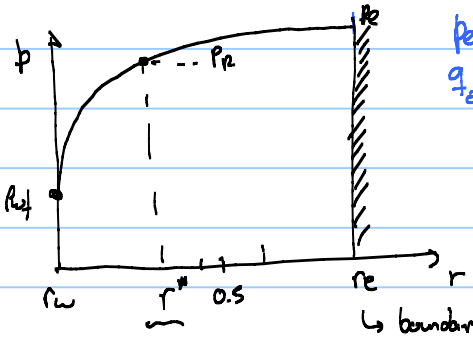
the biggest portion of pressure drop occurs very close to rw @ first 30 m

and that determines the productivity of well

IPR expression to provide:

$$q_o = f(p_R, p_{wf})$$

$$p_R = \frac{\int_{r_w}^{r_e} p\, dV}{\int_{r_w}^{r_e} dV}$$



p_R = constant SS

$q_o = 0$ at r_e PSS

↳ boundary of reservoir

the p_R

p_R

$$p = p_{wf} + \frac{18.42\,\mu_o B_o q_o}{2\pi k h} \ln\left(\frac{r}{r_w}\right)$$

if SS, p_R = constant

p_R occurs @ $r = 0.61 r_e$

if PSS, no flow at r_e

p_R occurs @ $0.47 r_e$

for SS

$$\frac{(p_R - p_{wf})\, 2\pi k h}{\ln\left(\frac{0.61 r_e}{r_w}\right) \mu_o B_o 18.42} = q_o$$

J productivity index

for liquid

$$(p_R - p_{wf})\, J = q_o$$

$$\ln(a \cdot b) = \ln a + \ln b$$

$$q_o = \frac{2\pi k h}{\mu_o B_o 18.42} \cdot \frac{(p_R - p_{wf})}{\left[\ln\left(\frac{r_e}{r_w}\right) + \ln(0.61)\right]}$$

J_{SS}

$\ln(0.61) = -0.49 \simeq -0.5$ effect boundary type (constant pressure)

$\ln\left(\frac{500\,m}{0.1\,m}\right)$ ↳ 8.5 effect of convergence

PSS:

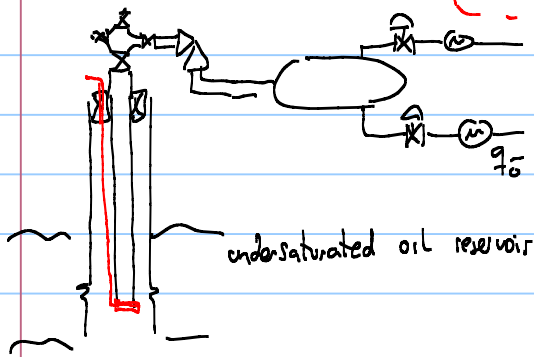
$$q_o = \frac{2\pi k h}{\mu_o B_o 18.42} \cdot \frac{(p_R - p_{wf})}{\left[\ln\left(\frac{r_e}{r_w}\right) + \ln(0.47)\right]}$$

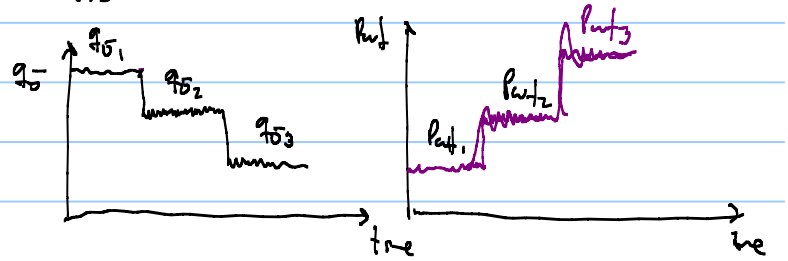
J_{PSS}

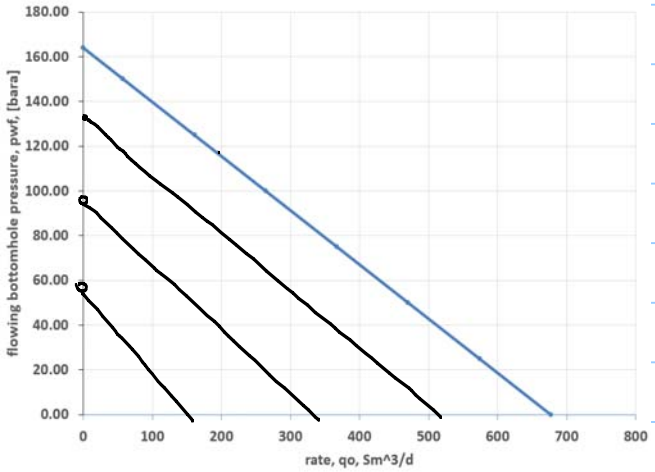
$\ln(0.47) = -0.75$

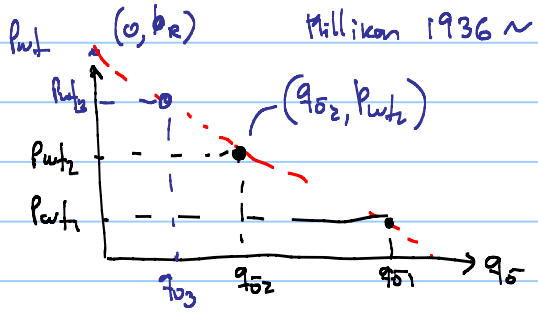
8.5

$$J = \frac{q}{\Delta p} \left[\frac{Sm^3/d}{bara}\right]$$

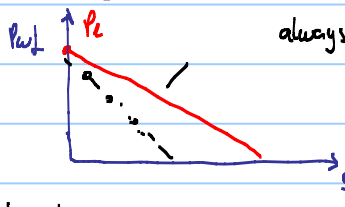






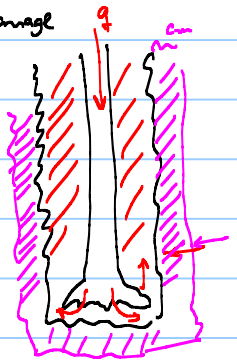


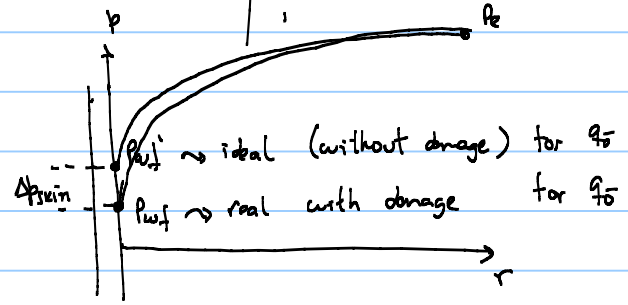
analytical IPR equation don't usually have high accuracy "right out of the box"



always do testing !! to verify IPR

S is called skin { flow impairment near wellbore { formation damage / perforation





ideal $P_R - P_{wf}' = \frac{18.42\, B_o \mu_o q_o}{kh}\left[\ln\frac{r_e}{r_w} - 0.75\right]$

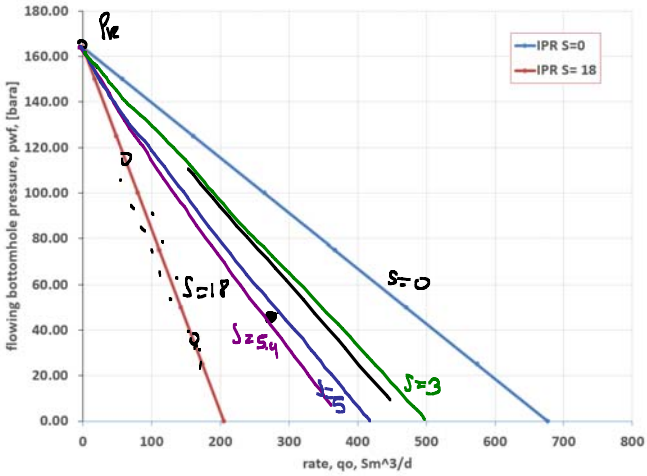
skin $P_{wf}' - P_{wf} = \frac{18.42\, B_o \mu_o q_o}{kh}[S]$

$$P_e - P_{wf} = 18.42\,\frac{q_o B_o \mu_o}{kh}\left[\ln\frac{r_e}{r_w} - 0.75 + S\right]$$ skin factor

$$q_o = \frac{kh\,(P_R - P_{wf})}{18.42\, B_o \mu_o\left[\ln\frac{r_e}{r_w} - 0.75 + S\right]}$$

S = 0 no-damage original reservoir
S > 0 damage [0 - 10]
S < 0 stimulation

8.5 -0.75 +


IPR S=0
IPR S= 18
flowing bottomhole pressure, pwf, [bara]
rate, qo, Sm^3/d
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0
100
200
300
400
500
600
700
800
S=0
S=3
S=5
S=18