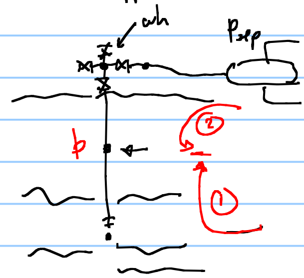
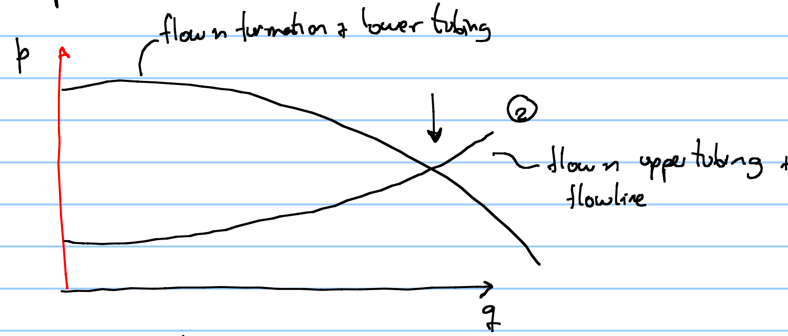
Note Title   10.10.2018

Day 2 20181010

- How to write and run and debug routines in excel VBA. | F8 - step by step; F5 - Continue Running
- what happens if we move the equilibrium point





if equilibrium point is at wellhead then the available pressure curve it is called WPR wellhead performance relationship

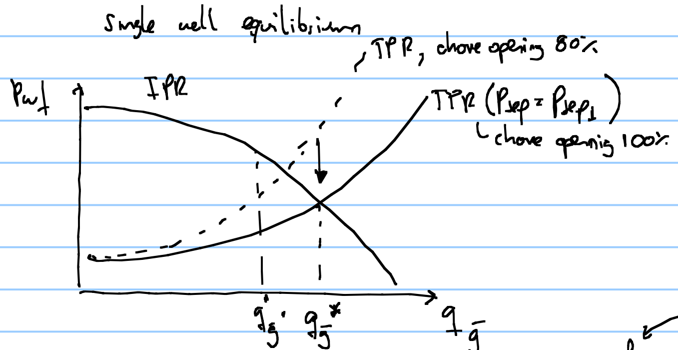
the tubing equation can be used for flowlines. for horizontal flowline $q_g = C_{FL}\left(p_1^2 - p_2^2\right)^{0.5}$ (↑ upstream, ↳ downstream)

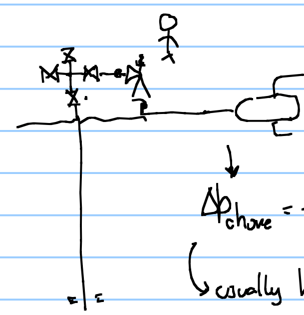
$$p_{wh} = p_2 = \left(\frac{p_1^2}{e^s} - \frac{q_g^2}{C_T^2}\right)^{0.5}$$

$$p_2 = \left(\frac{p_1^2}{1} - \frac{q_g^2}{C_T^2}\right)^{0.5}$$

L'Hopital theorem $\lim_{x\to c}\frac{f(x)}{g(x)} = \lim_{x\to c}\frac{f'(x)}{g'(x)}$. $\lim_{s\to 0}\frac{s}{e^s - 1} = \lim_{s\to 0}\frac{1}{e^s} = 1$

Single well equilibrium



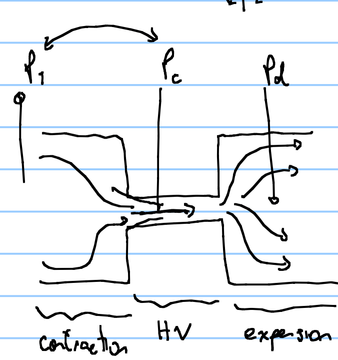


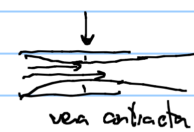
$\Delta p_{choke} = f(q_g, \text{opening})$

↳ usually has a lot of uncertainty

for gas is OK

but for multiphase is ± 100%

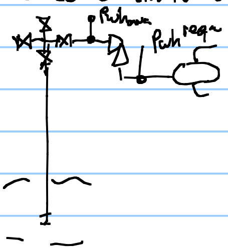


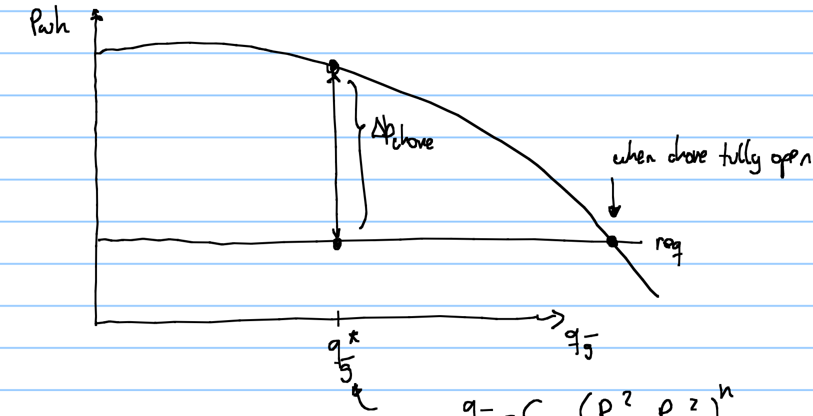


for liquid
$$q_o = \frac{A_2 \cdot C_d}{B_{o2}} \cdot \sqrt{\frac{2\cdot(p_2 - p_1)}{\rho(1-\beta^4)}}$$

for dry gas
$$q_{\bar{g}} = \frac{p_1 \cdot A_2 \cdot C_d \cdot T_{sc}}{p_{sc}} \cdot \sqrt{2 \cdot \frac{R}{Z_1 \cdot T_1 \cdot M_w} \cdot \frac{k}{k-1} \cdot \left(y^{\frac{2}{k}} - y^{\frac{k+1}{k}}\right)}$$

to overcome limitations in the choke equation, we place equilibrium point at wellhead

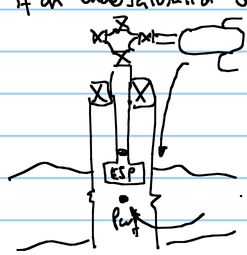


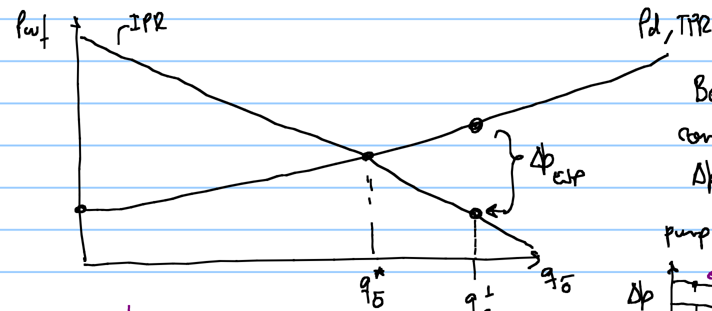


$$q_g = C_R \left(P_R^2 - P_{wf}^2\right)^n$$

$$p_{wh} = p_2 = \left(\frac{p_1^2}{e^s} - \frac{q_g^2}{C_T^2}\right)^{0.5}$$

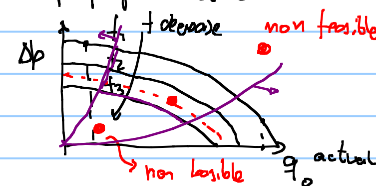
if an undersaturated oil well with ESP (electric submersible pump)





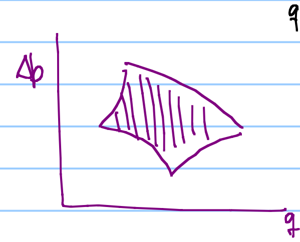
Be aware, not all combinations of q and Δp are feasible !

pump performance curve



assuming $q_g = q_o^{actual}$

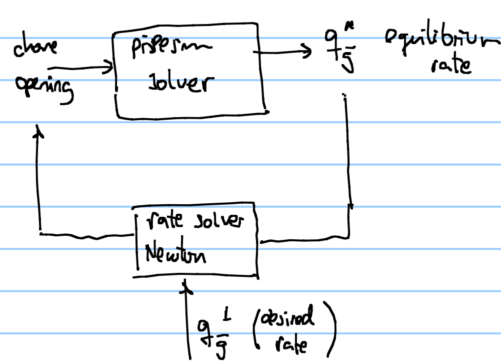
$$P_{ave} = \frac{\Delta p \cdot q}{\eta}$$



$f_{max} \approx 70\ hz$

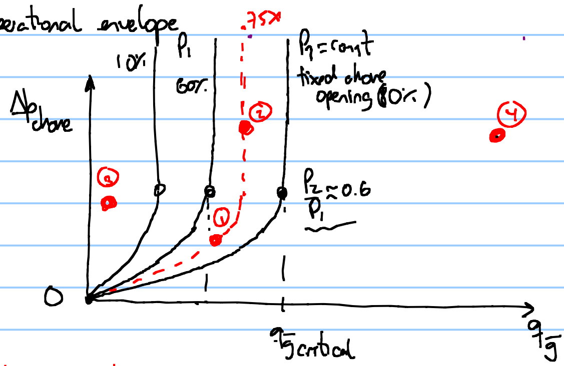
$f_{min} \approx 30\ hz$

be aware ! in commercial software if i want a specific rate

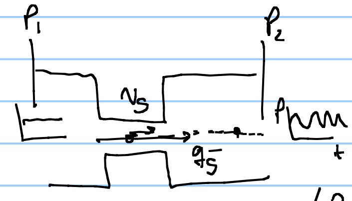


two solver levels
- equilibrium calculations
- choke opening calculations

Choke operational envelope



$\Delta p = a q^2$



$\Delta p = P_1 - P_2$

$\Delta p = f(q_g)$

sonic velocity 300 m/s

$\frac{P_2}{P_1} \simeq 0.6$ critical velocity in the throat is achieved!

① choke operating subcritical range

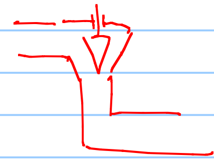
② choke operating in critical range

③ choke too big

④ choke too small

$$\left.\frac{P_2}{P_1}\right|_c = 0.6$$

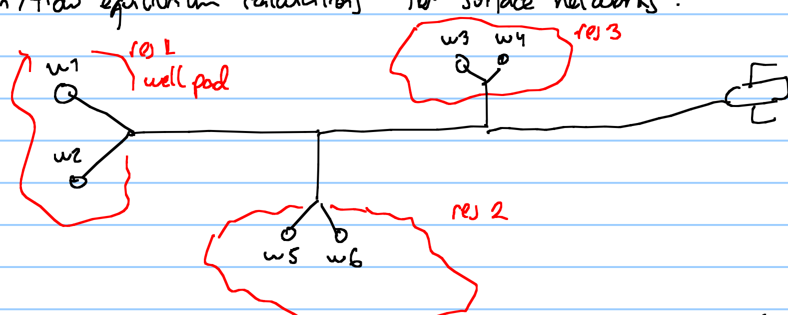
$$\Delta p_{critical} = P_1 - P_2 = P_1 - 0.6 P_1$$

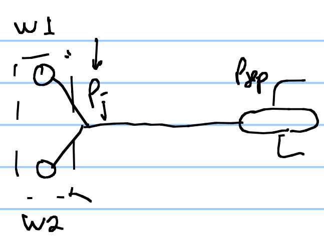


Homework

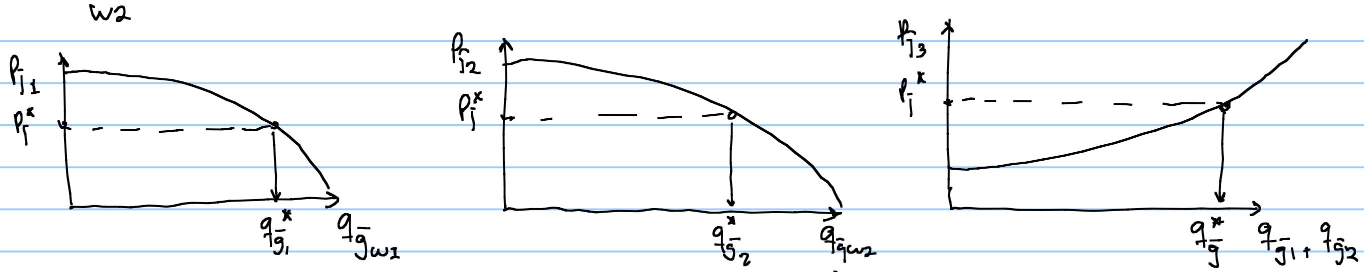
- Read choke equation development (single phase liquid) (dry gas)
- Read IPR for dry gas
- optional! generate choke performance curve with excel file
- optional! solve network of two wells in excel

Production/flow equilibrium calculations for surface networks:





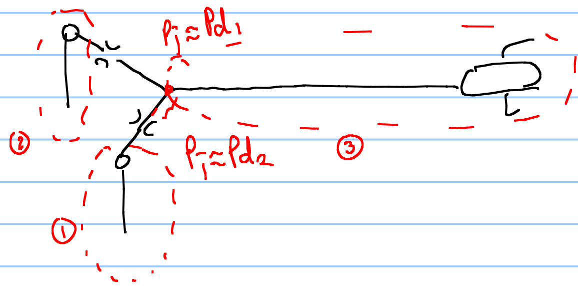
- define an equilibrium point (junction)
- calculate available and required pressure curves from boundaries
- intersect! $P_{j\,avail\,1} = P_{j\,available\,2} = P_{j\,required}$



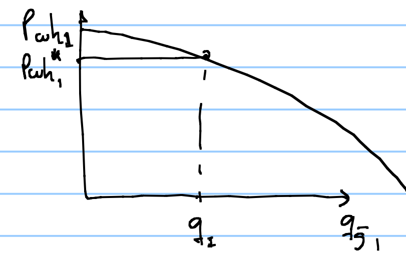
$q_g = q_{g1} + q_{g2}$?

$P_{j1} = P_{j2} = P_{j\,pipeline}$ momentum balance.

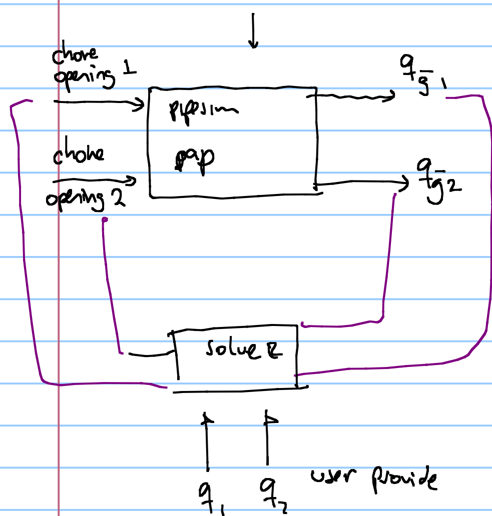
$$\boxed{q_g^* \overset{?}{=} q_{g1}^* + q_{g2}^*}$$ mass balance

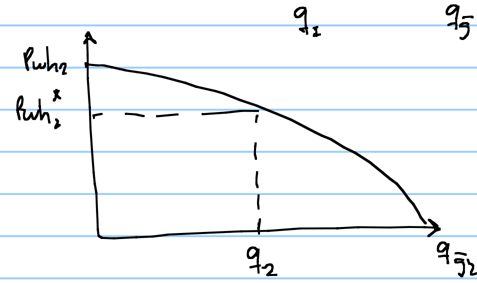


q_1 and q_2 desired rates



in commercial software:





$\Delta p_{choke\,1} > 0$

$P_{wh_1}^* - P_j^* > 0$

$\Delta p_{choke\,2} > 0$

$P_{wh_2}^* - P_j^* > 0$