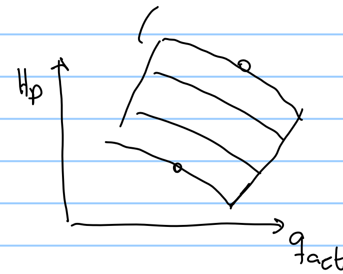
- more discussion on exercise set 3.
- class exercise P, T with multiphase flow.

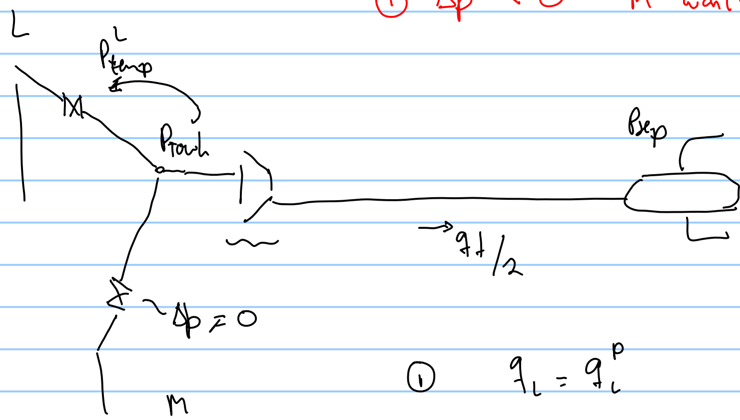


Problem 1 - Task 3 → operational map H_p, $q_{s\,actual}$ ✓

→ $T_{max,dis} = 120\ °C$ ✓

→ Power ≤ 12 MW ✓

① $\Delta p^{M} < 0$ M wants to enter in decline



① $q_L = q_L^{p}$

$q_M = q_M^{p}$

② $P_R^{L} \rightarrow P_{wh}^{L}$ co-current

$P_R^{M} \rightarrow P_{touch}^{M}$ co-current $(\Delta p^{M}_{choke} = 0)$

$P_{touch}^{M} \rightarrow P^{L}_{temp}$ counter-current

③ $P_{sep} \rightarrow P_{disch}$ counter-current

④ $P_{wh}^{L} > P^{L}_{temp}$ ✓

$P_{dis} > P_{touch}$

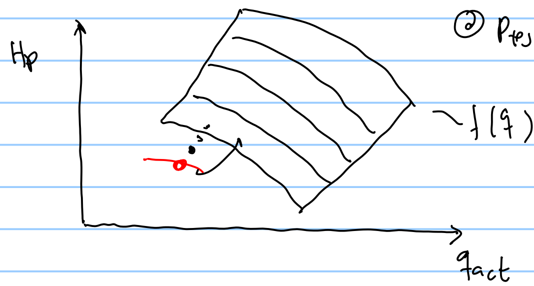
calculate

⑤ Power comp ✓

$$T_{dis} = T_{suc} \cdot (r_p)^{\frac{n-1}{n}}$$ ✓

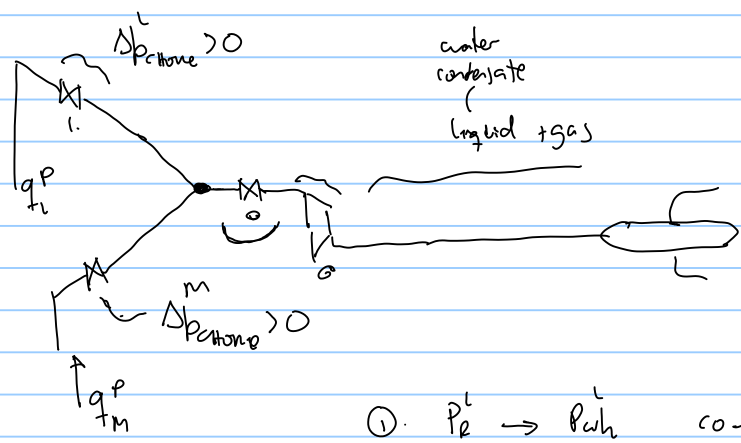
↳ [K], [°R]

H_p q_{act} → H_p^{test} q_{act}^{test}



② P_{test}, T_{test}, MW_{test}

I need to increase $\Delta p_{compressor}$



① $P^L_R \rightarrow P^L_{wh}$ co-current

② $P^M_R \rightarrow P^M_{wh}$ co-current

③ $P_{sep} \rightarrow P_{disch}$ counter current

④ assume $\Delta p_{comp} \rightarrow P_{suc}$ (same as before)

assume $\Delta p_{choke} \rightarrow P_{towh}$ ↪ 5

⑤ $P_{towh} \rightarrow P^L_{tem}$ counter current

$P_{towh} \rightarrow P^M_{tem}$ counter current

⑥ $\Delta p^M_{choke} > 0$

$\Delta p^L_{choke} > 0$

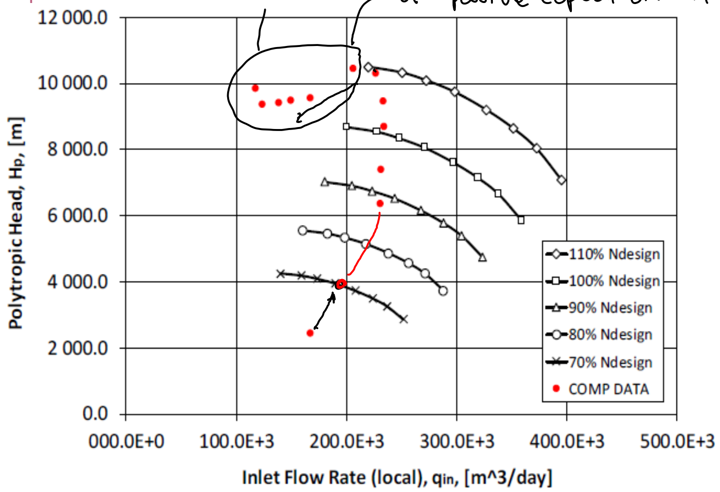
Power

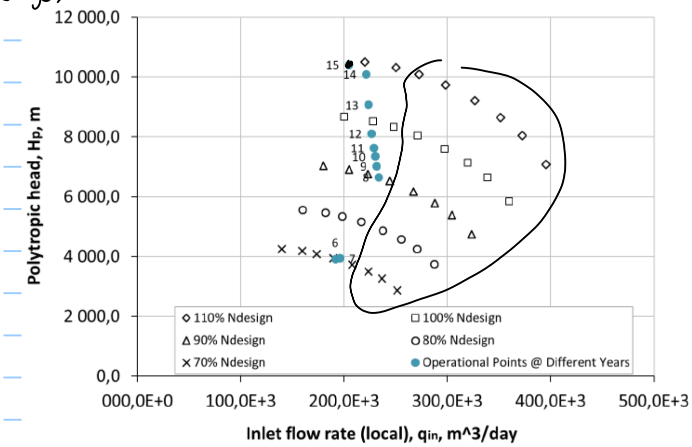
Tdisch

H_p^{test}, q_{act}^{test} }

time sequence ↓
- $\Delta p^{L}_{choke} < 0$
- both templates enter in decline

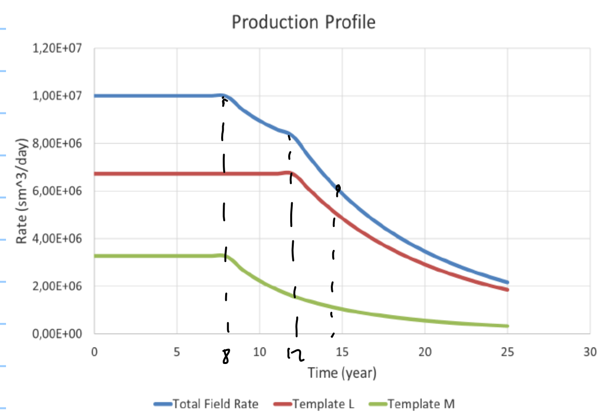
not possible (operation in surge)



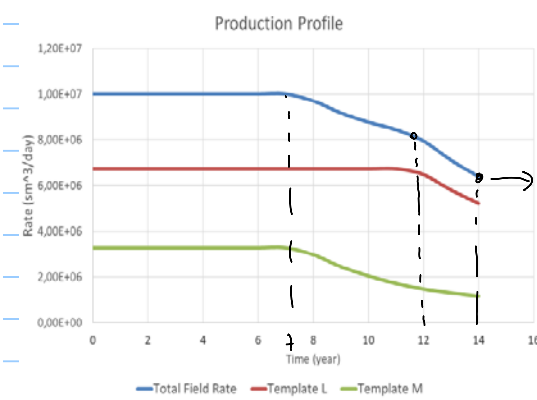


for our exercise the limit in compression power is reached (3-4) after compressor startup

Task 2



Task 3



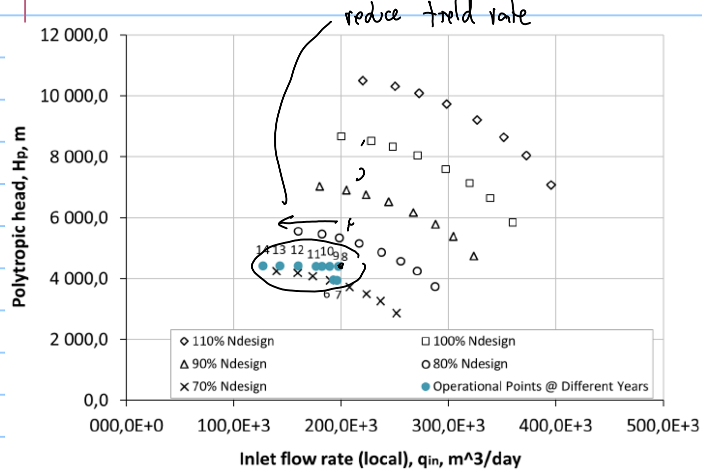
no compressor can be used

be careful about minimum flow condition

Effect of cooler if the cooler is removed → T_{ds} become a limitation

the q_{field} must be reduced

reduce field rate

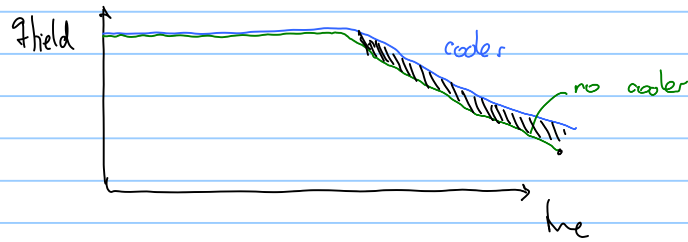


$q_{field} \downarrow \rightarrow \Delta p_{comp} \downarrow$

$\downarrow$

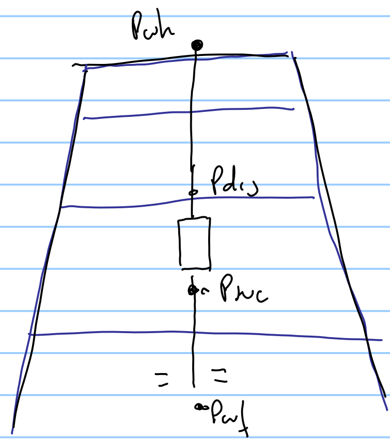
$T_{disch} \downarrow \leftarrow r_p \downarrow$

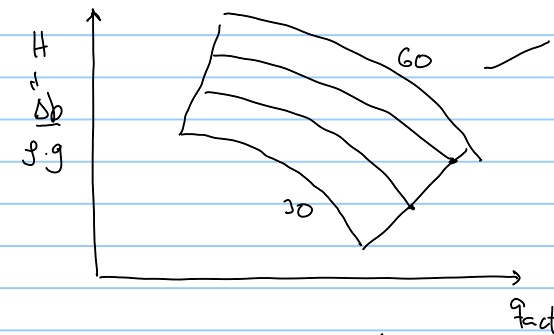
no cooler gives less production



• exercise 2

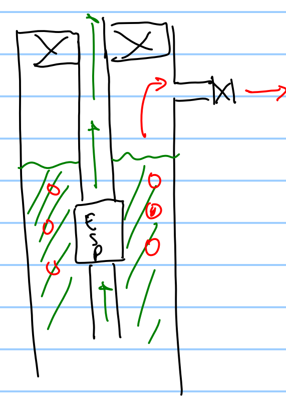
Power = 950 Hp ✓

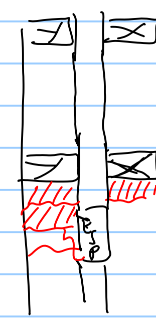




$P_{suc} \geq P_b$. ✓

↳ all fluid is produced through tubing





① exclude pump model

two methods

ESP maps are provided

↳ ρ, M

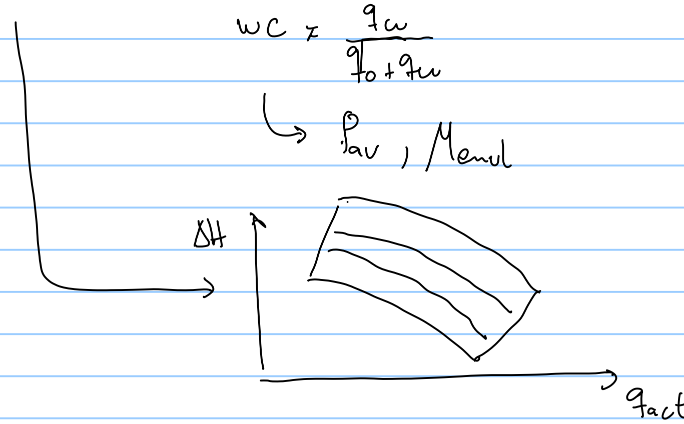
given

q_o

q_w

$$wc = \frac{q_w}{q_o + q_w}$$

↳ ρ_{av}, M_{emul}



- co-current $P_R \rightarrow P_{wf} \rightarrow P_{suc}$

- counter-current $P_{wh} \rightarrow P_{disc}$

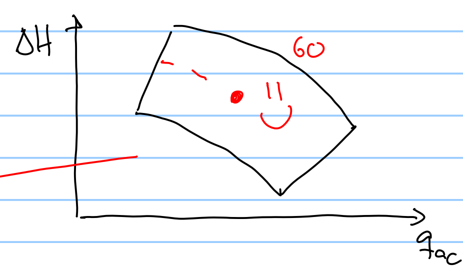
$$\Delta p_{esp} = P_{dis} - P_{suc}$$

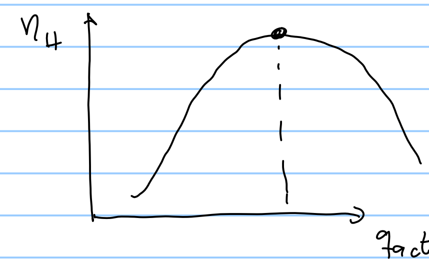
$$\Delta H_{esp} = \frac{\Delta p_{esp}}{\rho_{av} \cdot g}$$

$q_{ac} = q_L$ neglecting gas, assuming incompressible

if NOT ! $q_{act} = B_o(P_{suc}, T_{suc}) \cdot q_{\bar{o}} + B_w(P_{suc}, T_{suc}) \cdot q_{\bar{w}}$

- plot the point





check $P_{suc} \geq P_b$ (bubble point pressure at T_{suc})

$$Power = \frac{\Delta p_{esp} \cdot q_{act}^{suc}}{\eta_m \, \eta_H}$$

$\eta_H = f(q_{act}, f, \mu, \rho)$

estimate f graphically

f_{ref}

q_{BEP}

Best efficiency point

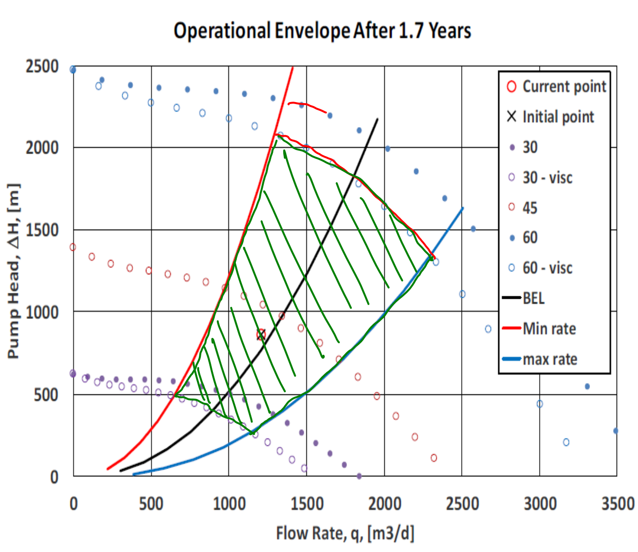
use VBA function pumpeff_visc(

q_{BEP}

use coefficients ΔH vs q

η vs q

for water !



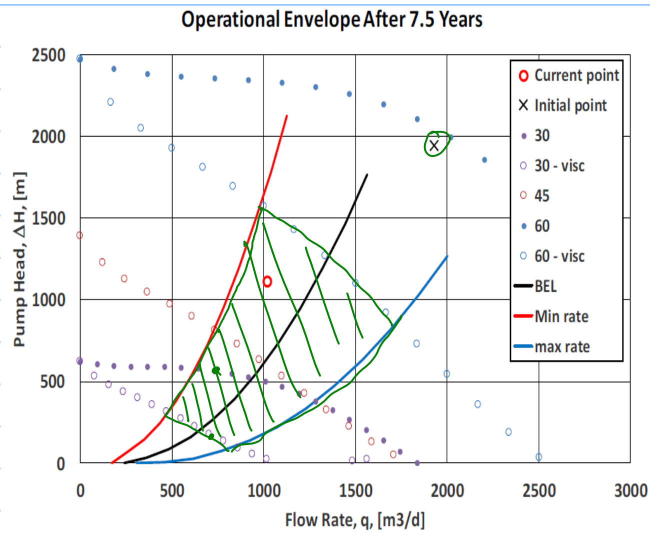
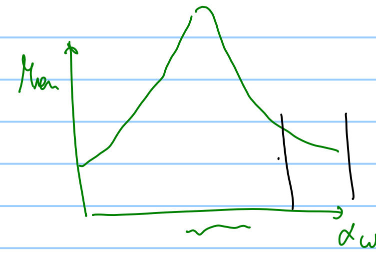
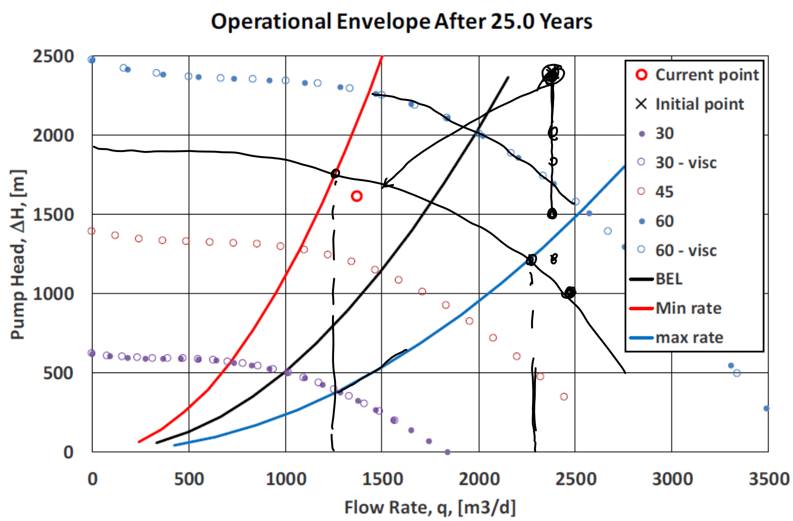
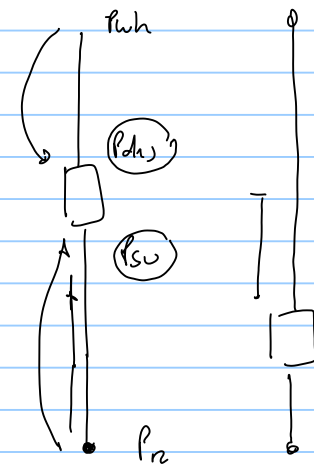


Figure 7 - The operational envelope of the ESP after 7.5 years

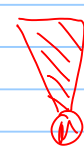


$P_{suct} < P_b$



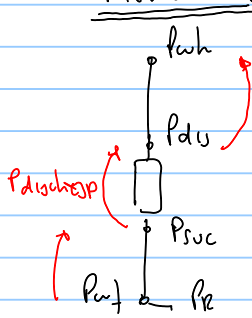


- Increase "J" → P_{suc} ↑
  ↘ Δp_{pump} ↓



- change ESP model
- change ESP motor (bigger)

Method 2: use the pump model (equation) (VBA function Pdischarge_pump_visc)
↳ $a_5 - a_1$ for water
↳ q_{BEP}
C_Q
C_H



using f as a "guess"

$P_{wh} \neq 7$ bara

change f until $P_{wh} = 7$ bara

↳ if solver fails → numerical reasons { starting seed, Nit, TOL
→ non feasible solutions

$$\Delta h_{tsp} = \frac{\Delta p_{tsp}}{\rho_{av} \cdot g}$$

q_{mm} = VBA function

q_{mass} = VBA function

• Class exercise. for $\frac{dP}{dx}$ calculator (multiphase aspect)

liquid superficial velocity $u_{sL} = \frac{q_L}{A}$ ~ cross section pipe area

gas superficial velocity $u_{sg} = \frac{q_g}{A}$

http://www.ipt.ntnu.no/~stanko/Resources.html

-Flash-Pack, an utility based on DWSIM to estimate fluid properties, generate compositions to match measured Gas oil ratios and generate black oil tables. Link

-Black-Oil Gen, a MS Excel utility to estimate Black Oil properties and generate tables using correlations. Link

-Multiphase calculator, a MS Excel utility to estimate multiphase flow (liquid-gas) pressure drop and flow patterns. Link

Estimating well IPR with test data

The Prudhoe bay field is a large oil field on Alaska's North Slope. The field has been producing since 1977 and it is currently producing around half a million barrels per day.

The field has 1330 wells, from which 591 are naturally flowing. The wells shut-in pressure is 166 bara (corresponding to a reservoir pressure of 400 bara). The wells are arranged in production modules that provide protection and insulation to the Christmas trees from the harsh artic environment. The various modules are connected through flowlines to the main

$\dot{m}_T = q_{\bar{o}} \rho_{\bar{o}} + q_{\bar{g}} \rho_{\bar{g}}$

$\dot{m}_T$ $\dot{m}_o$ $\dot{m}_g$

with hysys $P, T, z_i \longrightarrow x_o$ $x_g = 1 - x_o$

$x_o \rightarrow \frac{m_L}{m_L + m_V}$ $x_g \rightarrow \frac{m_V}{m_L + m_V}$

$\dot{m}_o = x_o \cdot \dot{m}_T$

$\dot{m}_g = x_g \cdot \dot{m}_T$