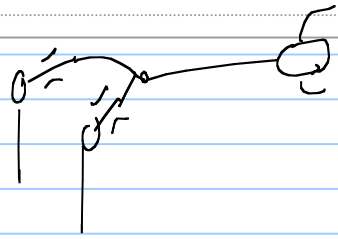
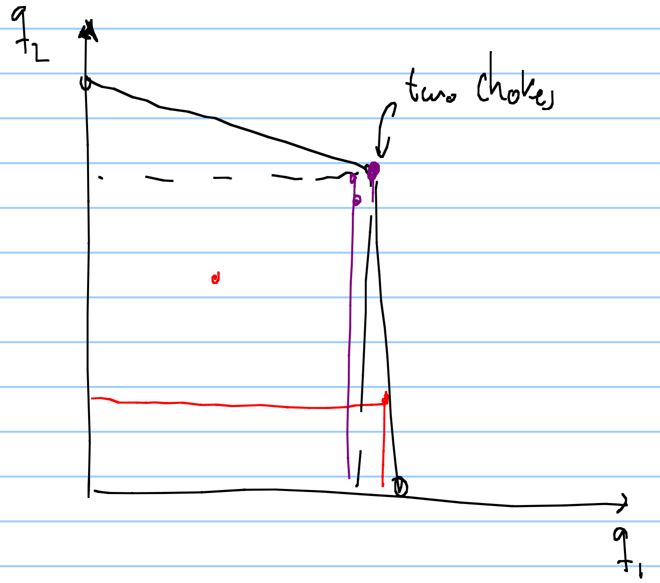
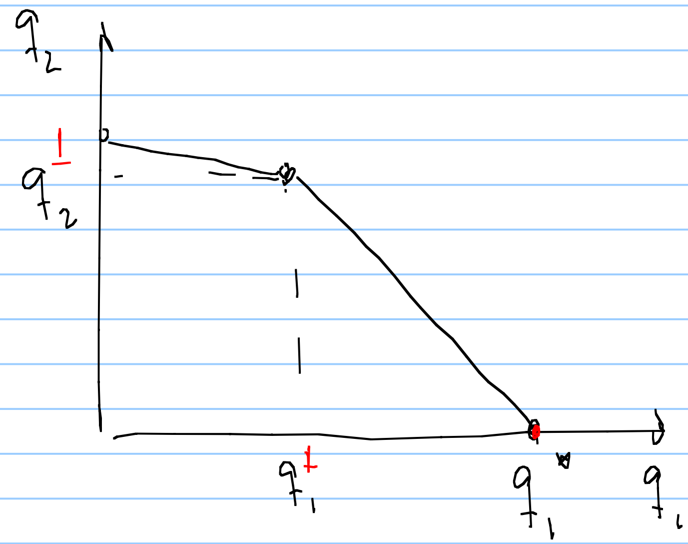
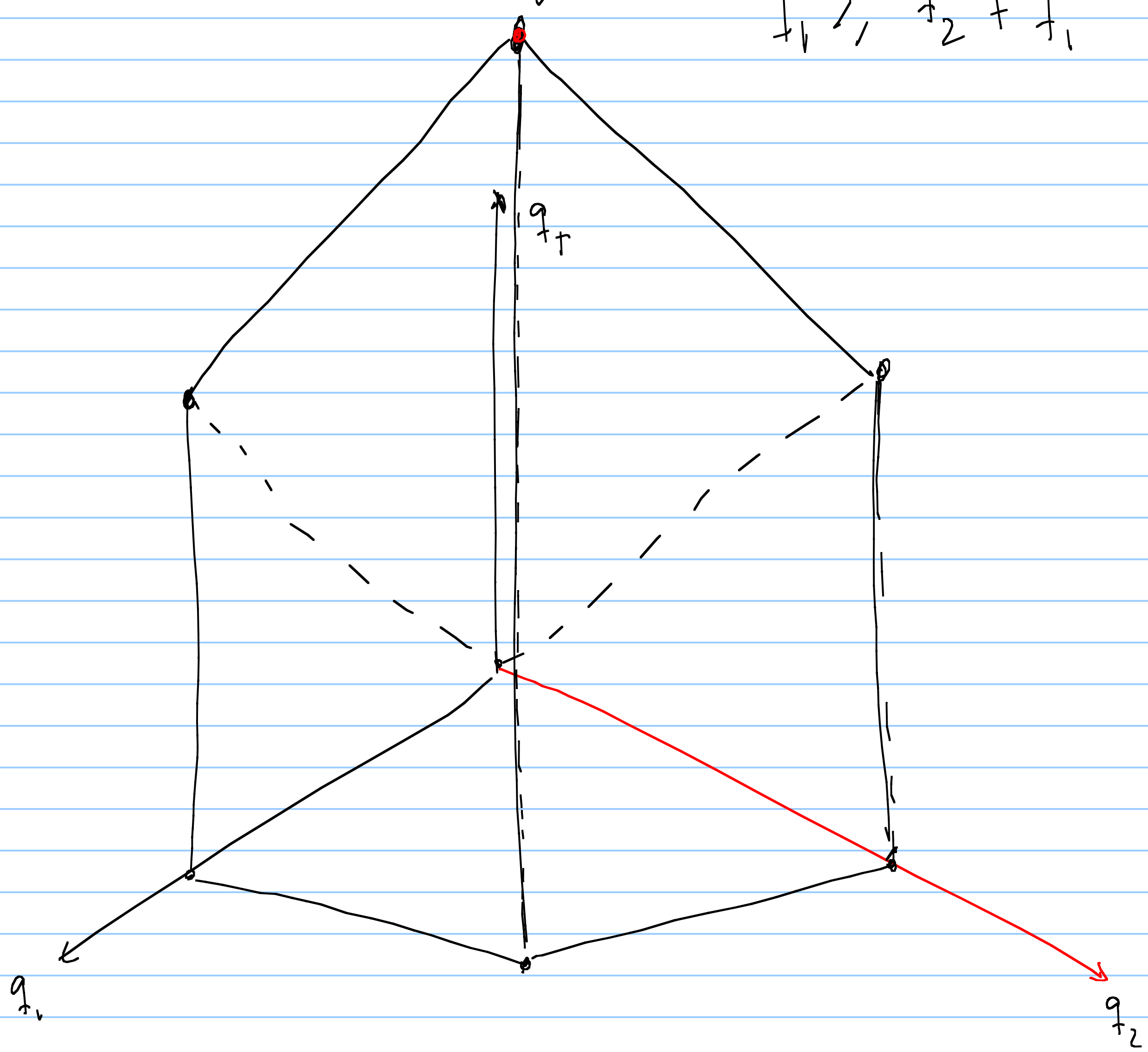
Comment to choked well operating area



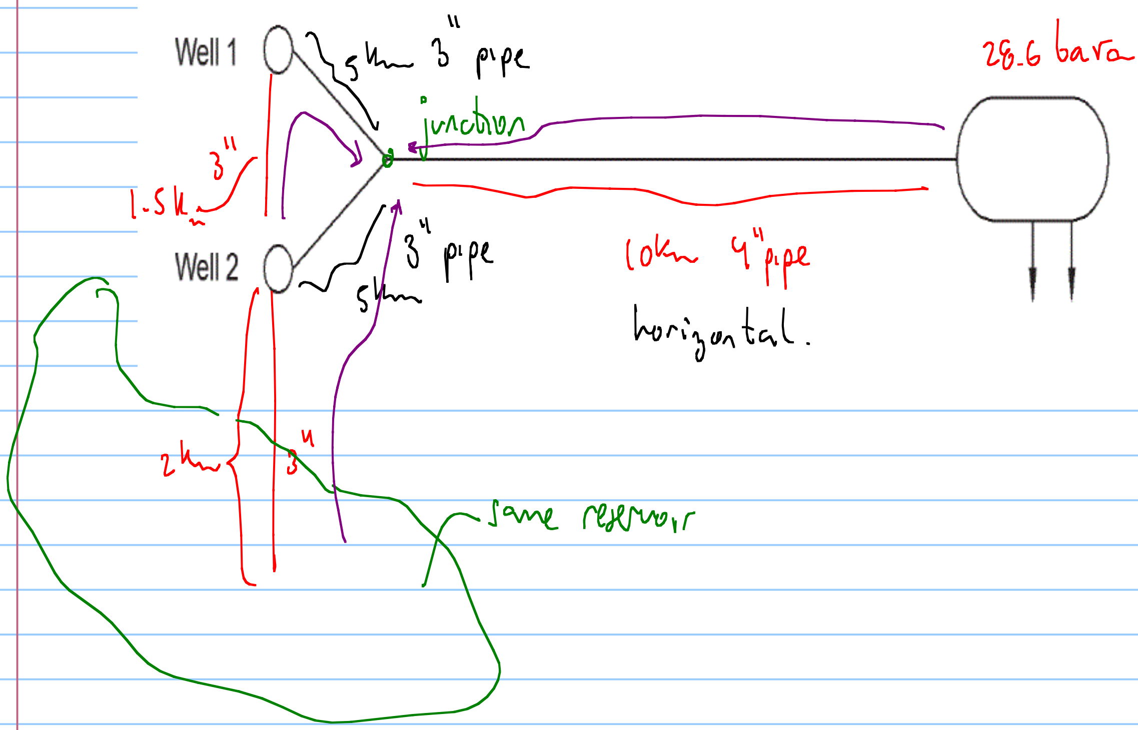




$$q_{t_1}^{*} \geq q_{t_2}^{1} + q_{t_1}^{1}$$



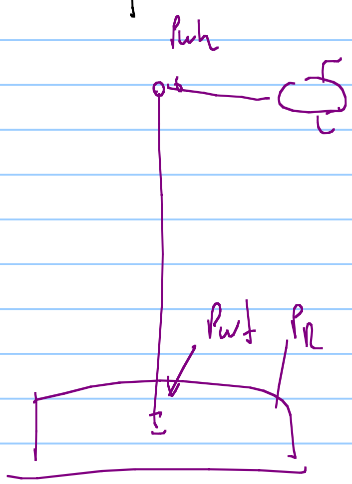
Excel exercise



Network of two gas wells

		IPR		Tubing		Flowline	
Component Name	p_R	C	n	S	Ct	Cfl	psep
	[bara]	[Sm^3/bar^2n]			[Sm^3/bar^2]	[Sm^3/bar^2]	[bara]
W_1	120	52	0.8	0.13	7680	8673	
W_2	120	40	0.75	0.11	8600	7563	
Pipeline						14080	28.6

1 Hydraulic equilibrium of the system (no choke)



	IPR			Tubing	Flowline					
p_R	C	n	S	Ct	Cfl	psep	pwf	qg	pwh	pj
[bara]	[Sm^3/bar^2n]			[Sm^3/bar^2]	[Sm^3/bar^2]	[bara]	[bara]	[Sm^3/d]	[bara]	[bara]
120	52	0.8	0.13	7680	8673		110	25432	103	103
120	40	0.75	0.11	8600	7563		110	13285	104	104
					14080	28.6				

up to this point co-current calculations.

	IPR			Tubing	Flowline					
p_R	C	n	S	Ct	Cfl	psep	pwf	qg	pwh	pj
[bara]	[Sm^3/bar^2n]			[Sm^3/bar^2]	[Sm^3/bar^2]	[bara]	[bara]	[Sm^3/d]	[bara]	[bara]
120	52	0.8	0.13	7680	8673		110	25432	103	103
120	40	0.75	0.11	8600	7563		110	13285	104	104
					14080	28.6		3.87E+04		29

Pav 4(↓)

Error

$(p_{j_1} - p_{jav})^2$

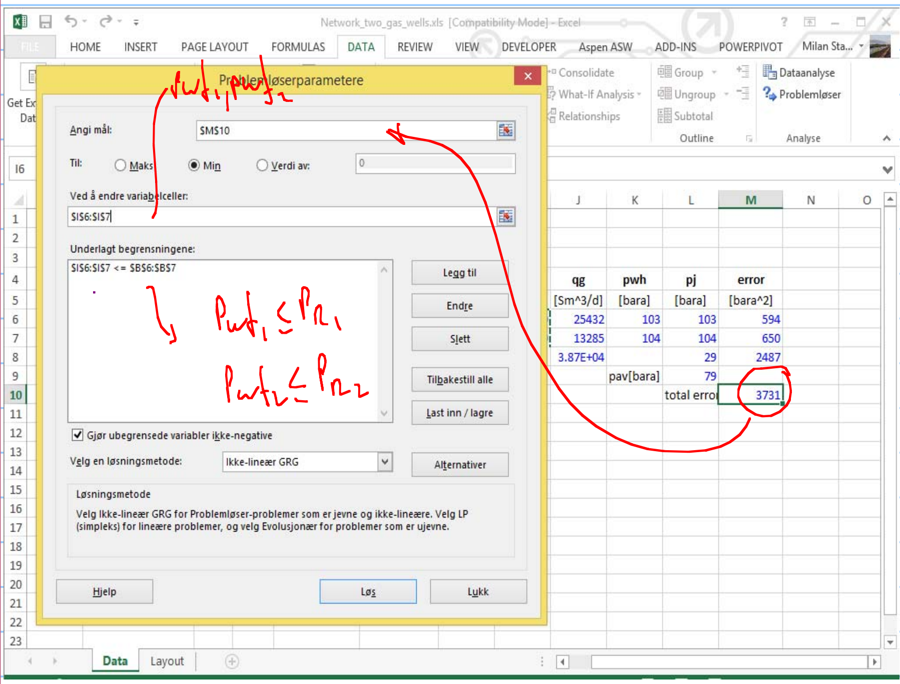
$(p_{j_2} \quad " \quad)^2$

$(p_{j_3} \quad " \quad)^2$

$\Sigma(\quad)$

solver objective → 0

by changing



	IPR		Tubing		Flowline						
p_R	C	n	S	Ct	Cfl	psep	pwf	qg	pwh	pj	error
[bara]	[Sm^3/bar^2n]			[Sm^3/bar^2]	[Sm^3/bar^2]	[bara]	[bara]	[Sm^3/d]	[bara]	[bara]	[bara^2]
120	52	0.8	0.13	7680	8673		3	11[illegible]75	#VALUE!	#VALUE!	#VALUE!
120	40	0.75	0.11	8600	7563		0	52581	#VALUE!	#VALUE!	#VALUE!
					14080	28.6		1.63E+05		31	#VALUE!
									pav[bara]	#VALUE!	
										total error	#VALUE!

pwf is too low ⟶ q too high

Pwh is negative

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

$$P_{wh} = \sqrt{\frac{P_{wf}^2}{e^s} - \left(\frac{q}{C_T}\right)^2}$$

is too big

Convergence using as starting point $P_{wf_1} = P_{wf_2} = 50$ bara.

	IPR		Tubing		Flowline						
p_R	C	n	S	Ct	Cfl	psep	pwf	qg	pwh	pj	error
[bara]	[Sm^3/bar^2n]			[Sm^3/bar^2]	[Sm^3/bar^2]	[bara]	[bara]	[Sm^3/d]	[bara]	[bara]	[bara^2]
120	52	0.8	0.13	7680	8673		38	101551	33	31	0
120	40	0.75	0.11	8600	7563		34	49466	31	31	0
					14080	28.6		1.51E+05		31	0
									pav[bara]	31	
										total error	0

Fixed production rate?

$q_{g_1} = 8063 \ Sm^3/d$

$q_{g_2} = 3063 \ Sm^3/d$

for choking, my point of interest is where the choke is

co-current from $P_R \to P_{wf} \to P_{wh}$

counter curren from $P_{sep} \to P_j \to P_{whreq_1}$ or $P_{downstream\ choke}$

$\to P_{whreq_2}$

	IPR		Tubing		Flowline							
p_R	C	n	S	Ct	Cfl	psep	qg	pwf	pwh avail	pj	pwhreq	deltap choke
[bara]	[Sm^3/bar^2n]			[Sm^3/bar^2]	[Sm^3/bar^2]	[bara]	[Sm^3/d]	[bara]	[bara]	[bara]	[bara]	[bar]
120	52	0.8	0.13	7680	8673		80000	69	64		31	33
120	40	0.75	0.11	8600	7563		30000	87	82		30	52
					14080	28.6	110000			30		
						total						

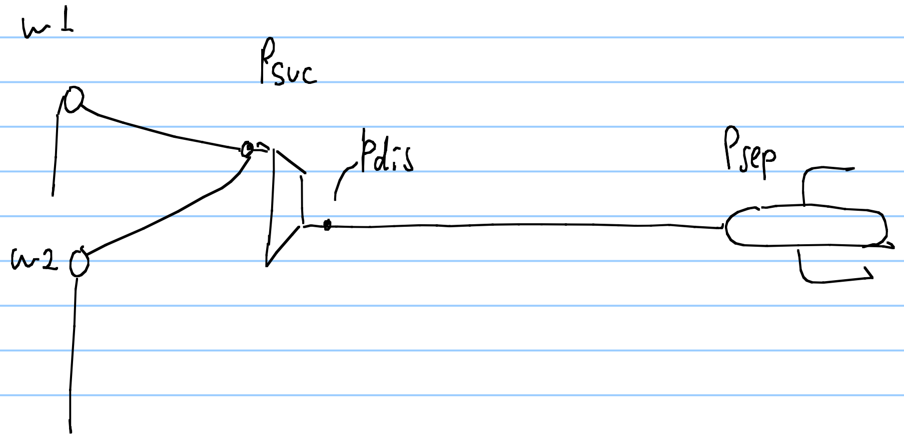
choke Δps to apply to get the desired rate

non-feasible rates

	IPR		Tubing		Flowline							
p_R	C	n	S	Ct	Cfl	psep	qg	pwf	pwh avail	pj	pwhreq	deltap choke
[bara]	[Sm^3/bar^2n]			[Sm^3/bar^2]	[Sm^3/bar^2]	[bara]	[Sm^3/d]	[bara]	[bara]	[bara]	[bara]	[bar]
120	52	0.8	0.13	7680	8673		80000	69	64		31	32
120	40	0.75	0.11	8600	7563		50000	31	28		31	-2
					14080	28.6	130000			30		
						total						

Compression:

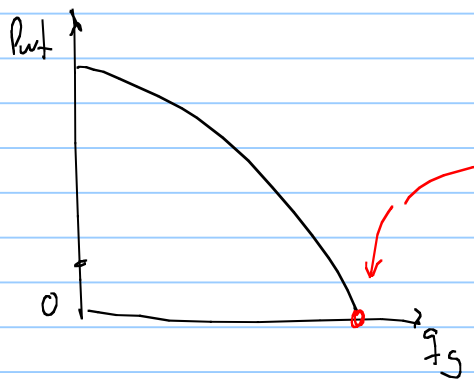
at a later stage (when $P_R = 40$ bars), you are evaluating to install a compressor in the system



fix the rate and estimate Δp comp.

what is the maximum rate that I can get?

		IPR		Tubing		Flowline			
Component Name	p_R	C	n	S	Ct	Cfl	psep	pwf	qg
	[bara]	[Sm^3/bar^2n]			[Sm^3/bar^2]	[Sm^3/bar^2]	[bara]	[bara]	[Sm^3/d]
W_1	40	52	0.8	0.13	7680	8673		0	19024
W_2	40	40	0.75	0.11	8600	7563		0	10119
Pipeline						14080	28.6		
							total		

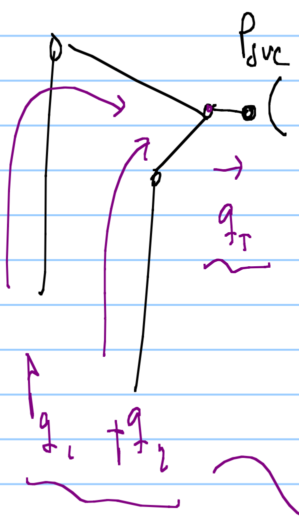


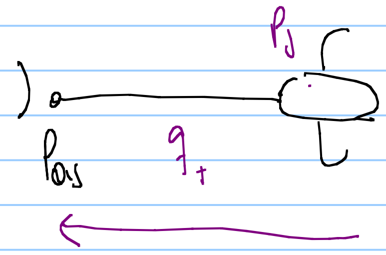
I want to produce 28000 Sm^3/d

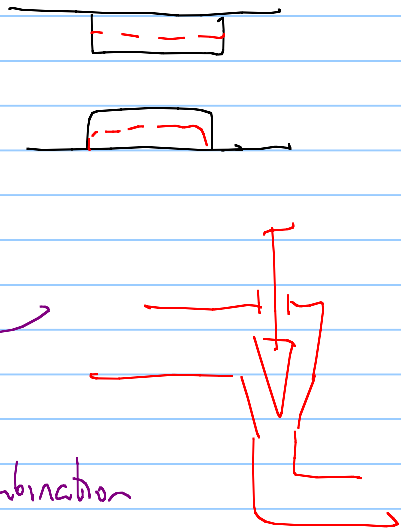
where is my equilibrium point?

open choke

bean choke, positive.







fixed rate

flow eq

unique q_1, q_2 combination

that gives $\underline{q_T}$

that gives $P_{s1} = P_{suc2}$

$$q_1 + q_2 = 28000 \ \mathrm{Sm^3/d}$$

q_1

$$q_2 = 28000 - q_1$$

	IPR		Tubing		Flowline						
p_R	C	n	S	Ct	Cfl	psep	qg	pwf	pwh	psuc	pdisc
[bara]	[Sm^3/bar^2n]			[Sm^3/bar^2]	[Sm^3/bar^2]	[bara]	[Sm^3/d]	[bara]	[bara]	[bara]	[bara]
40	52	0.8	0.13	7680	8673		18000	10	9	9	
40	40	0.75	0.11	8600	7563		10000	5	5	4	
					14080	28.6	2.80E+04				29

← need a compressor

$P_{os} \geq P_{suc1}, P_{suc2}$

counter-current.

IPR		Tubing		Flowline								
C	n	S	Ct	Cfl	psep	qg	pwf	pwh	psuc	error	pdisc	Deltapcomp
[Sm^3/bar^2n]			[Sm^3/bar^2]	[Sm^3/bar^2]	[bara]	[Sm^3/d]	[bara]	[bara]	[bara]	[bara^2]	[bara]	[bar]
52	0.8	0.13	7680	8673		18231	9	8	8	0.0		21
40	0.75	0.11	8600	7563		9769	9	8	8	0.0		
				14080	28.6	2.80E+04		pav	8		29	
									SUM=	2E-28		

use solver to change

to drive

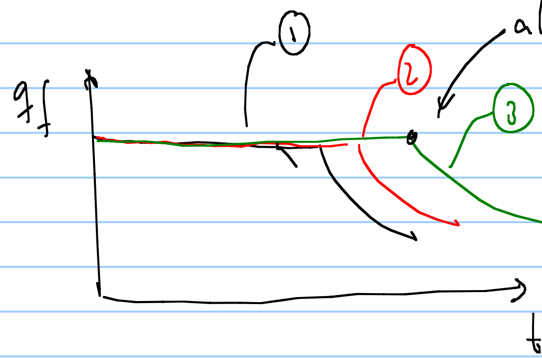
to zero

How to define well production scheduling? How to determine how much each well is going to produce with time?

Plateau mode (A)

depletion mode (B)

mode A? :

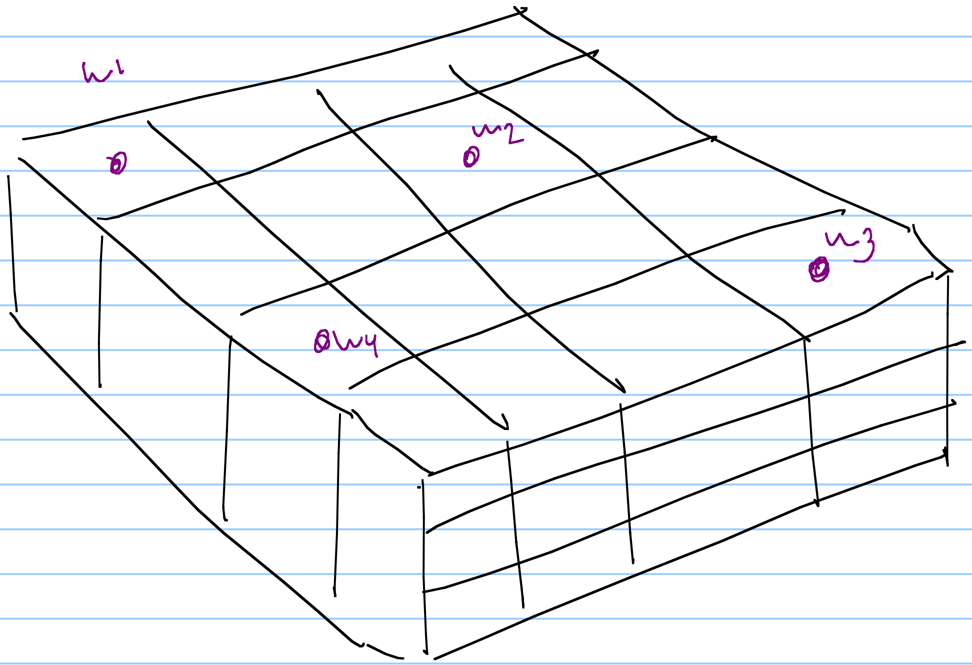


with different well offtake

all wells should have open choke at this point

- try for all wells to enter into decline at the same time (open choke).

from reservoir simulator side



in the reservoir simulator each well needs two inputs at the boundary

- $P_{wf\,min}$
- q_{RATE} ⤳ target rate

in every time step the reservoir simulator tries first with $P_{wf\,min}$ in the boundary ⤳ calculates a maximum rate

$$q_{max} = q^{i}_{POT}$$

⤷ open potential

- if $q_{max} > q_{RATE}$ then i produce q_{RATE}
- if $q_{max} < q_{RATE}$ the i produce q_{max}

the well potential is used to split the plateau rate between wells,

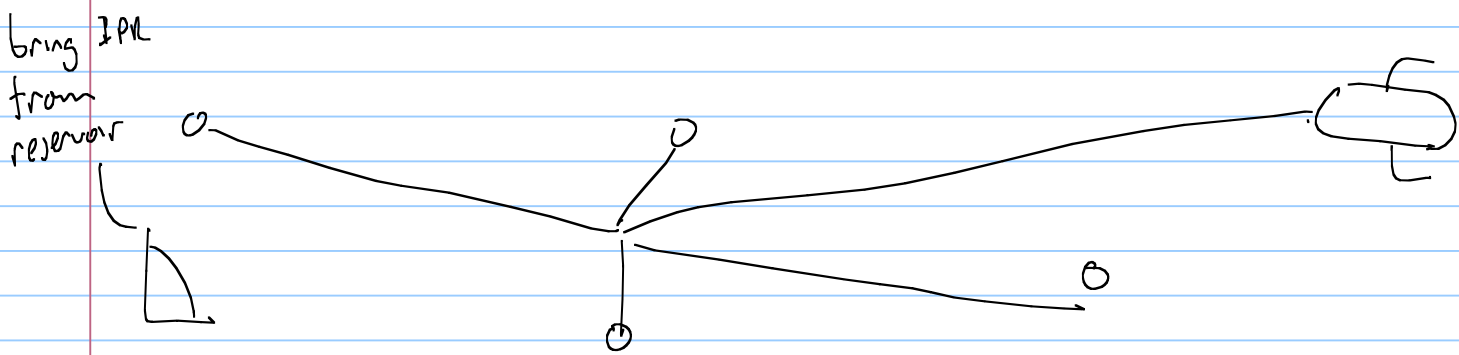
$$q_{F\,potential} = \sum_{i=1}^{\overset{\text{N wells}}{N}} q^i_{pot} \qquad X_i = \frac{q_{i\,pot}}{q_{F\,pot}}$$

$$q^i_{well} = q_{plateau} \cdot X_i$$

~> ∘ do at the beginning and never change

∘ calculate potential at every time step and calculate new well rates

Another proposal using the production network.



Calculate $\overbrace{\text{open choke}}^{oc}$ rates, q^i_{oc} $\qquad X_i^{prod} = \frac{q^i_{oc}}{\sum_{i=1}^{N} q^i_{oc}}$

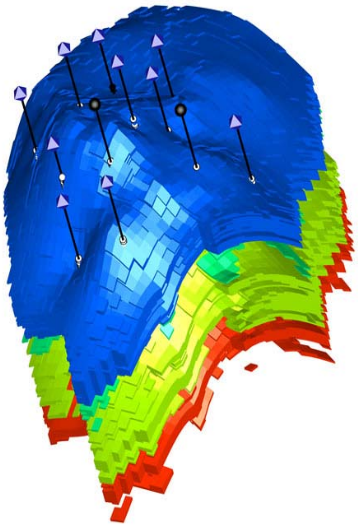
GAP (software for network simulation) is using this splitting method.

• Use model based optimization to define well production schedule

rate of each well with time

$q_i(t)$

input ⇒



⇒ run lifetime simulation

RF

Q_p

optimize

optimization engine

change

Resolve

IAM (slb)

Pipe-it

integrated asset modeling software

for mode B, depletion

↳ the rate that each well produces comes from flow equilibrium.. — however, some changes can be introduced to the system to

: produce as much as possible

GOR WC ↑ with time and can overload the processing facilities

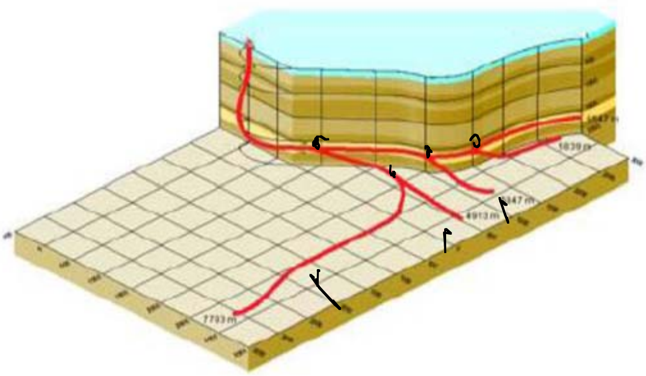
↳ decide to choke well that produce too much water or gas.

DOWNHOLE NETWORKS

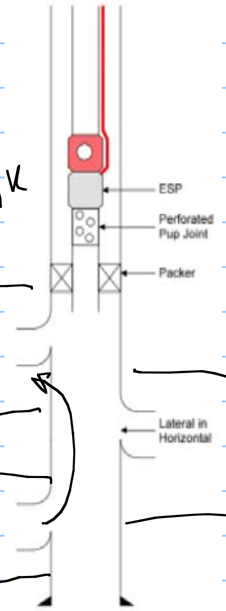
So far we have been dealing with surface networks.

We have another type of network

multi-branch



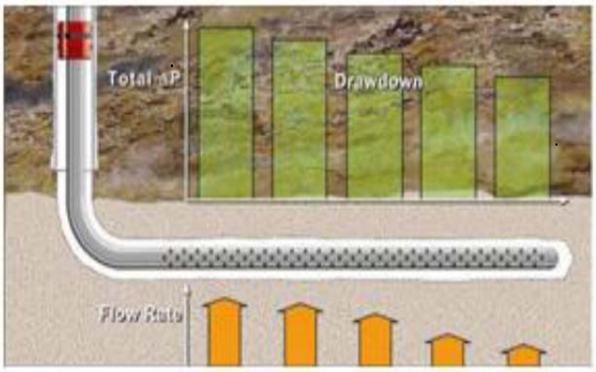
$\downarrow P_R \uparrow K$

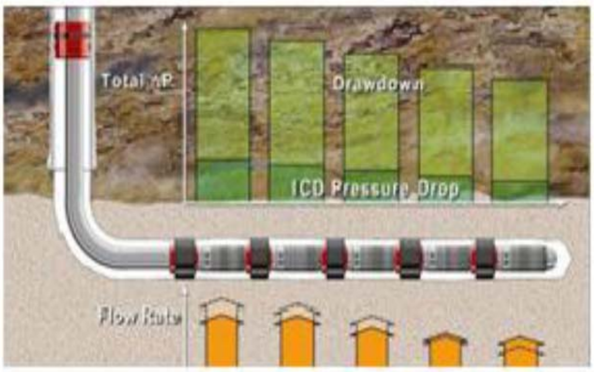


multi-layer

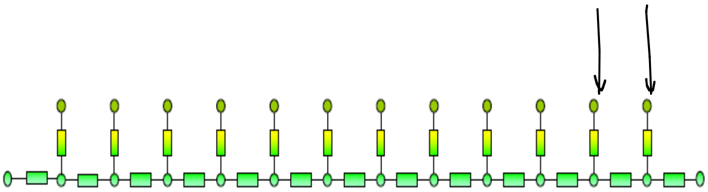
$\downarrow K \uparrow P_R$

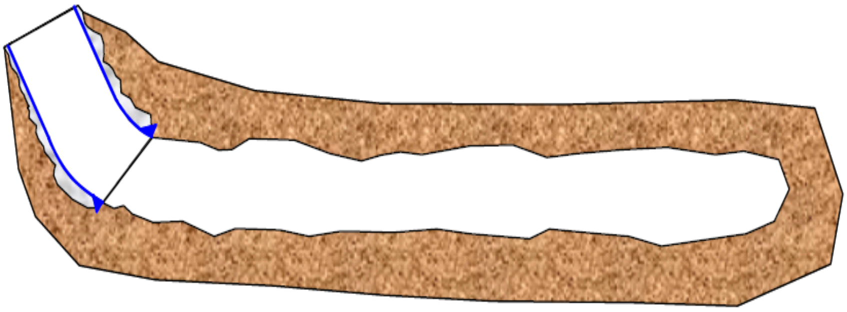
"You shall **not plow** with an ox and a **donkey together**.

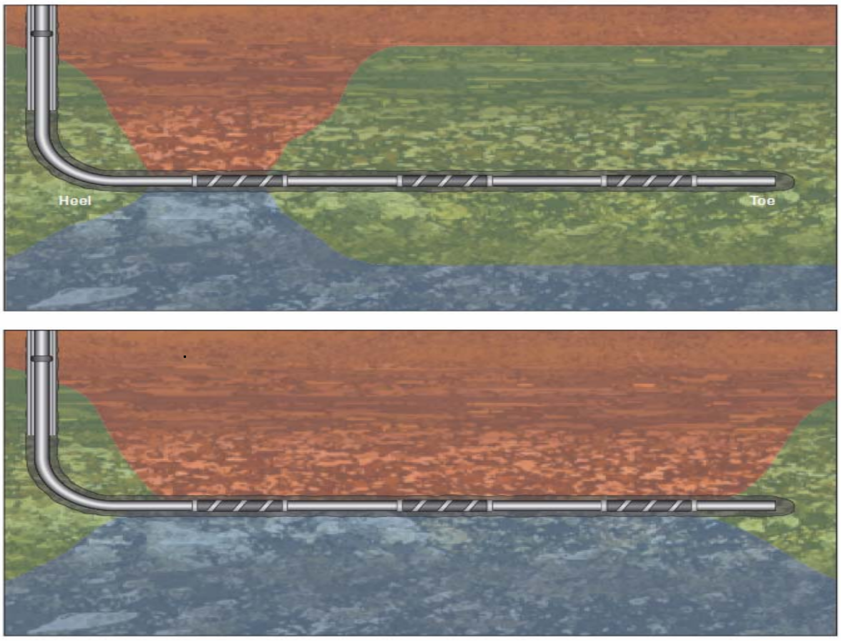




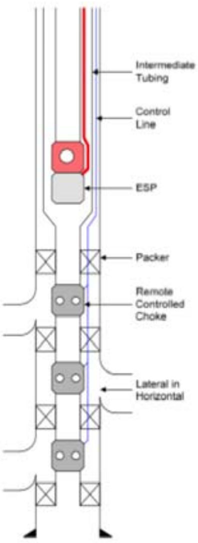
- ***Horizontal well with Open Hole completion***
  - ***Including damage zone***

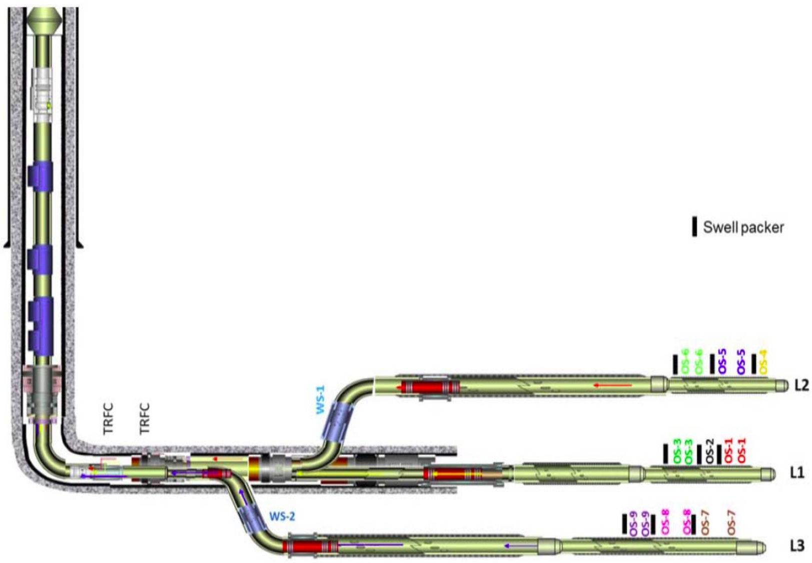






^ Heel-toe effect. Pressure losses along a horizontal wellbore in a homogeneous formation cause the flowing tubing pressure to be lower at the well's heel than at the toe. In time, and long before oil (green) from sections near the toe arrives at the wellbore, water (blue) or gas (red) is drawn to the heel (*top*), resulting in an early end to the well's productive life. Inflow control devices inside sand screen assemblies equalize the pressure drop along the entire length of the wellbore, promoting uniform flow of oil and gas through the formation (*bottom*) so that the arrivals of water and gas are delayed and simultaneous.

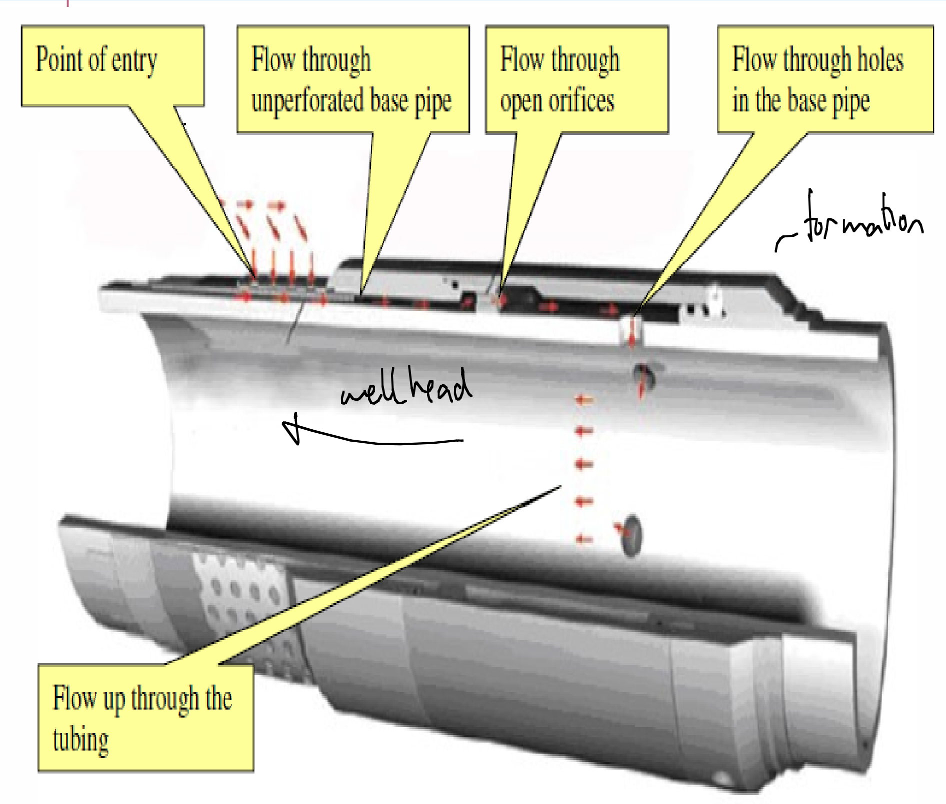




ICD inflow control device ~ passive ~> opening is fixed

ICV inflow control valve ~> active

Passive



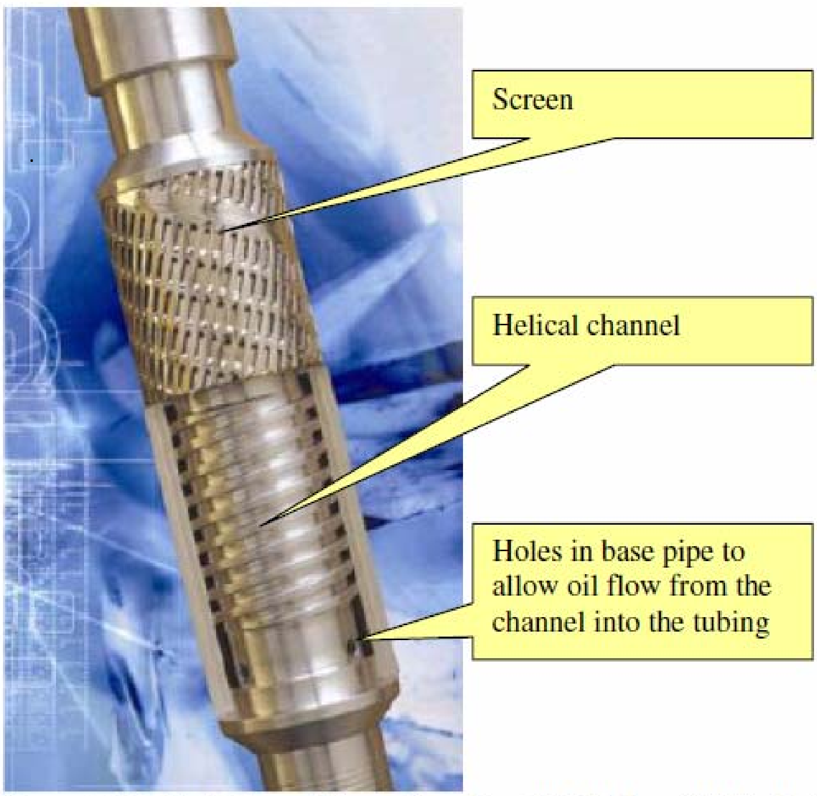
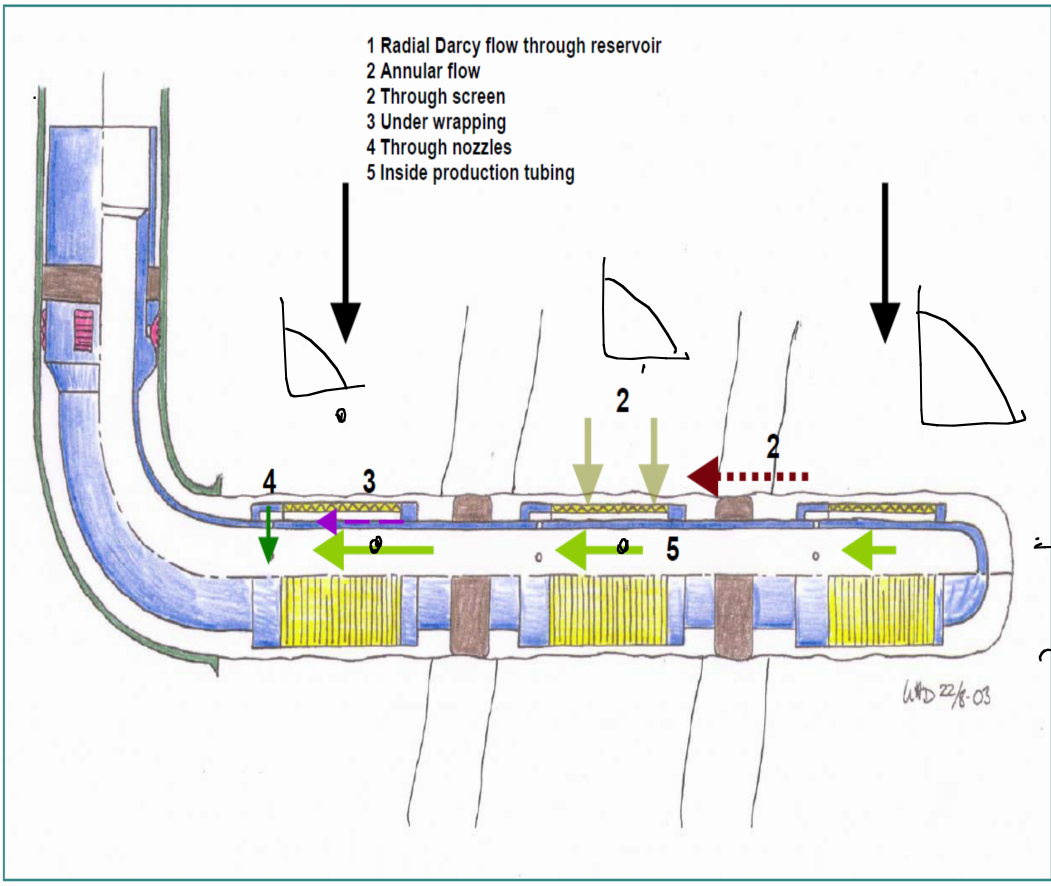
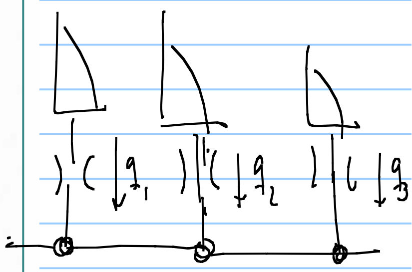


Figure 14 Helical channel type, EqualizerTM, Baker Oil Tools [22]



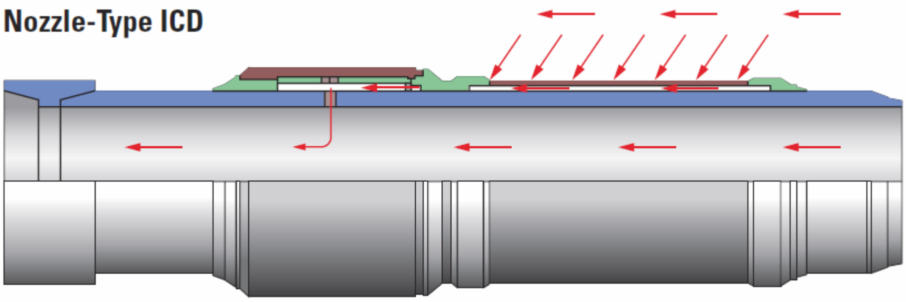


Net tool, landmark? weatherford.

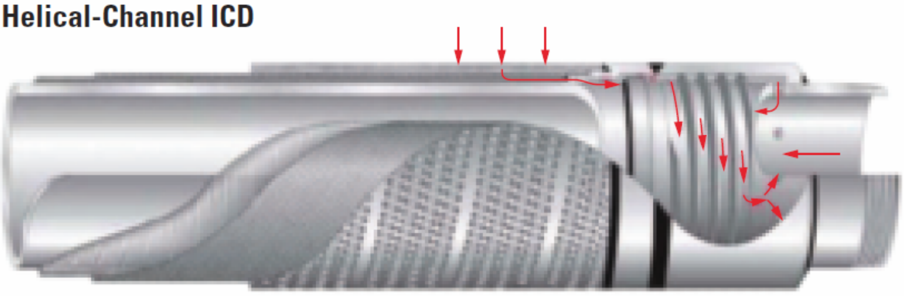
completion design.

Figure-8 Functioning and interplay of an ICD completion architecture. Fluids enter the screen and flow between the axial wires and the un-perforated base pipe into the ICD housing, before passing through the nozzles and entering into the base pipe. All these flow issues are properly analyzed and put in the right perspective to achieve an optimal well completion design and solution.

Nozzle-Type ICD

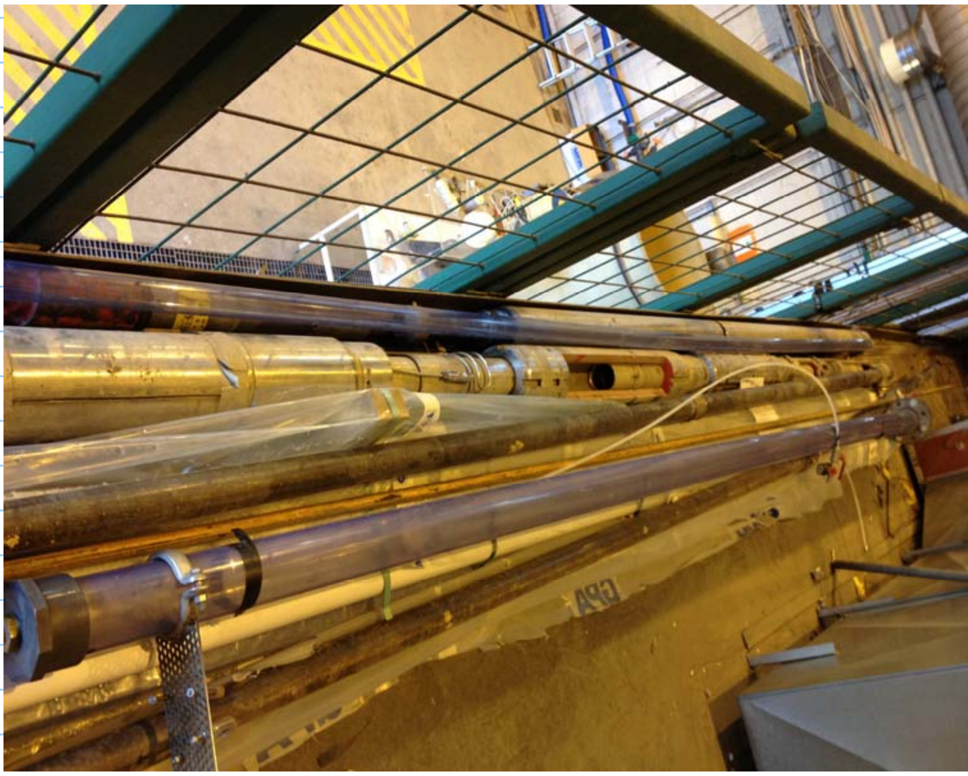


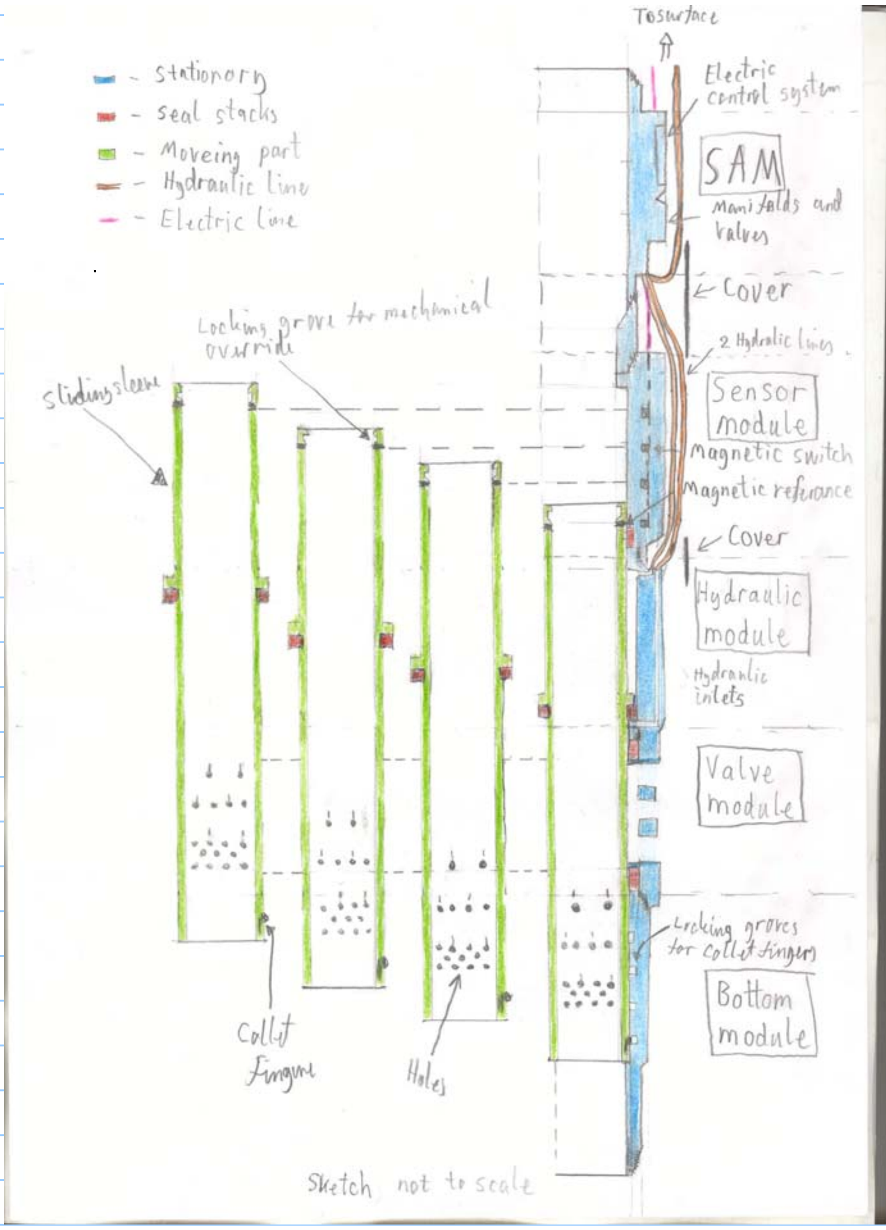
Helical-Channel ICD



^ Leading ICD types. Fluid from the formation (red arrows) flows through multiple screen layers mounted on an inner jacket, and along the annulus between the solid basepipe and the screens. It then enters the production tubing through a restriction in the case of nozzle- and orifice-based tools (*top*), or through a tortuous pathway in the case of helical- and tube-based devices (*bottom*).

active




To surface
- Stationary
- Seal stacks
- Moveing part
- Hydraulic line
- Electric line
Electric control system
SAM
Manifolds and valves
Cover
Locking grove for mechanical override
2 Hydralic lines
Sensor module
magnetic switch
magnetic reference
sliding sleeve
Cover
Hydraulic module
Hydraulic inlets
Valve module
Locking groves for collet fingers
Bottom module
Collet Fingers
Holes
Sketch not to scale

autonomous ⇝ self regulable I control device (ICD)

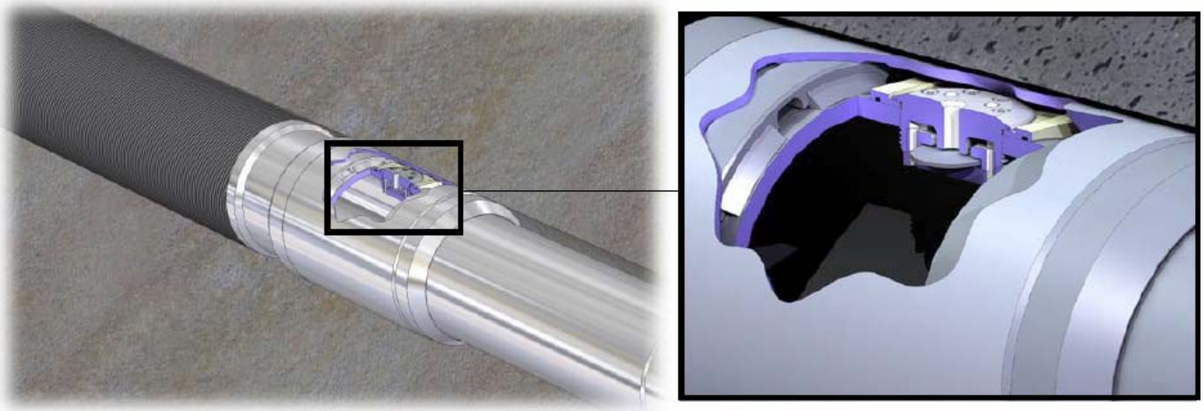


Figure 1: Statoil's RCP valve conneted to the base pipe in a sand screen joint in the well.

Figure 2: Statoil's RCP valve

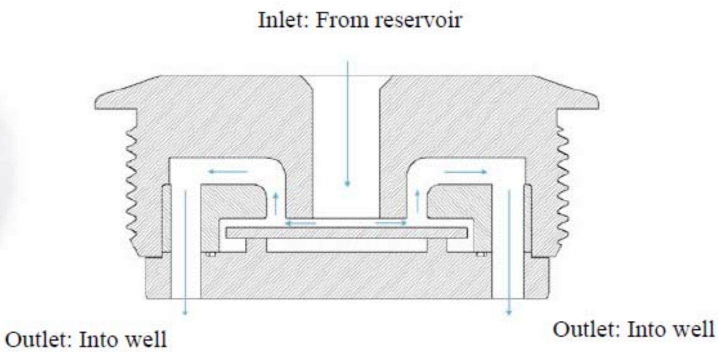


Figure 3: Schematic sketch of Statoil's RCP valve