TPG 4230 - 20160119

Note Title 19.01.2016

- Monday 25.01.2016 Prof. Michael Golan
- tuesday 26.01.2016 Dr. Mahmoud Etemaddar, Seven Marine

"Deep water field developments planning"

Summary of yesterday

- Expertise using excel: VOF, VBA, solver, linear interpolation in tables

table interpolator: excel solver doesn't work properly with this function

time [years]	qfield [sm^3/d]	Gp [sm^3]	qppf [sm^3/d]
0.0	2.00E+07	0	7.64E+07
0.5	2.00E+07	3.55E+09	7.53E+07
1.0	2.00E+07	7.10E+09	7.42E+07
1.5	2.00E+07	1.07E+10	7.29E+07
2.0	2.00E+07	1.42E+10	7.17E+07
2.5	2.00E+07	1.78E+10	7.04E+07
3.0	2.00E+07	2.13E+10	6.91E+07
3.5	2.00E+07	2.49E+10	6.78E+07
4.0	2.00E+07	2.84E+10	6.66E+07
4.5	2.00E+07	3.20E+10	6.54E+07
5.0	2.00E+07	3.55E+10	6.41E+07
5.5	2.00E+07	3.91E+10	6.29E+07
6.0	2.00E+07	4.26E+10	6.17E+07
6.5	2.00E+07	4.62E+10	6.05E+07
7.0	2.00E+07	4.97E+10	5.93E+07
7.5	2.00E+07	5.33E+10	5.82E+07
8.0	2.00E+07	5.68E+10	5.70E+07
8.5	2.00E+07	6.04E+10	5.58E+07
9.0	2.00E+07	6.39E+10	5.47E+07
9.5	2.00E+07	6.75E+10	5.36E+07
10.0	2.00E+07	7.10E+10	5.24E+07
10.5	2.00E+07	7.46E+10	5.13E+07
11.0	2.00E+07	7.81E+10	5.02E+07
11.5	2.00E+07	8.17E+10	4.91E+07
12.0	2.00E+07	8.52E+10	4.80E+07
12.5	2.00E+07	8.88E+10	4.69E+07
13.0	2.00E+07	9.23E+10	4.58E+07
13.5	2.00E+07	9.59E+10	4.47E+07
14.0	2.00E+07	9.94E+10	4.37E+07
14.5	2.00E+07	1.03E+11	4.26E+07
15.0	2.00E+07	1.07E+11	4.15E+07
15.5	2.00E+07	1.10E+11	4.05E+07
16.0	2.00E+07	1.14E+11	3.94E+07
16.5	2.00E+07	1.17E+11	3.84E+07
17.0	2.00E+07	1.21E+11	3.73E+07
17.5	2.00E+07	1.24E+11	3.63E+07
18.0	2.00E+07	1.28E+11	3.52E+07
18.5	2.00E+07	1.31E+11	3.42E+07
19.0	2.00E+07	1.35E+11	3.31E+07
19.5	2.00E+07	1.38E+11	3.21E+07
20.0	2.00E+07	1.42E+11	3.11E+07
20.5	2.00E+07	1.46E+11	3.00E+07
21.0	2.00E+07	1.49E+11	2.90E+07
21.5	2.00E+07	1.53E+11	2.79E+07
22.0	2.00E+07	1.56E+11	2.69E+07
22.5	2.00E+07	1.60E+11	2.59E+07
23.0	2.00E+07	1.63E+11	2.48E+07
23.5	2.00E+07	1.67E+11	2.38E+07
24.0	2.00E+07	1.70E+11	2.27E+07
24.5	2.00E+07	1.74E+11	2.17E+07
25.0	2.00E+07	1.78E+11	2.06E+07
eau 25.291	2.00E+07	1.80E+11	2.00E+07
26.0	1.85E+07	1.85E+11	1.85E+07

Error 1.38778E-17 20000000 18487362

table interpolator

linear interpolator

- Calculation of the production profile: sequential
  - choose a timestep
  - decide how I want to produce { mode a, mode b
  - for current G_p^i → q_{pp} (linear interpolation) { if mode a $q_{pp} > q_{pla}$; if mode b $q_f = q_{pp}$
  - rectangle method: constant production
  - G_p^{i+1}

- Two examples: open chance, plateau mode.

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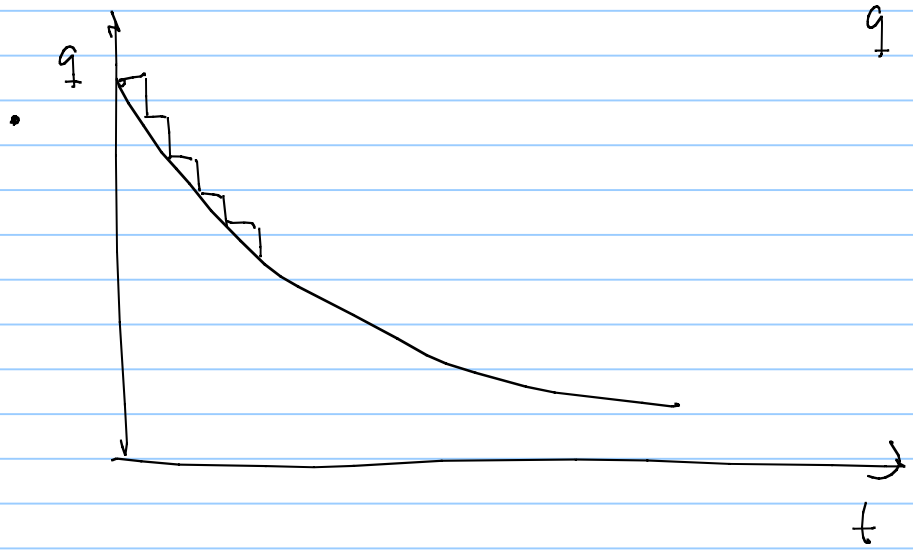
- Calculation of production profile
- Exercise 1 - clarification
- Architecture of the production system



Producing with open choke, calculate q_f vs. t using sequential calculations and trapezoidal integration

- Name of variable, symbol, units
- plots: font size big enough 16-18, Bold thickness of line

Red: Input (user given input)

Blue: Result of a calculation

Violet: constants

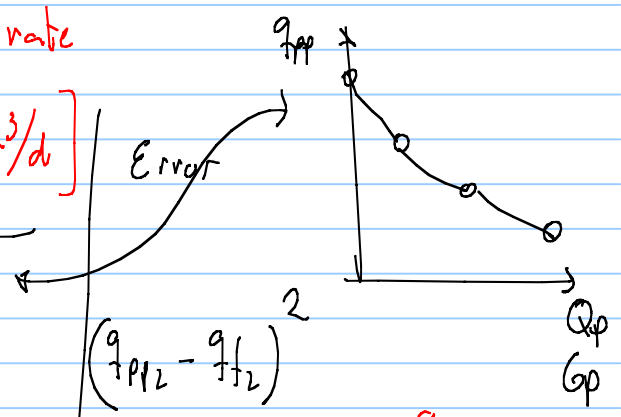
excel etiquette

Using the trapezoidal method to calculate cumulative production

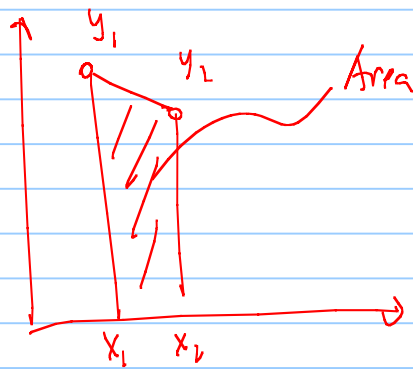
time [y]	q_f [Sm^3/d]	G_p [Sm^3]	q_{fpp} [Sm^3/d]
t_1 0	q_{fpp_1}	0	q_{fpp_1}
t_2 0.5	$q_{fpp_1} \cdot 0.9$	$\frac{(q_{f_1}+q_{f_2})(t_2-t_1)}{2}$, Nds/year	q_{fpp_2}
1			
1.5			
2			
2.5			
⋮			

open choke rate

Error $\left(q_{fpp_2} - q_{f_2}\right)^2$

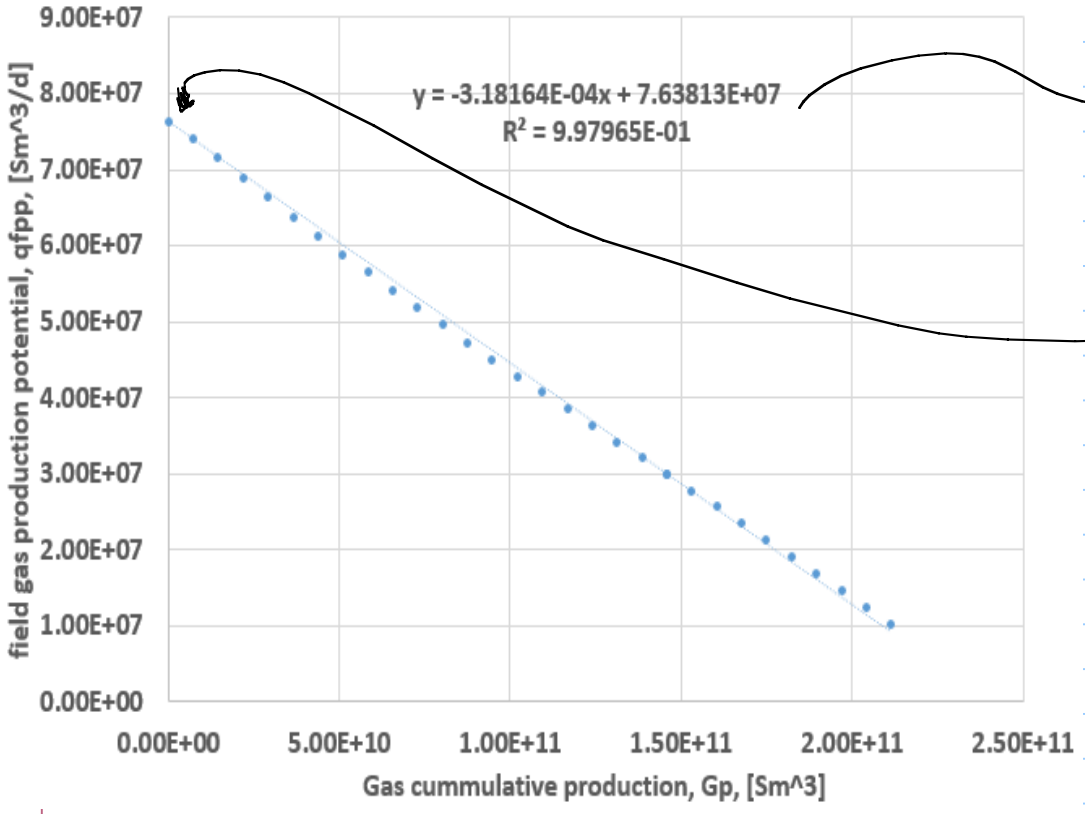


Assume $q_{f_2} = q_{fpp_1} \cdot 0.9$



$$\text{Area} = \frac{(y_1+y_2)(x_2-x_1)}{2} = \frac{(q_1+q_2)(t_2-t_1)}{2}$$

$Sm^3/d \left(\frac{365d}{1year}\right)$ years



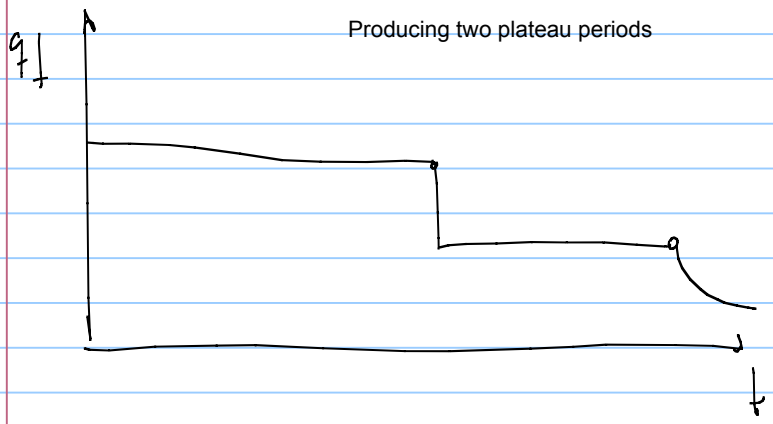
$q_{fpp} = -m \cdot Gp + q_{fpp0}$

```
Sub test()
    For i = 8 To 69
        SolverReset
        OBJSTRING = "$J$" & (i)
        VARSTRING = "$H$" & (i)
        SolverOk SetCell:=Range(OBJSTRING), MaxMinVal:=3, valueof:="1e-10", ByChange:=VARSTRING
        SolverSolve UserFinish:=True
    Next
    'Reading Results
End Sub
```

value of

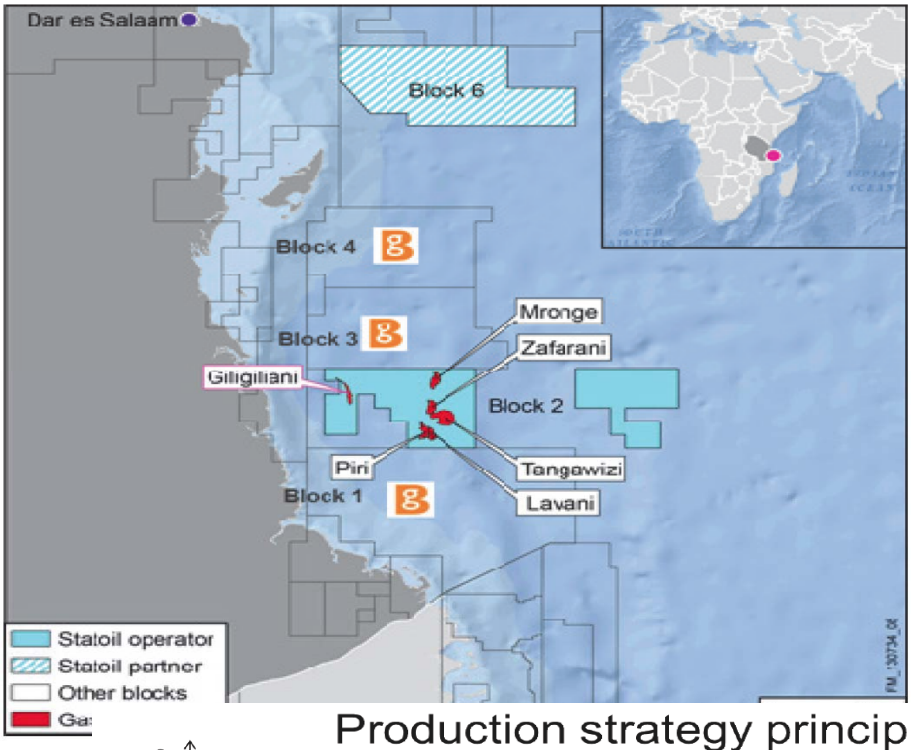
set of instructions

time	qf	Gp	qfpp	error
[year]	[Sm^3/d]	[Sm^3]	[Sm^3/d]	
0.0	7.64E+07	0	7.64E+07	
0.5	7.22E+07	1.32E+10	7.22E+07	0
1.0	6.82E+07	2.56E+10	6.82E+07	0
1.5	6.45E+07	3.74E+10	6.45E+07	0
2.0	6.09E+07	4.86E+10	6.09E+07	0
2.5	5.76E+07	5.91E+10	5.76E+07	0
3.0	5.44E+07	6.90E+10	5.44E+07	5.55112E-17
3.5	5.14E+07	7.84E+10	5.14E+07	0
4.0	4.86E+07	8.73E+10	4.86E+07	0
4.5	4.59E+07	9.57E+10	4.59E+07	5.55112E-17
5.0	4.34E+07	1.04E+11	4.34E+07	0
5.5	4.10E+07	1.11E+11	4.10E+07	0
6.0	3.88E+07	1.18E+11	3.88E+07	5.55112E-17
6.5	3.66E+07	1.25E+11	3.66E+07	0



Tanzania gas development – flow assurance challenges

H Holm
Statoil ASA, Norway



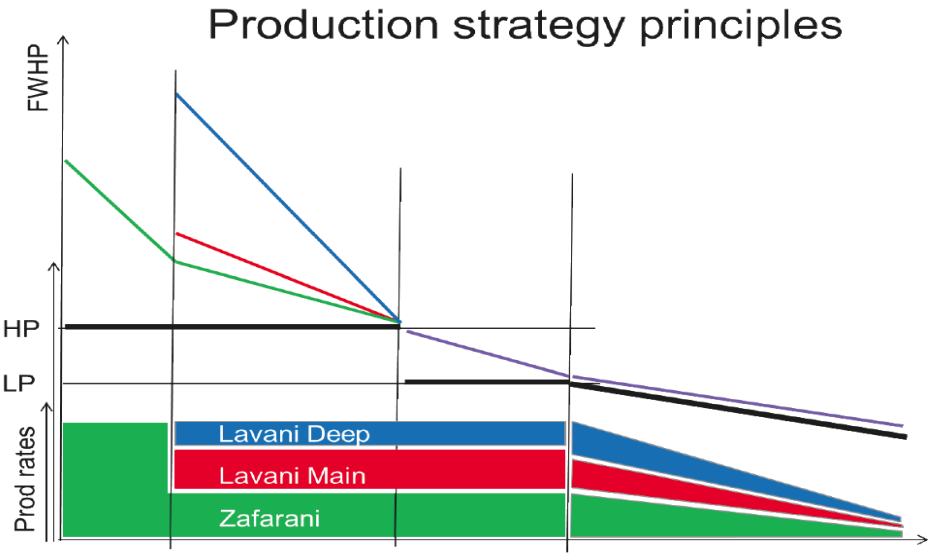
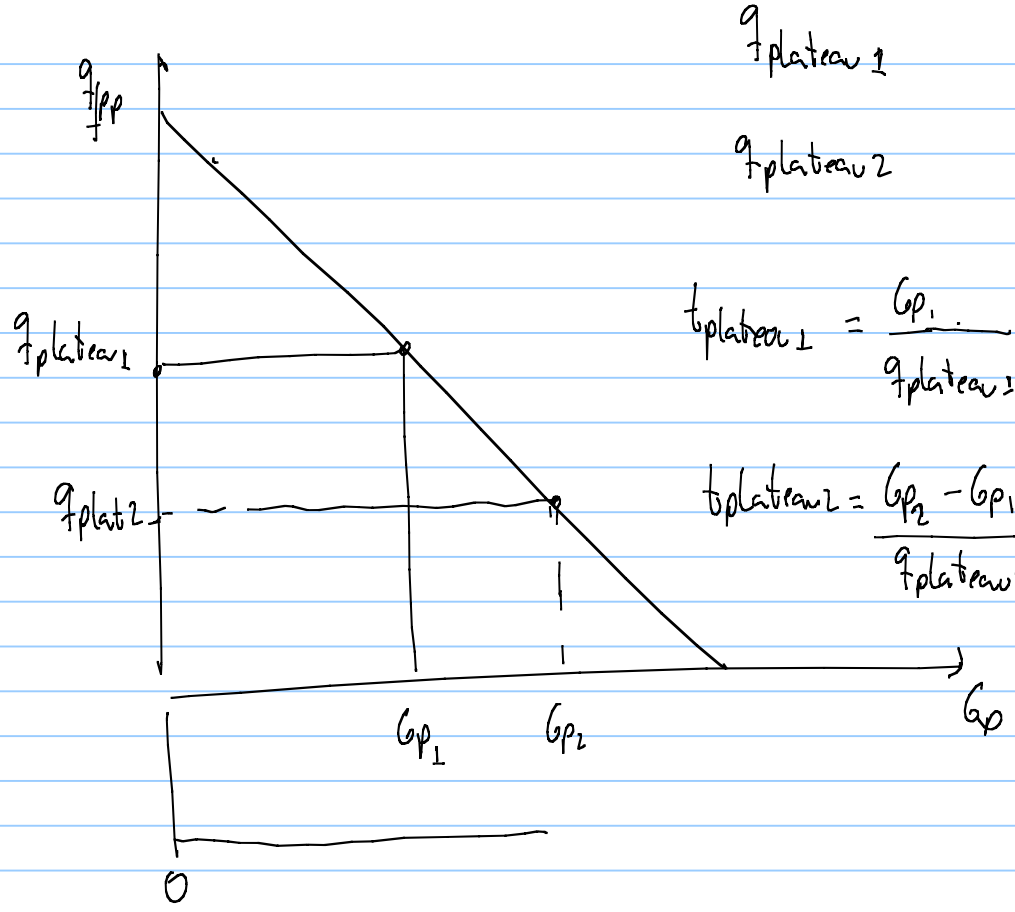


Figure 9 Production strategy inhomogeneous reservoirs



$$t_{plateau\,1} = \frac{G_{p_1}}{q_{plateau\,1}}$$

$$t_{plateau\,2} = \frac{G_{p_2} - G_{p_1}}{q_{plateau\,2}}$$

Calculating production profile analytically

$$Q_p(t) = \int_0^t q\, dt$$

producing all the time at open choke.

$$q = q_{pp}$$

$$Q_p(t) = \int_0^t q_{pp}\, dt$$

$$\begin{cases} q_{pp} = -m\, G_p + q_{pp_0} \\ G_p = \frac{-q_{pp} + q_{pp_0}}{m} \end{cases}$$

q_{pp_0} → production potential at initial conditions

$$\frac{q_{pp_0} - q_{pp}}{m} = \int q_{pp}\, dt$$

$$q_{pp_0} - q_{pp} = \int m\, q_{pp}\, dt \qquad \frac{d}{dt}$$

$$-\frac{dq_{pp}}{dt} = m\, q_{pp}$$

→ Snowhite example

It might actually look different for other cases

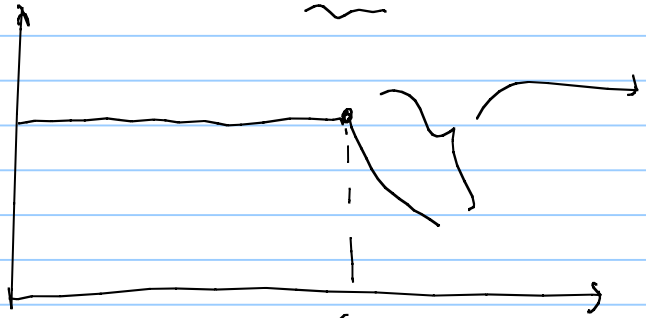
$$\int_{q_{ppo}}^{q_{pp}(t)} \frac{dq_{pp}}{q_{pp}} = \int_0^t -m\,dt$$

$$\ln\left(q_{pp}\right)\Big|_{q_{ppo}}^{q_{pp}(t)} = -m(t-0)$$

$$\ln\left(\frac{q_{pp}(t)}{q_{ppo}}\right) = -m(t-0)$$

$-m(t-0)$ $\quad$ $G_p = 0$

$$q_{pp}(t) = q_{ppo} \cdot e$$



for this period, use $q_{pp}(t) = q^*_{ppo}\, e^{-m(t-t^*)}$

with * values at plateau end.

G_p → @ end of the plateau

Decline curve analysis ~

$$q(t) = q_i / e^{\left\{D_i / \left[1 - \left(p_{wf}/\overline{p}_R\right)\right]\right\} t}$$

TABLE 1—SUMMARY OF PRODUCTION DECLINE EQUATIONS

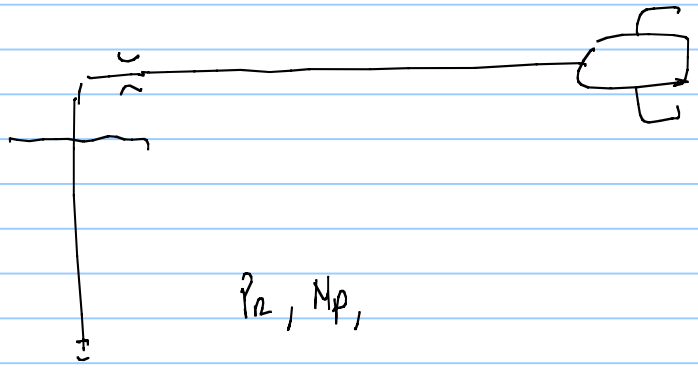
Decline Type	Hyperbolic	Exponential	Harmonic
Rate–Time	$q(t) = q_i/\left(1 + bD_i t\right)^{1/b}$	$q(t) = q_i/e^{D_i t}$	$q(t) = q_i/\left(1 + D_i t\right)$

DECLINE CURVE ANALYSIS USING TYPE CURVES

by

M. J. Fetkovich
SPE, Phillips Petroleum Co.

How do we calculated the production potential

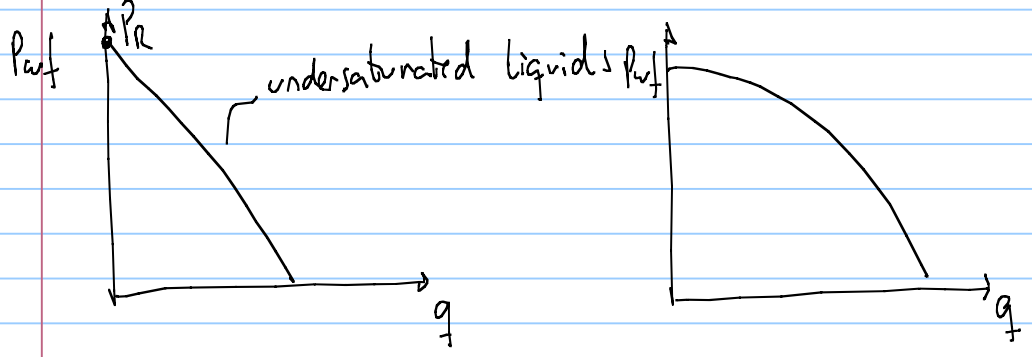


P_R, N_p,

IPR

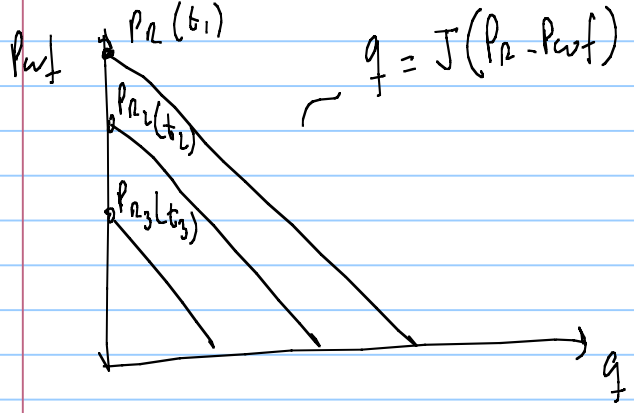
↳ hydraulic equilibrium in the production system with open choke. calculate the rate.

↳ production simulators
- Pipesim
- GAP

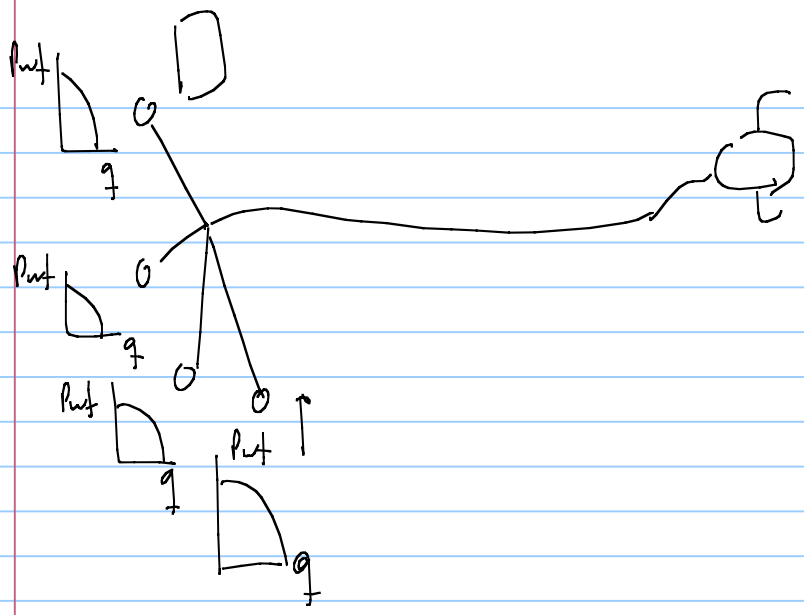


$q_f = f(P_R - P_{wf})$

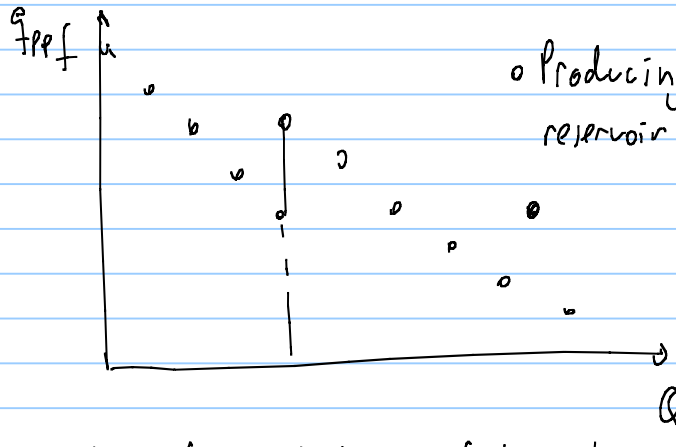
IPR: pseudo-steady state representation of the deliverability of the reservoir at a given P_R, N_p,



$q_f = J(P_R - P_{wf})$

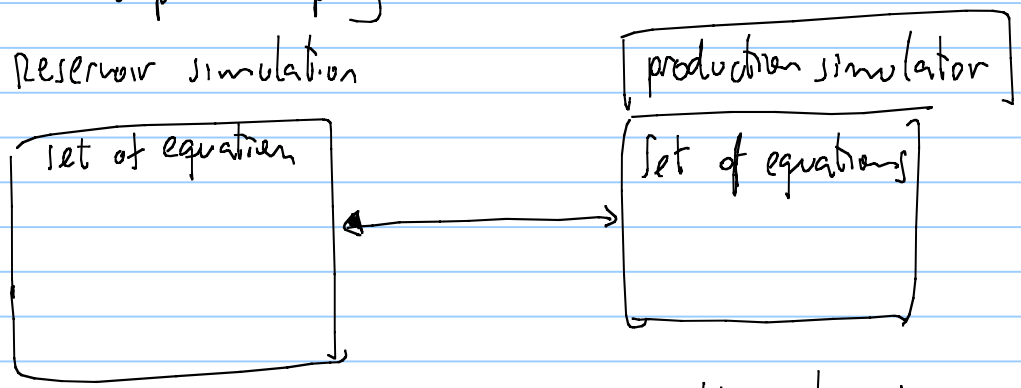


- Some complexities to calculate the production potential
  - IPR changes with depletion
  - GOR, WC of each well changes with depletion
  - Changes in the production system
    - adding new wells
    - add boosters
    - add Artificial lift
  - Producing from different reservoir units



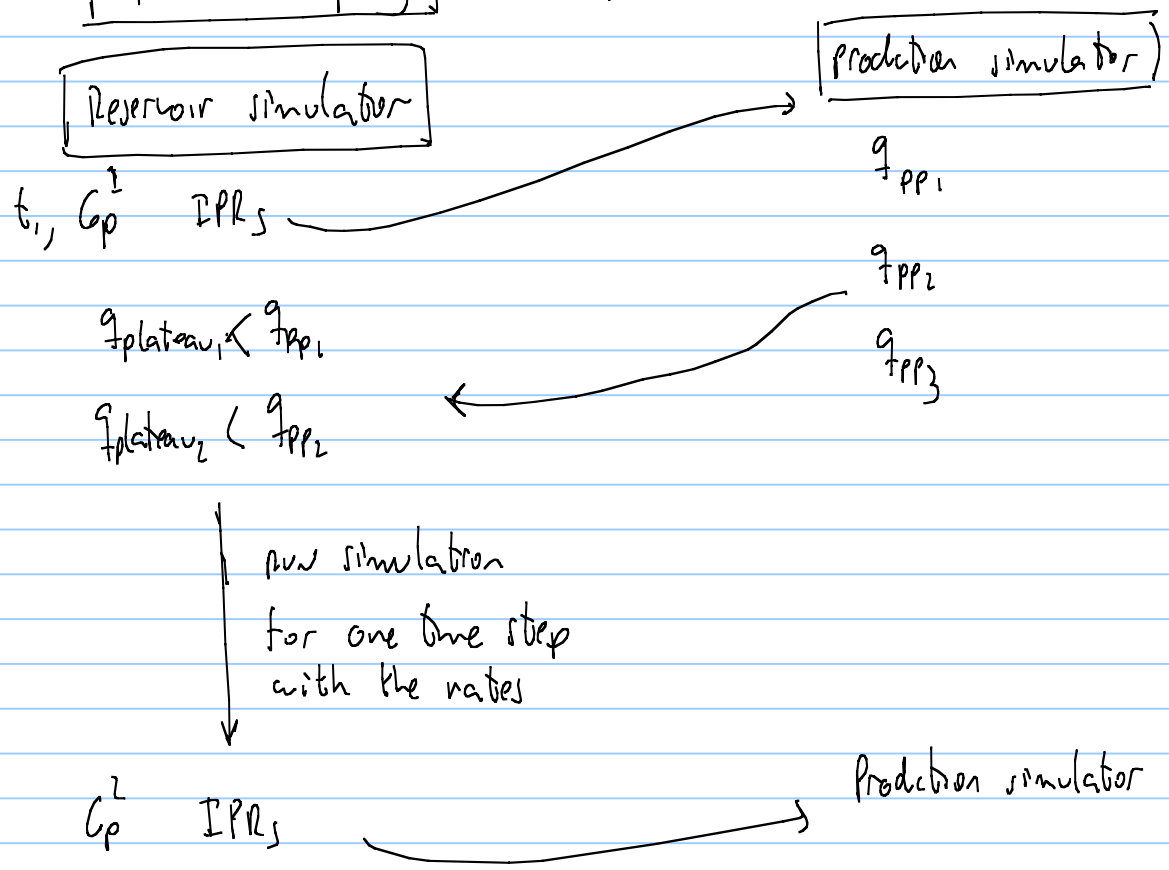
Usually, for calculating field performance we use:

- Coupled models reservoir + production system
  - implicit coupling



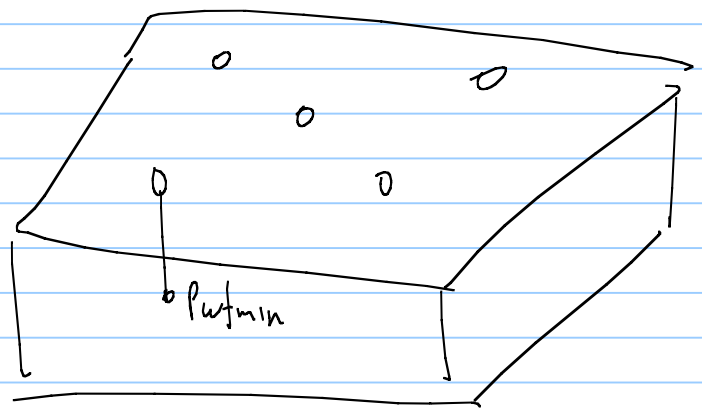
solve all equations simultaneously, time consuming, not very practical

Explicit coupling to compute field performance.

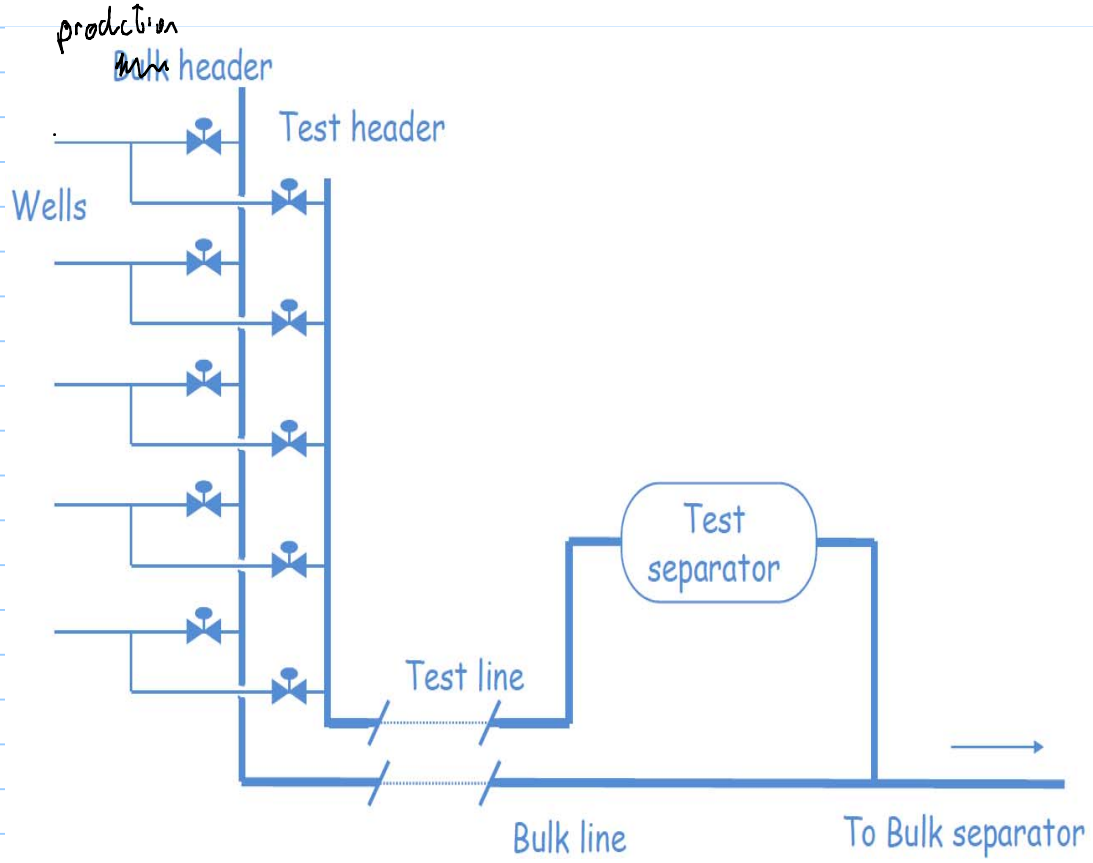


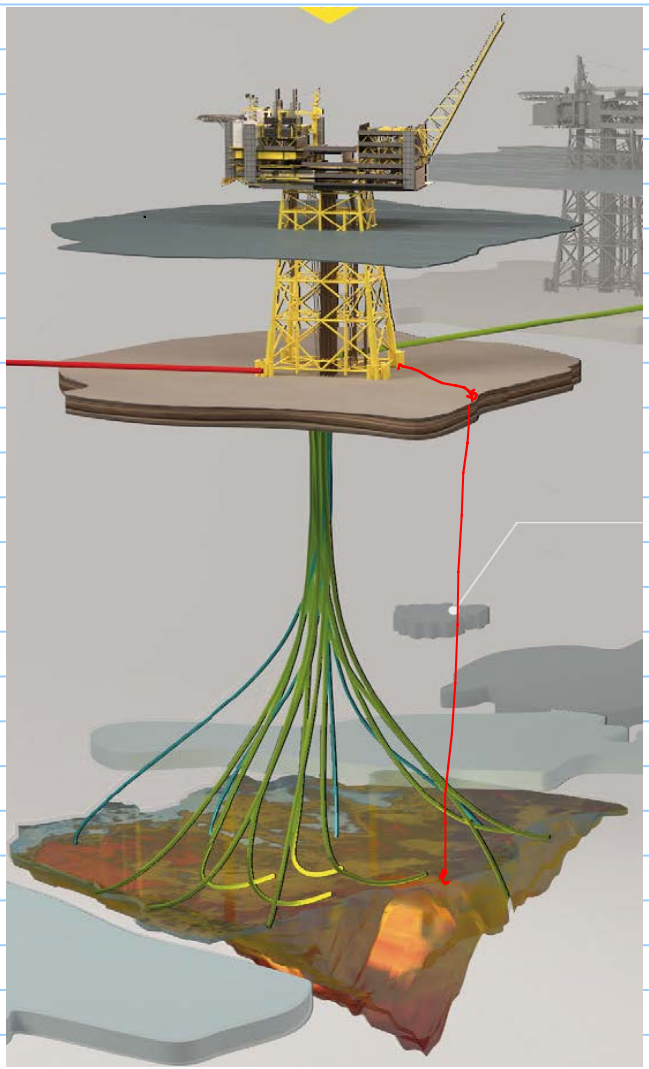
Very often the reservoir simulator is used standalone, with a minimum flowing bottomhole pressure to represent network backpressure

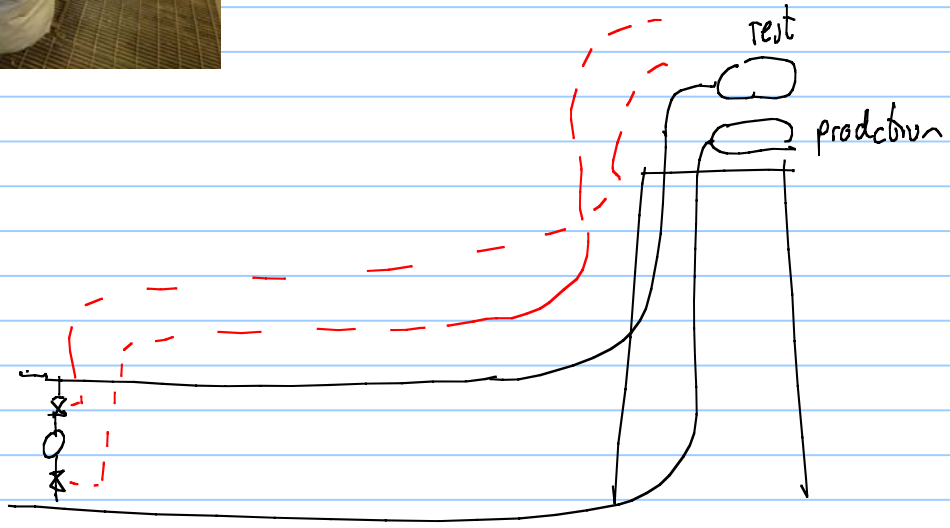
this is not always an accurate representation of the production system (well, pipeline, flowline, sep).



architecture of production systems

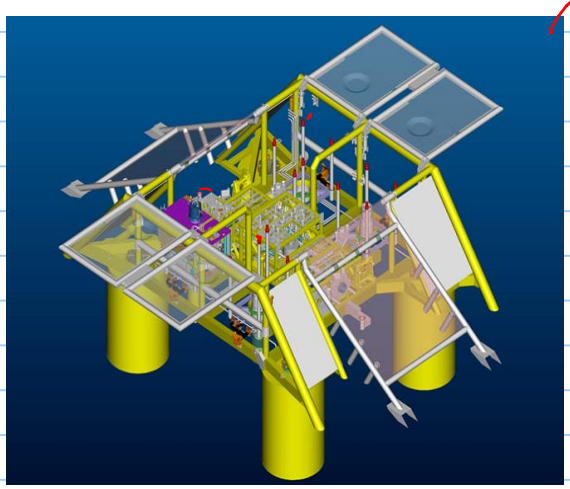


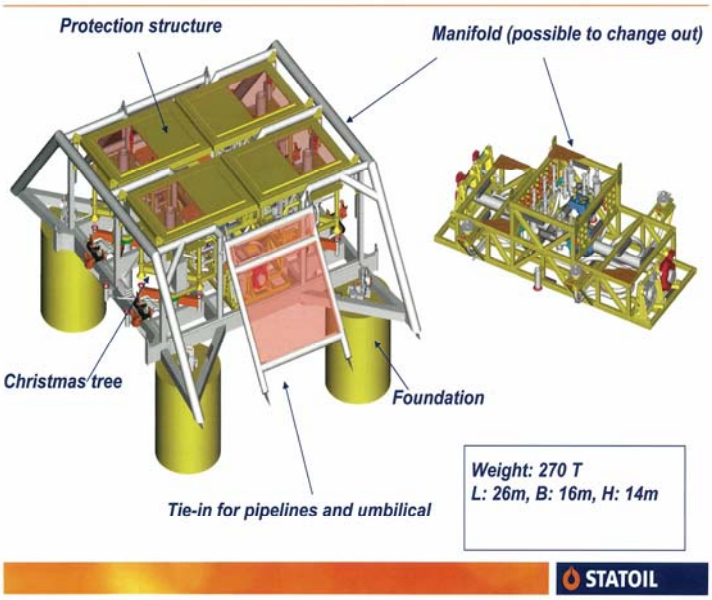


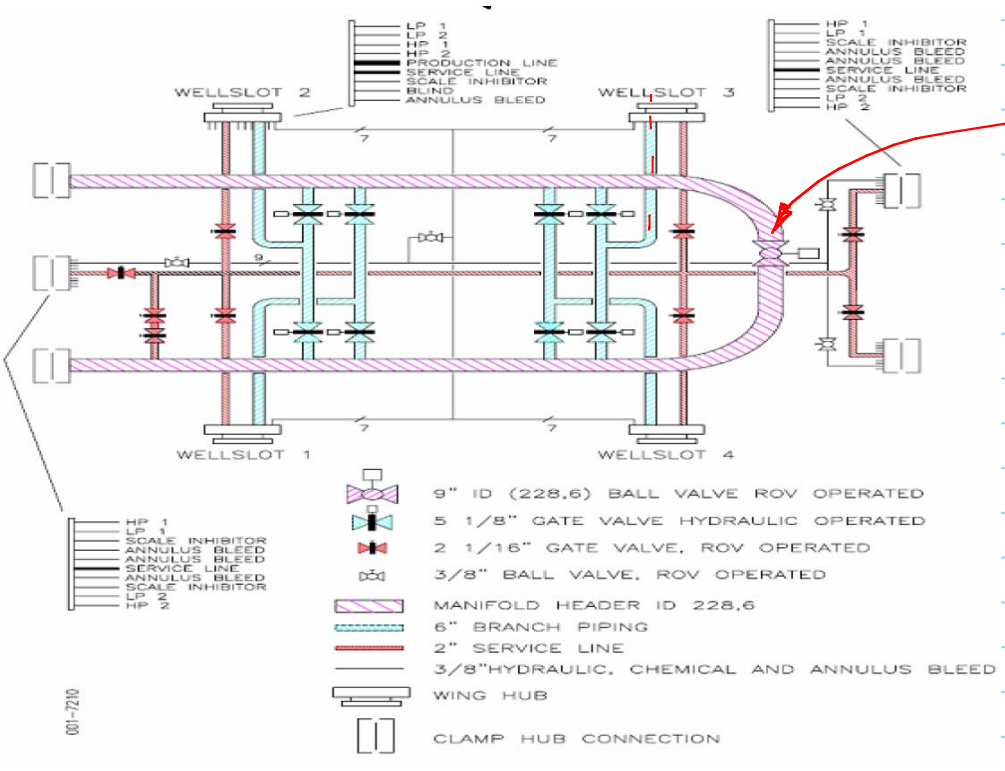


template

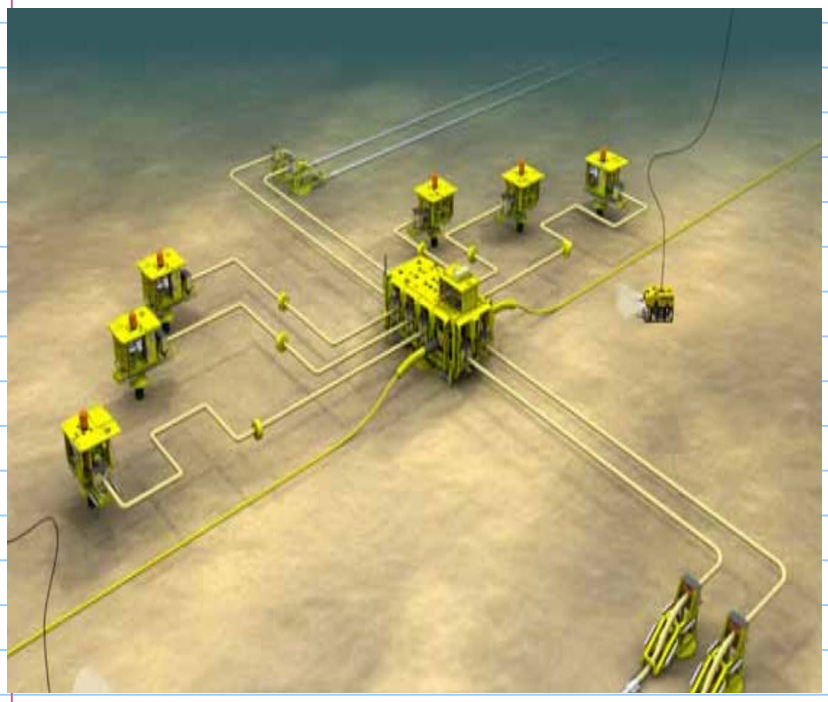
→ stabil 3/4

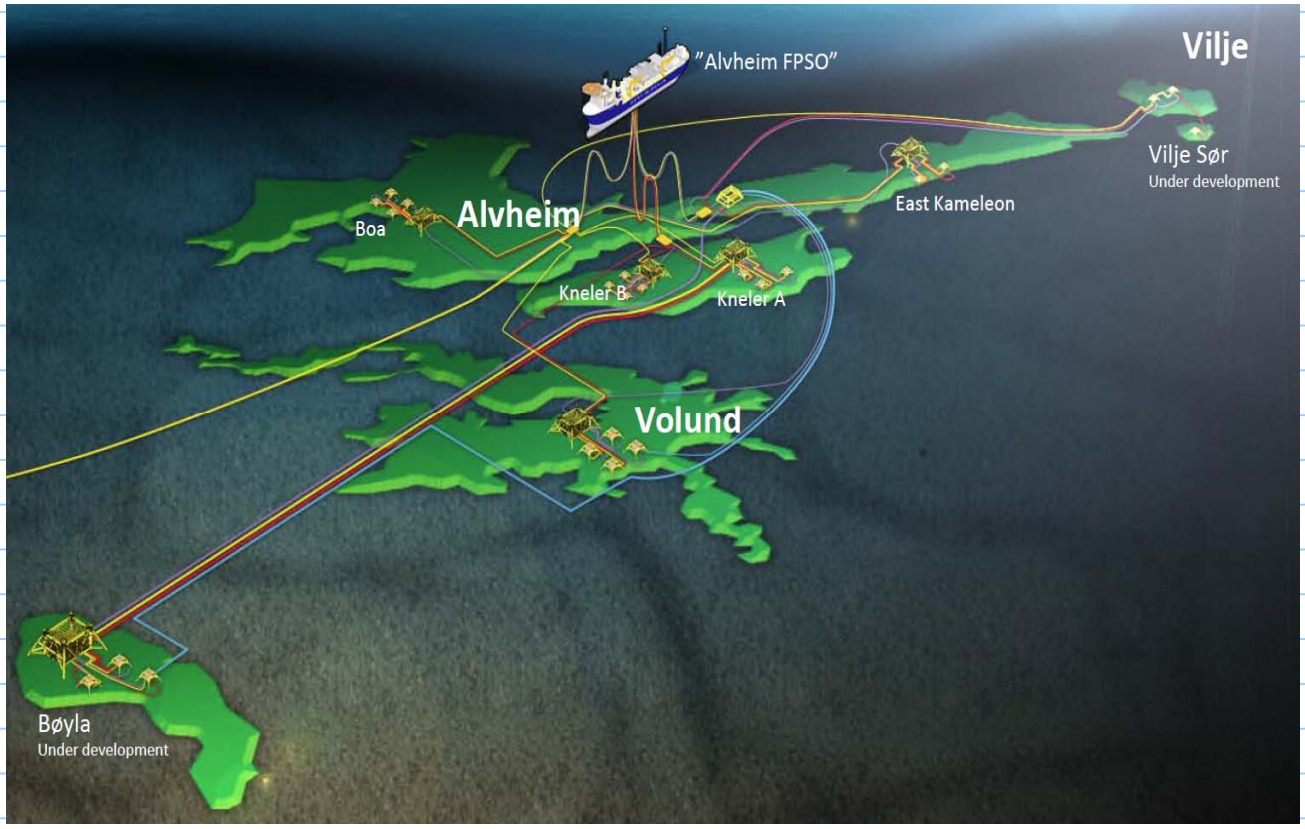



Protection structure
Manifold (possible to change out)
Christmas tree
Foundation
Tie-in for pipelines and umbilical
Weight: 270 T
L: 26m, B: 16m, H: 14m
STATOIL


WELLSLOT 2
WELLSLOT 3
WELLSLOT 1
WELLSLOT 4
LP 1
LP 2
HP 1
HP 2
PRODUCTION LINE
SERVICE LINE
SCALE INHIBITOR
BLIND
ANNULUS BLEED
HP 1
LP 1
SCALE INHIBITOR
ANNULUS BLEED
ANNULUS BLEED
SERVICE LINE
ANNULUS BLEED
SCALE INHIBITOR
LP 2
HP 2
crossover valve
9" ID (228.6) BALL VALVE ROV OPERATED
5 1/8" GATE VALVE HYDRAULIC OPERATED
2 1/16" GATE VALVE, ROV OPERATED
3/8" BALL VALVE, ROV OPERATED
MANIFOLD HEADER ID 228.6
6" BRANCH PIPING
2" SERVICE LINE
3/8"HYDRAULIC, CHEMICAL AND ANNULUS BLEED
WING HUB
CLAMP HUB CONNECTION
001-7210

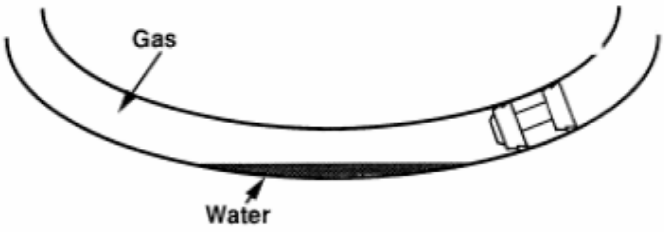
satellite wells



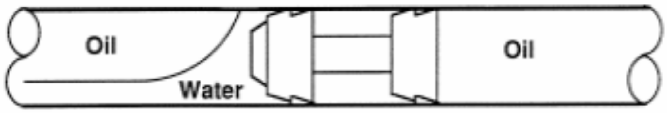


function of test and production line : for pigging operations.

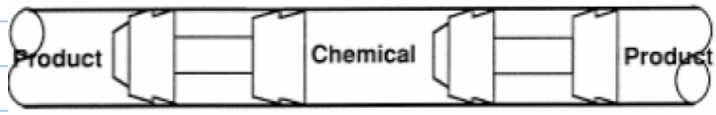
Removing water in a gas flow system



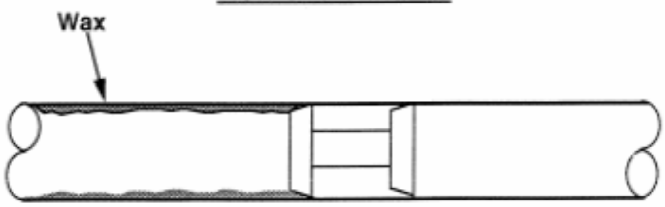
Removing water in a oil system

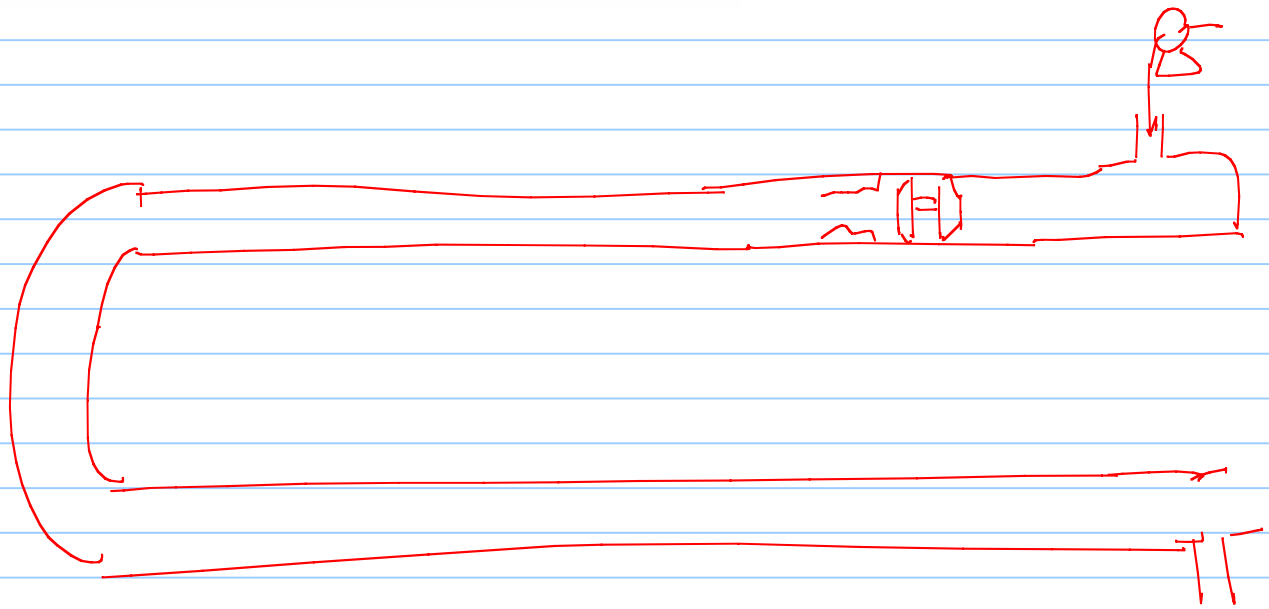


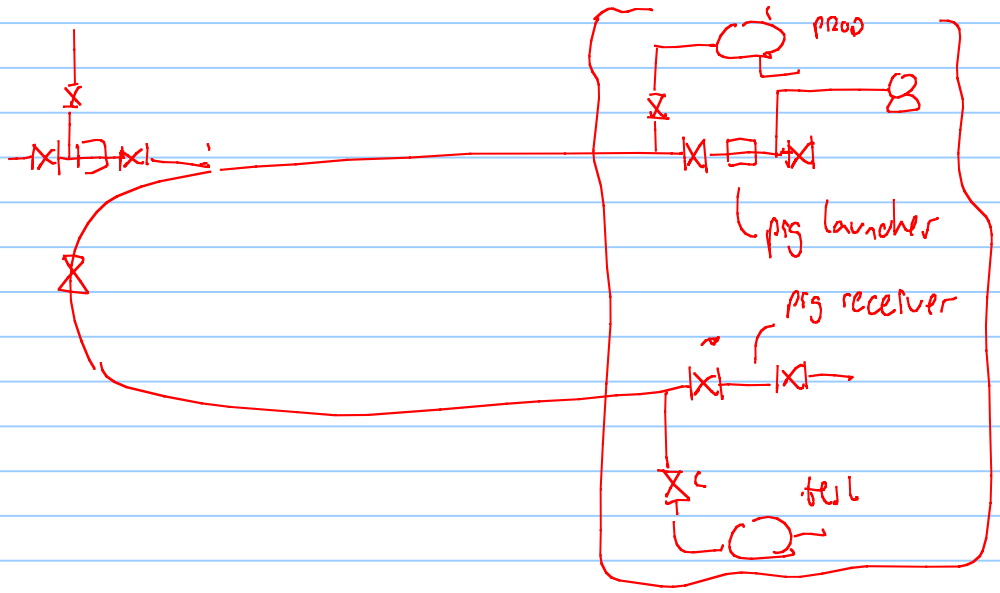
Treating by chemicals



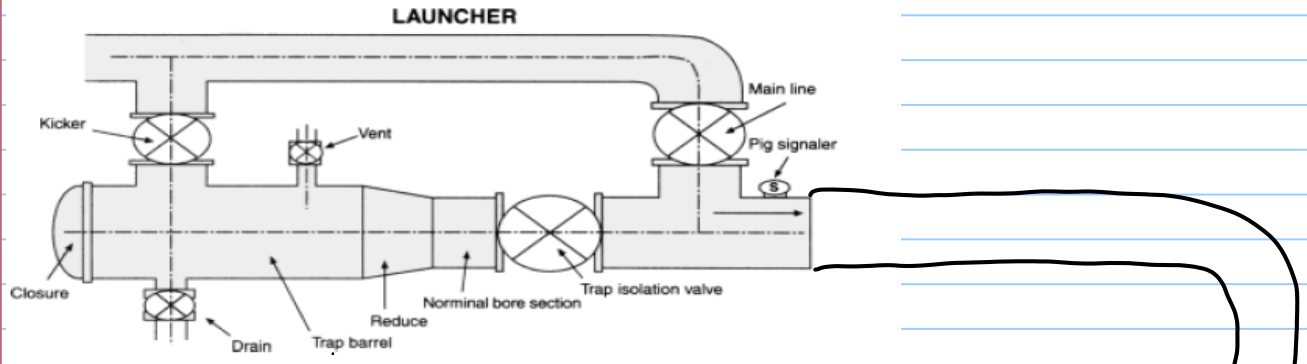
Removal of Wax

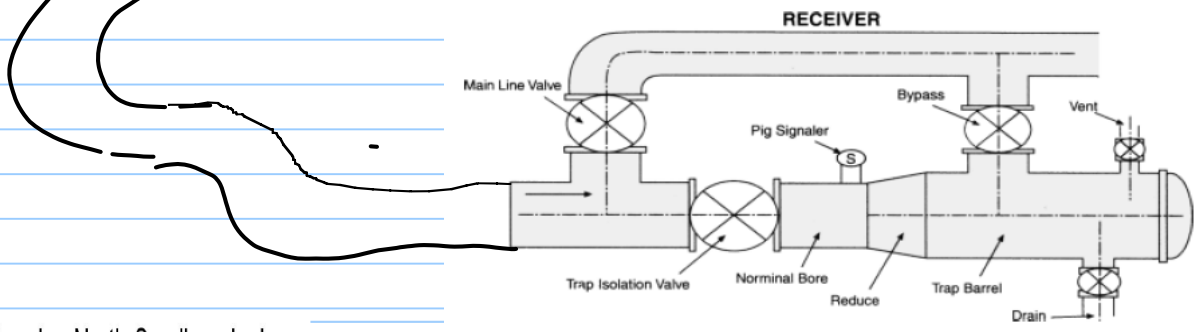






Pigging animation: https://www.youtube.com/watch?v=CDHtL-J1Xxo

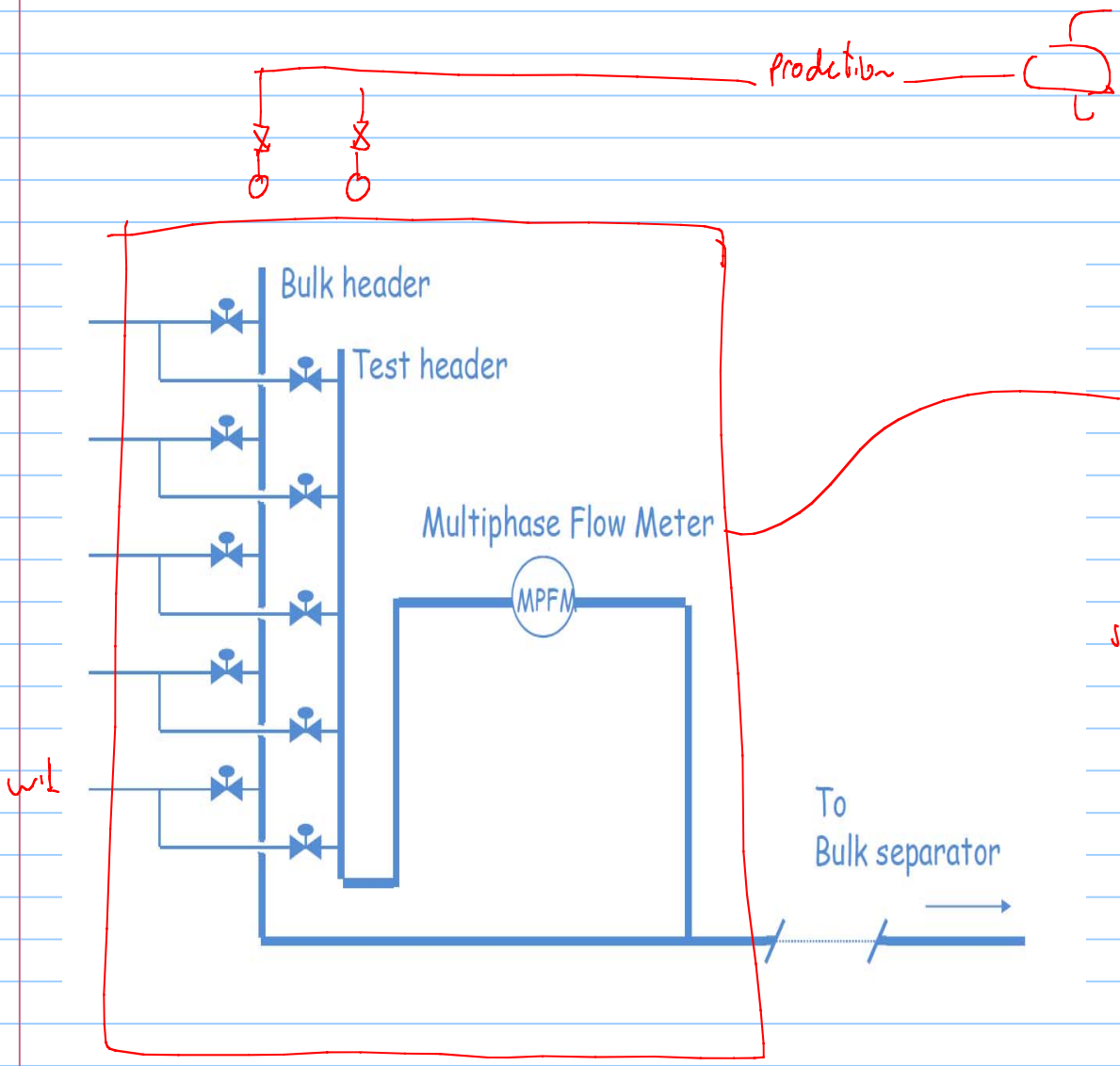




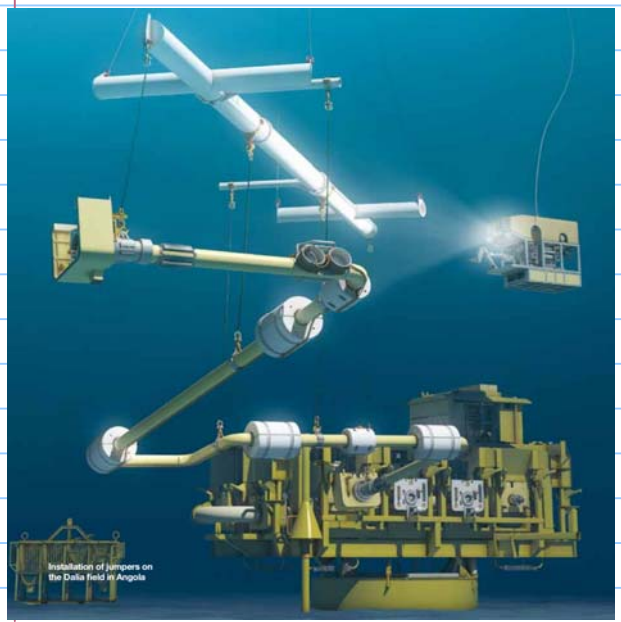
Wax plug-North Sea line pigging

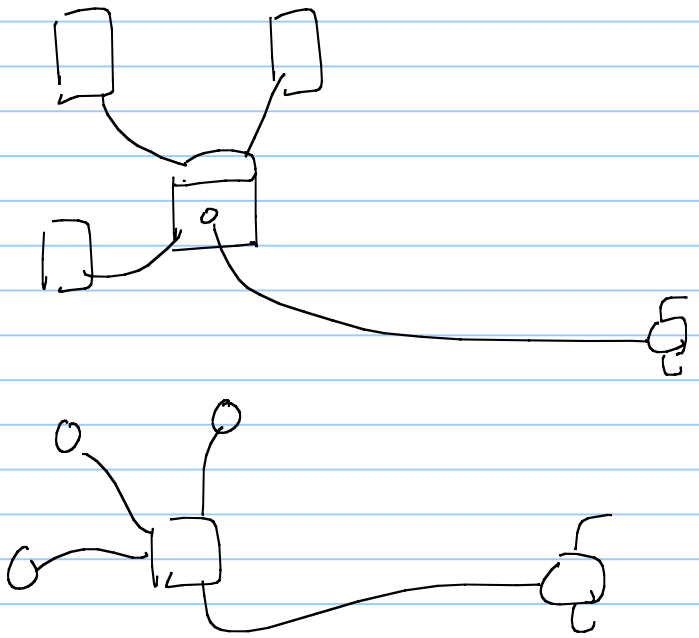
Various pig types

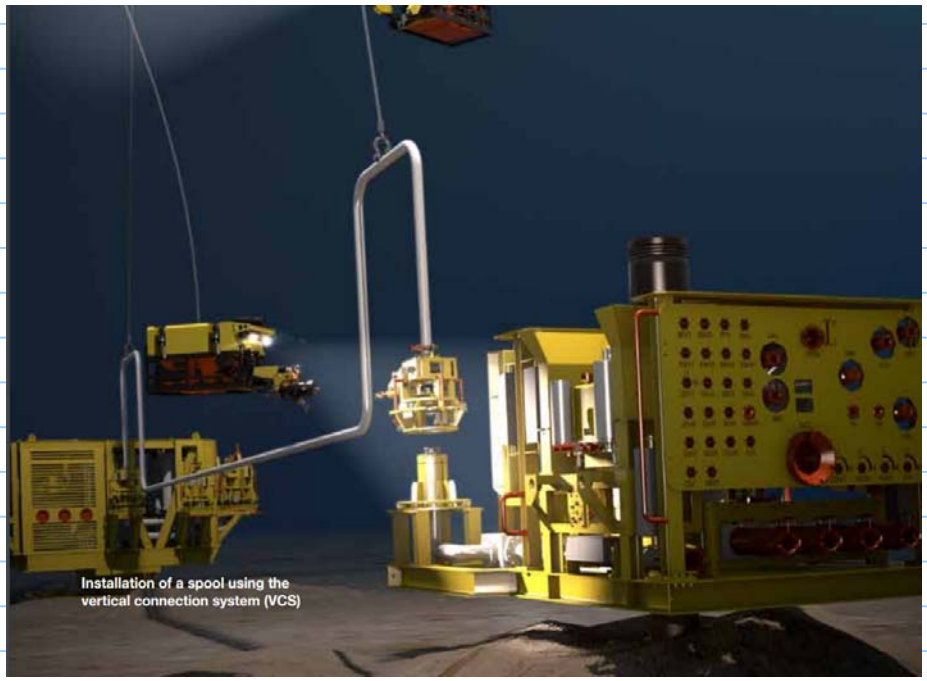
offshore pigging offshore pig launcher.



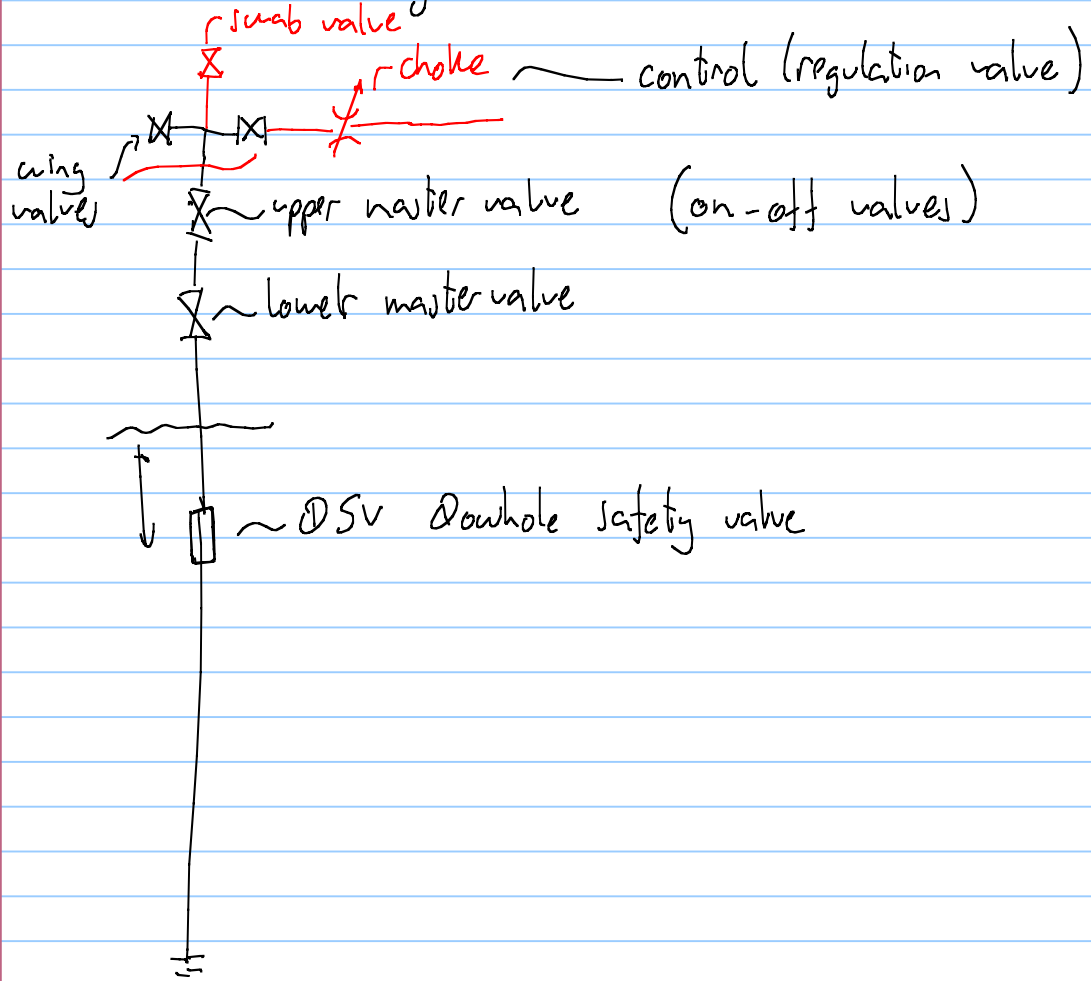
Connectors between well template, satellite well to manifold







main valves that you have in a well



SSSV subsurface safety valve.