Class exercise on Dry gas network

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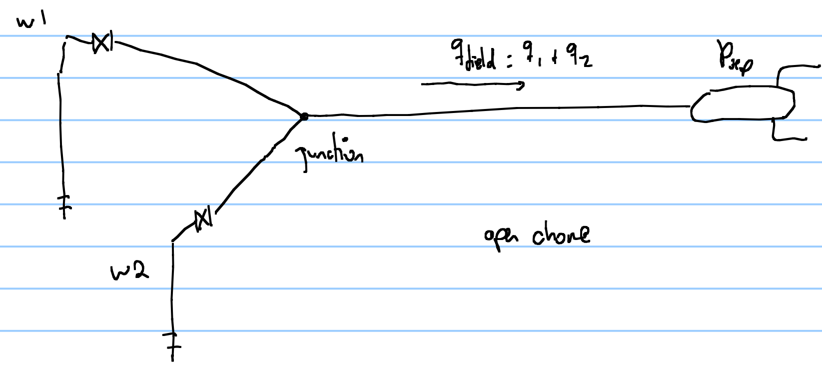
Name	Last modified	Size	Description
Parent Directory		-	
Network_two_gas_wells.xls	07-Feb-2020 08:43	44K	



we have to assume either $\bar{q}_1$, $\bar{q}_2$

OR: P_{wf_1}, P_{wf_2} ← $P_{wf} < P_R$

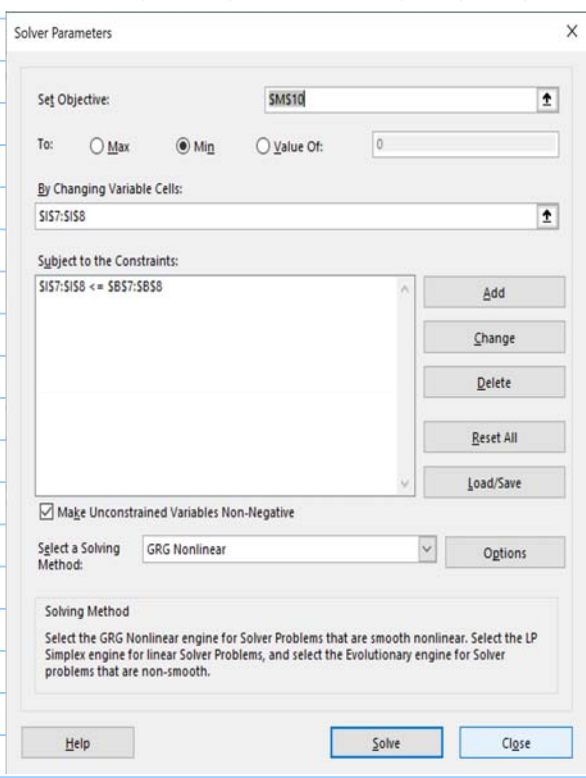
↳ we prefer to assume P_{wf} because I know the upper bound

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

$$P_{wf} = \sqrt{P_R^2 - \left(\frac{q}{C_R}\right)^{1/n}}$$

i don't know q_{max}, and can give problems in eq.

		IPR			Tubing	Flowline						
Component Name	p_R	C	n	S	Ct	Cfl	psep	pwf	qwell	pwh	pjunc	error
	[bara]	[Sm^3/bar^2n]			[Sm^3/bar^2]	[Sm^3/bar^2]	[bara]	[bara]	[Sm^3/d]	[bara]	[bara]	(bara^2)
W_1	120	52	0.8	0.13	7680	8673		38	1.02E+05	33	31	1E-0
W_2	120	40	0.75	0.11	8600	7563		34	4.95E+04	31	31	9E-1
Pipeline						14080	28.6		1.51E+05		31	2E-0
										Average=	31	4E-0



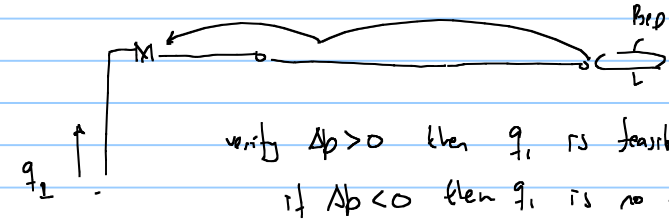
If solver is not available

Activate solver → excel menu → options
↓
Add in
↓
"go"
↓
tick on "solver" or "problemsolver"

solving the network
with choke

- option 1, fixing rates
(option usually not available in commercial software)

for Snøhvit ; we choose the wellhead as equilibrium point



verify $\Delta p > 0$ then q_1 is feasible
if $\Delta p < 0$ then q_1 is no feasible

for example, it is desirable to produce

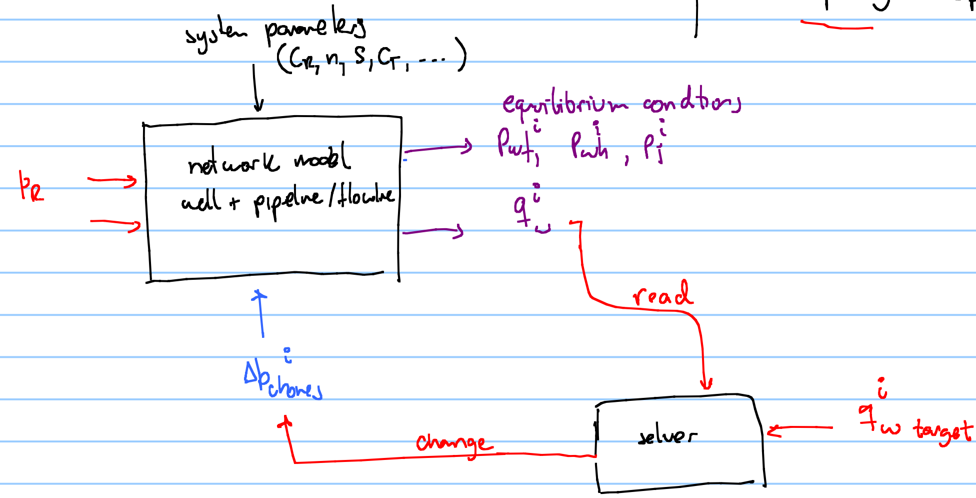
$$\begin{cases} q_1 = 80000 \ Sm^3/d \\ q_2 = 40000 \ Sm^3/d \end{cases}$$

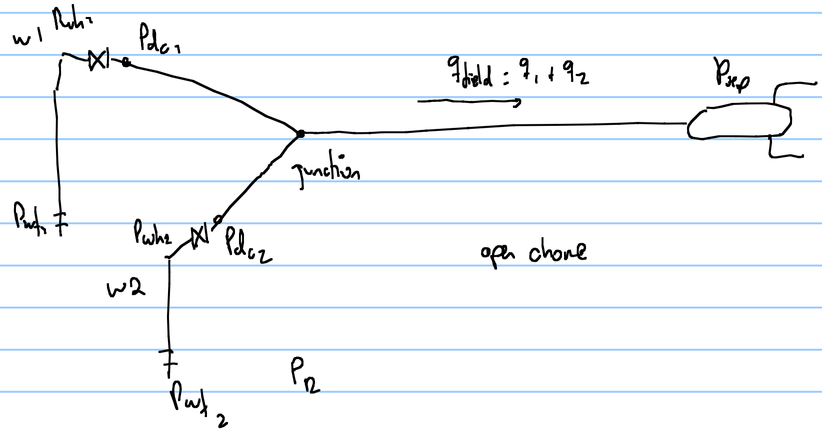
		IPR			Tubing	Flowline							
Component Name	p_R	C	n	S	Ct	Cfl	psep	pwf	qwell	pwh	dpchoke	pdc	pjunc
	[bara]	[Sm^3/bar^2n]			[Sm^3/bar^2]	[Sm^3/bar^2]	[bara]	[bara]	[Sm^3/d]	[bara]	[bar]	[bar]	[bara]
W_1	120	52	0.8	0.13	7680	8673		69	8.00E+04	64	33	31	30
W_2	120	40	0.75	0.11	8600	7563		66	4.00E+04	63	32	30	30
Pipeline						14080	28.6		1.20E+05				30

IPM (PETEX)

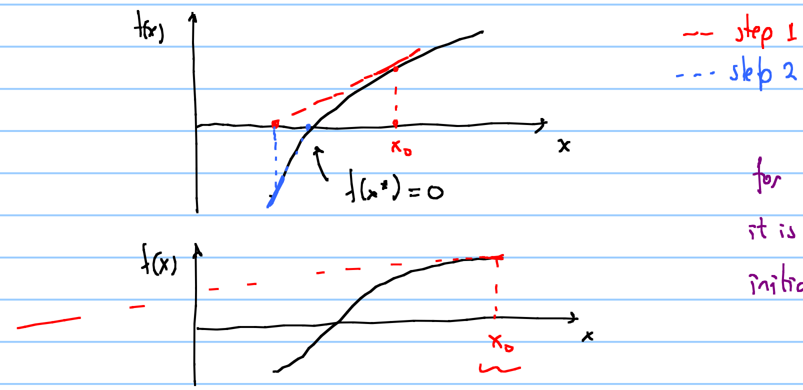
Next week : tutorial on predicting production and production profiles using Prosper (well), MBAL (material balance), GAP (Network)
remake the snøhvit (Snøhvit) field

- option 2 : include the choke "model" → 2 options
  - Δp_{choke} ← this option will be discussed next
  - choke opening $\Delta p_{choke} = f(q_g, \text{Opening}, p_1)$





	IPR			Tubing	Flowline								
pR	C	n	S	Ct	Cfl	psep	pwf	qwell	pwh	dpchoke	pdc	pjunc	error
[bara]	[Sm^3/bar^2n]			[Sm^3/bar^2]	[Sm^3/bar^2]	[bara]	[bara]	[Sm^3/d]	[bara]	[bar]	[bar]	[bara]	(bara^2)
120	52	0.8	0.13	7680	8673		42	9.92E+04	38	5	33	30	3E-10
120	40	0.75	0.11	8600	7563		39	4.84E+04	36	5	31	30	1E-09
					14080	28.6		1.48E+05				30	3E-09
									Average=			30	4E-09

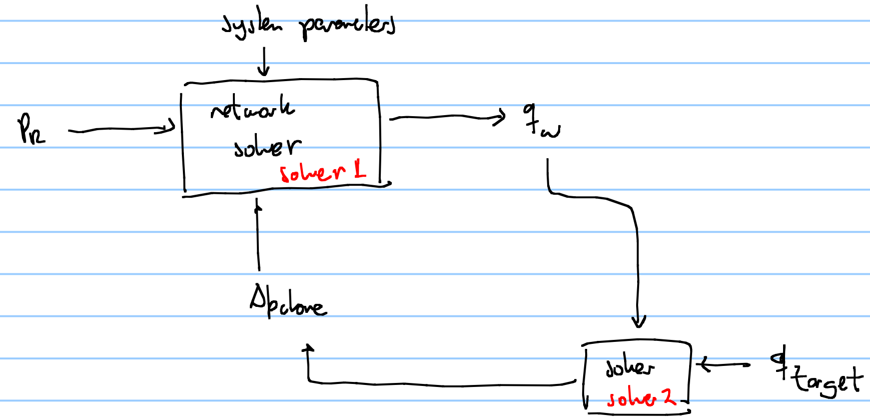


for derivative based solver it is necessary to give a good initial seed

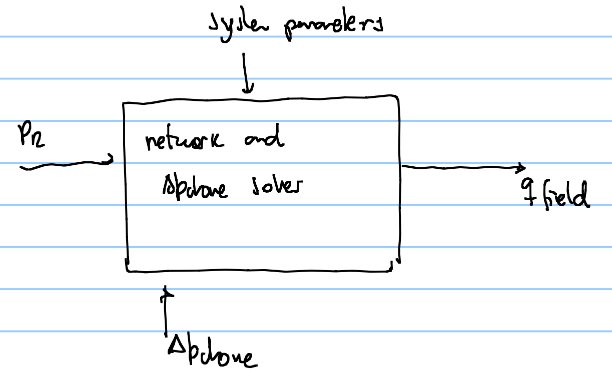
	IPR			Tubing	Flowline								
pR	C	n	S	Ct	Cfl	psep	pwf	qwell	pwh	dpchoke	pdc	pjunc	error
[bara]	[Sm^3/bar^2n]			[Sm^3/bar^2]	[Sm^3/bar^2]	[bara]	[bara]	[Sm^3/d]	[bara]	[bar]	[bar]	[bara]	(bara^2)
120	52	0.8	0.13	7680	8673		57	9.01E+04	52	20	32	30	1E-09
120	40	0.75	0.11	8600	7563		54	4.44E+04	51	20	31	30	8E-10
					14080	28.6		1.35E+05				30	4E-09
									Average=			30	6E-09

- How to use this model to find Δp_{choke} such that $q_1 = 80000\ Sm^3/d$, $q_2 = 40000\ Sm^3/d$

in excel it is not possible to have two levels of solver



"Merging the two solvers"

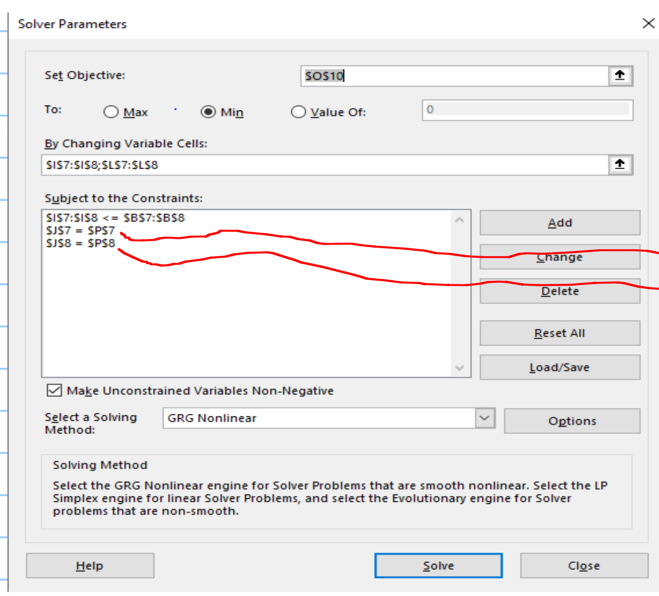


objective variable:

$$(P_{j_{av}} - P_{j_1})^2 + (P_{j_{av}} - P_{j_2})^2 + (P_{j_{av}} - P_{j_{sep}})^2$$

variables

changing P_{wf_1}, P_{wf_2}, $\Delta p_{choke\ 1}$, $\Delta p_{choke\ 2}$



constraints

$q_1 = q_{1\,target}$

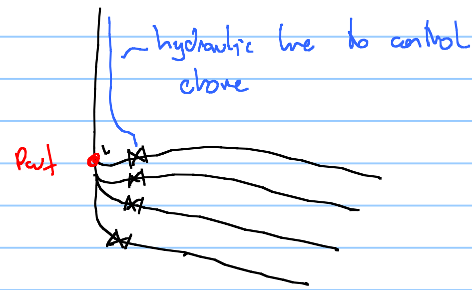
$q_2 = q_{2\,target}$

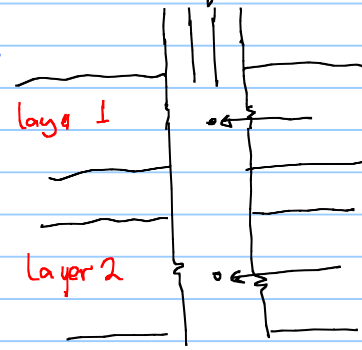
	IPR		Tubing		Flowline									
p_R	C	n	S	Ct	Cfl	psep	pwf	qwell	pwh	dpchoke	pdc	pjunc	error	qtarget
[bara]	[Sm^3/bar^2n]			[Sm^3/bar^2]	[Sm^3/bar^2]	[bara]	[bara]	[Sm^3/d]	[bara]	[bar]	[bar]	[bara]	(bara^2)	[Sm3/d]
120	52	0.8	0.13	7680	8673		69	8.00E+04	64	33	31	30	9E-11	80000
120	40	0.75	0.11	8600	7563		87	3.00E+04	82	52	30	30	5E-11	30000
					14080	28.6		1.10E+05				30	7E-12	
									Average=			30	2E-10	

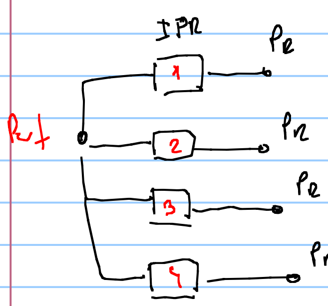
Downhole networks

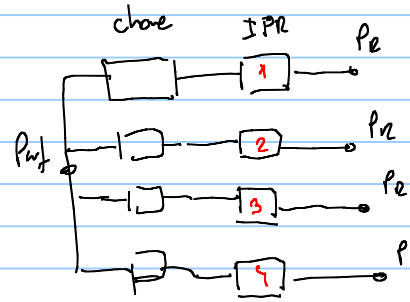
multilateral wells

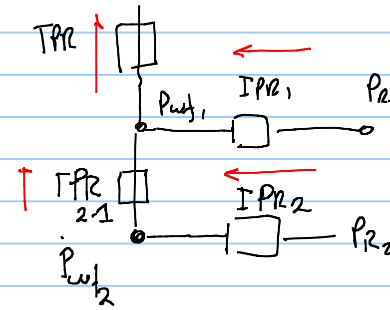
smart well | multi layer

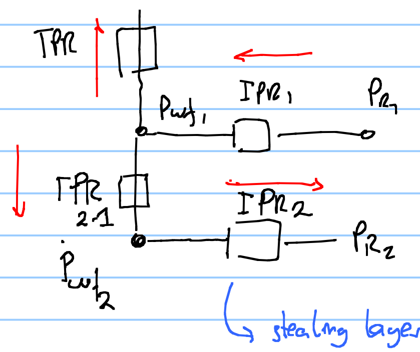




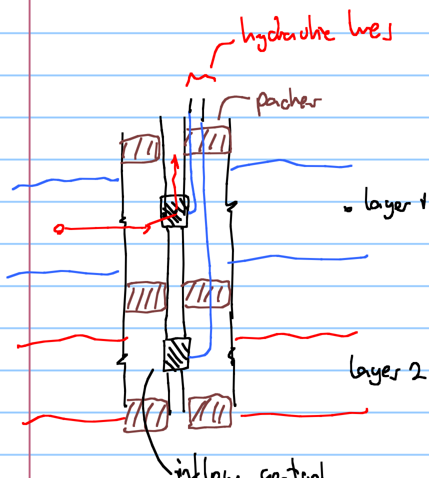


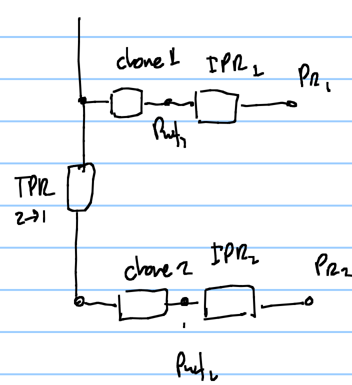




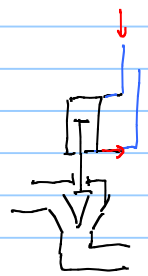


multi layer with inflow control



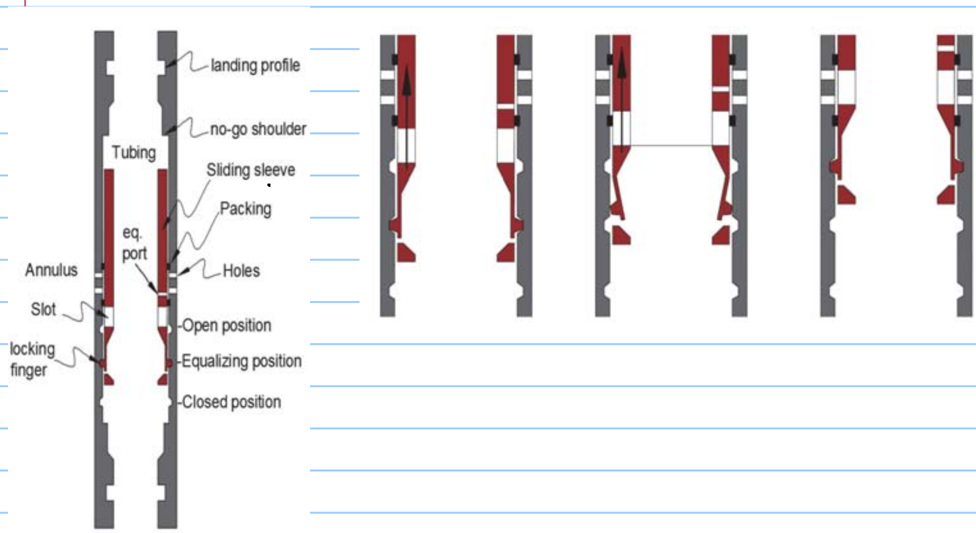


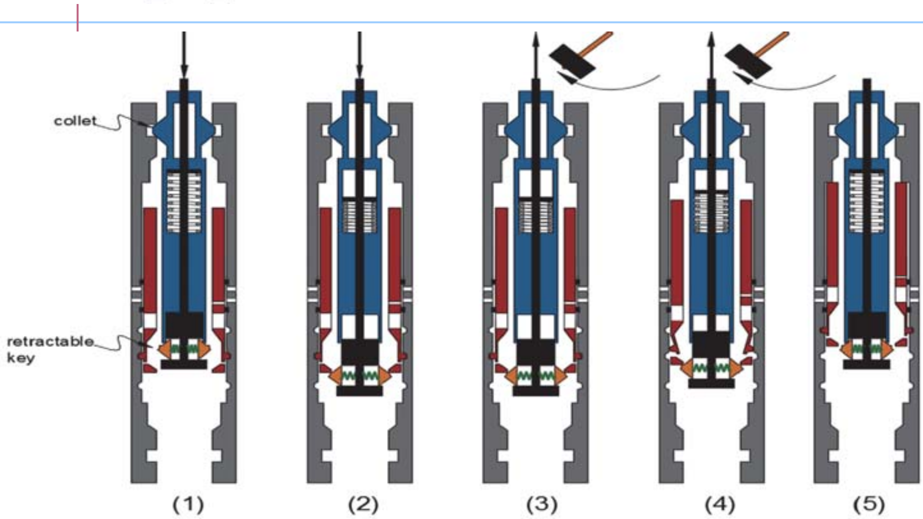
these chokes can be actuated from surface ($$$) or mechanically ($$)
actuated for example with wire line, coil tubing

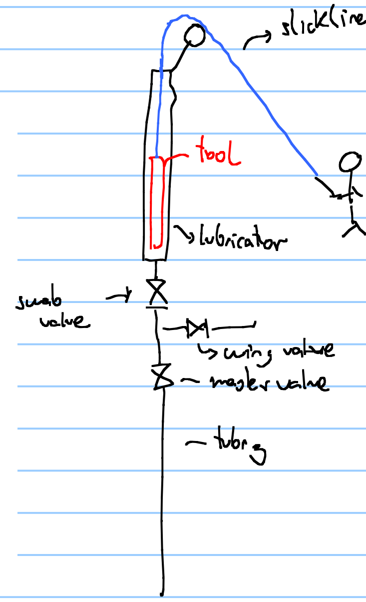


example of
hydraulic activation of choke

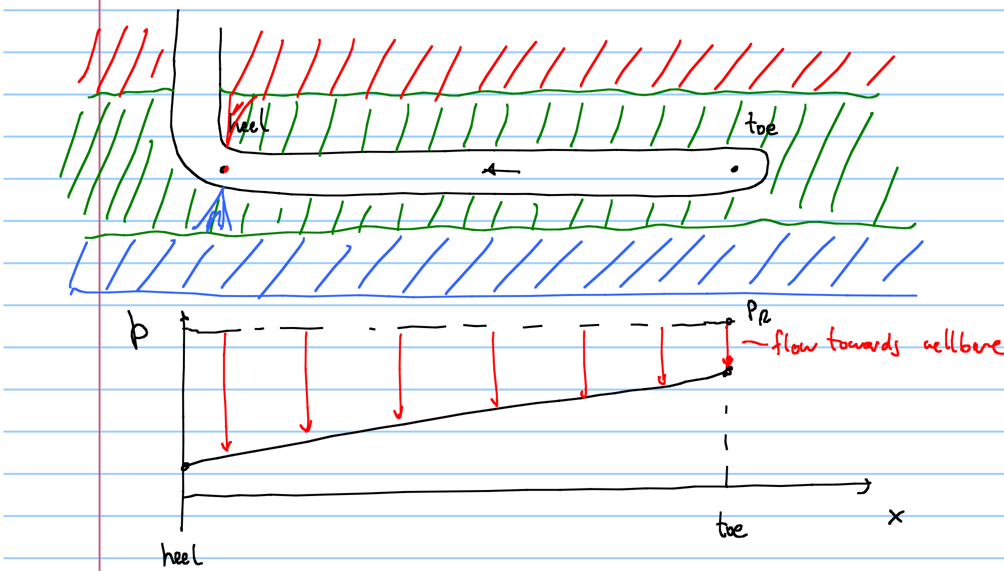
sliding sleeve functionality page 71 of compendium





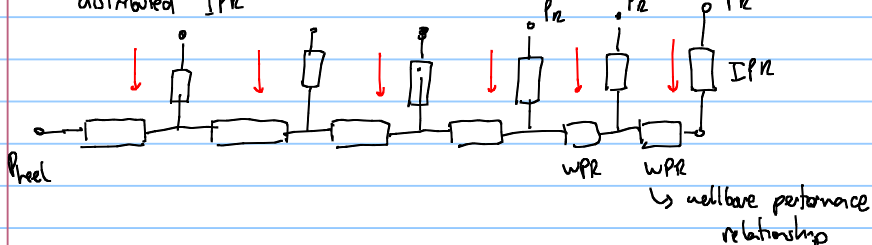


Networks to study a long horizontal well

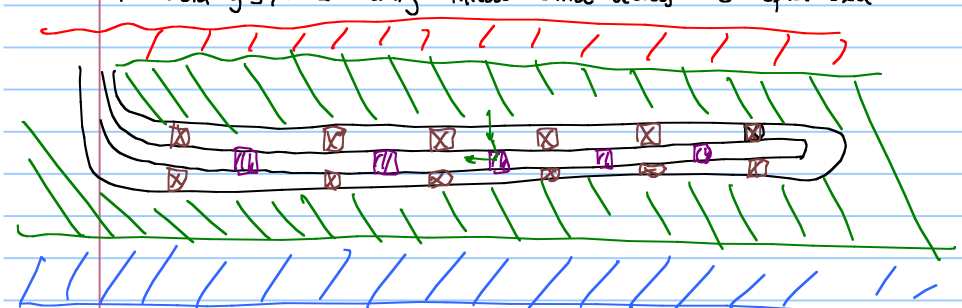


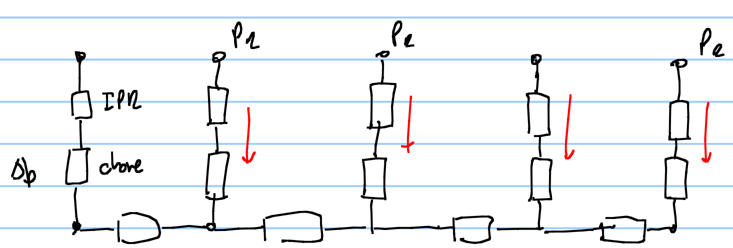
$$q \propto (p_R - p_{wf})$$

distributed IPR



to avoid gas/water coning inflow control devices are often used



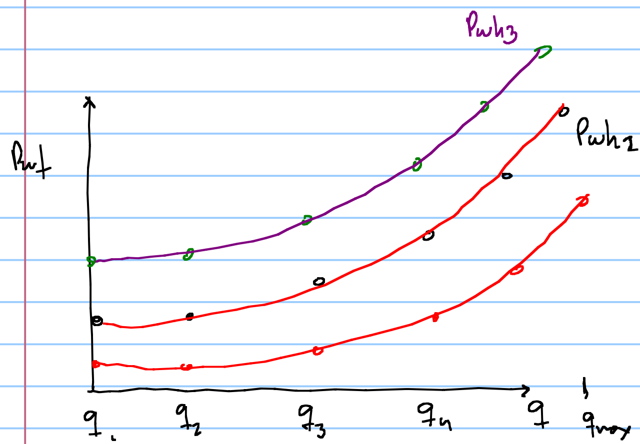


the chokes are used to even the rate profile along well. to ensure even depletion and high recovery factor

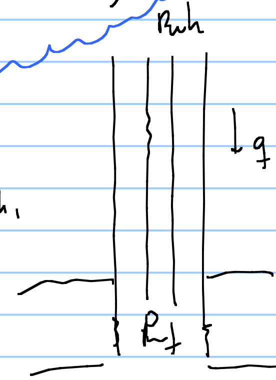
Discussion on TPR (tubing performance relationship)

In commercial software, instead of running Δp calculation along tubing each time is needed (flow equilibrium calculations), tubing tables are used instead (Δp tubing is precomputed for many operational conditions) and later on interpolation is made on table

$$q_g = \left(\frac{P_{wf}^2}{e^S} - P_{wh}^2\right)^{0.5}$$



$P_{wh_3} < P_{wh_2} < P_{wh_1}$

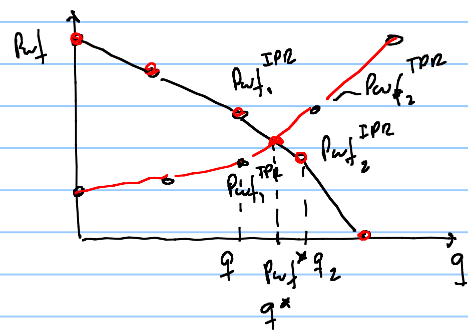


Pwh

	P_{wh_1}	P_{wh_2}	P_{wh_3}	-
q_1	$P_{wf_{11}}$	$P_{wf_{12}}$	-	
q_2	-	.	-	
q_3				
q_4	-	.	-	
q_5				

tubing table

interpolation on this table is much more computationally efficient than using the equation/method $\Delta p = f(q, P_{wh},)$ specially for multiphase flow, gas with liquid



- IPR

task find equilibrium for $P_{wh} = P_{wh_1}$

go to tubing table and extract column $P_{wh} = P_{wh_1}$

and impose on plot

from the table

$$\frac{P_{wf_1}^{IPR} - P_{wf_2}^{IPR}}{q_1 - q_2} = \frac{P_{wf_1}^{IPR} - P_{wf}^*}{q_1 - q^*}$$

System of two linearequations with two unknowns

$$\frac{P_{wf_1}^{TPR} - P_{wf_2}^{TPR}}{q_1 - q_2} = \frac{P_{wf_1}^{TPR} - P_{wf}^*}{q_1 - q^*}$$