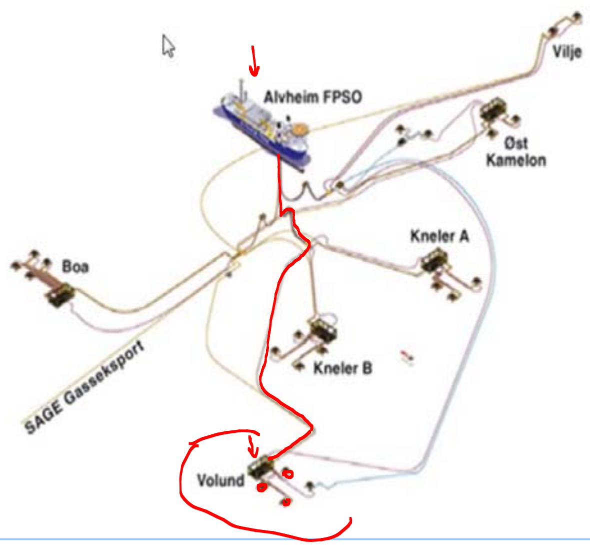
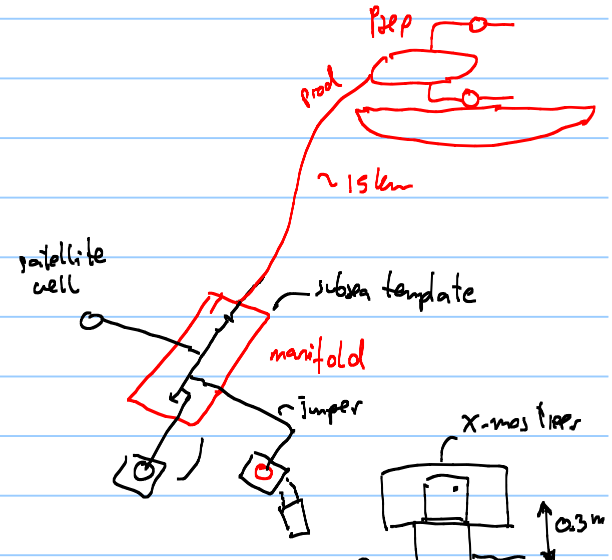
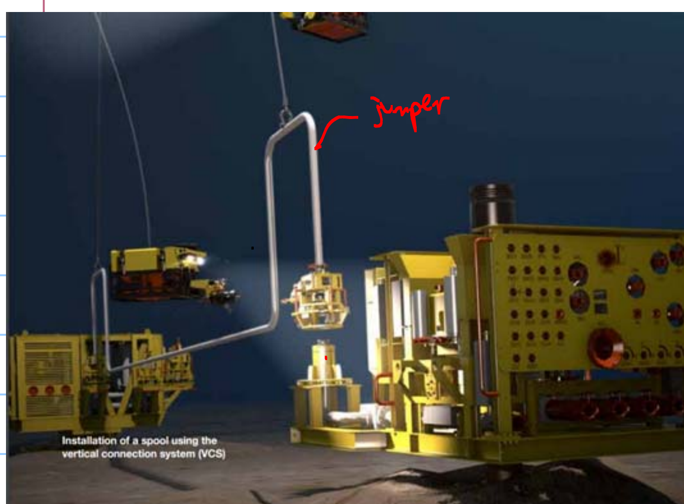
# Day 3

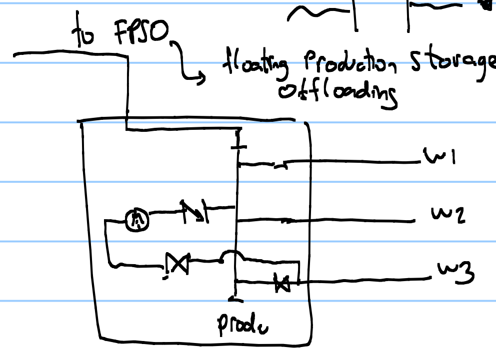
- exercise 1



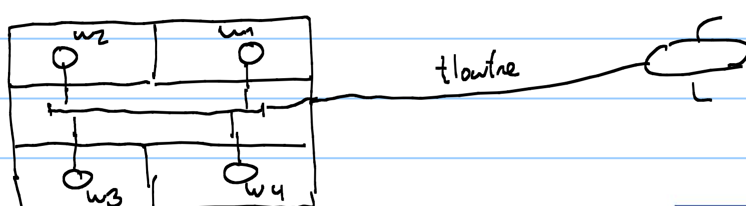



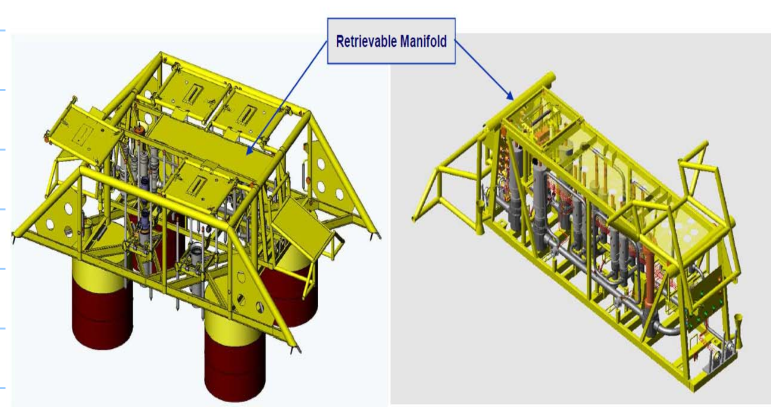
Installation of a spool using the vertical connection system (VCS)

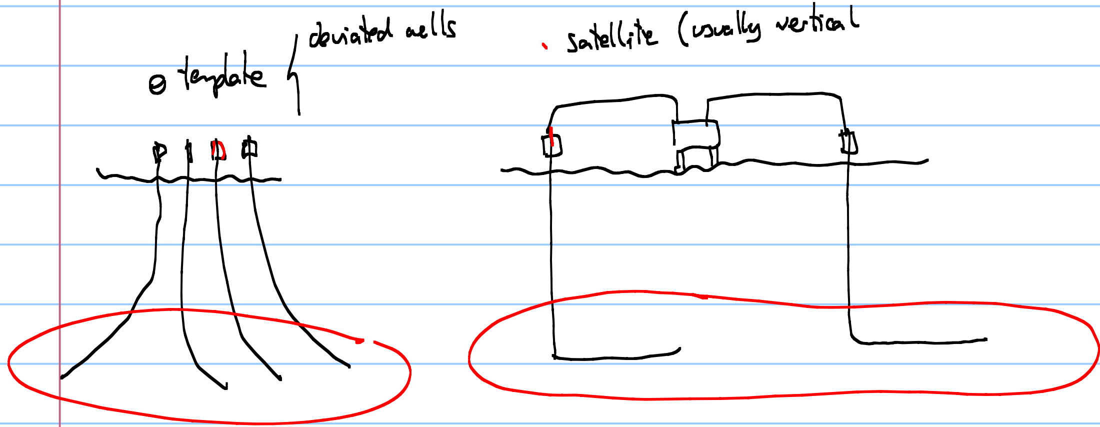


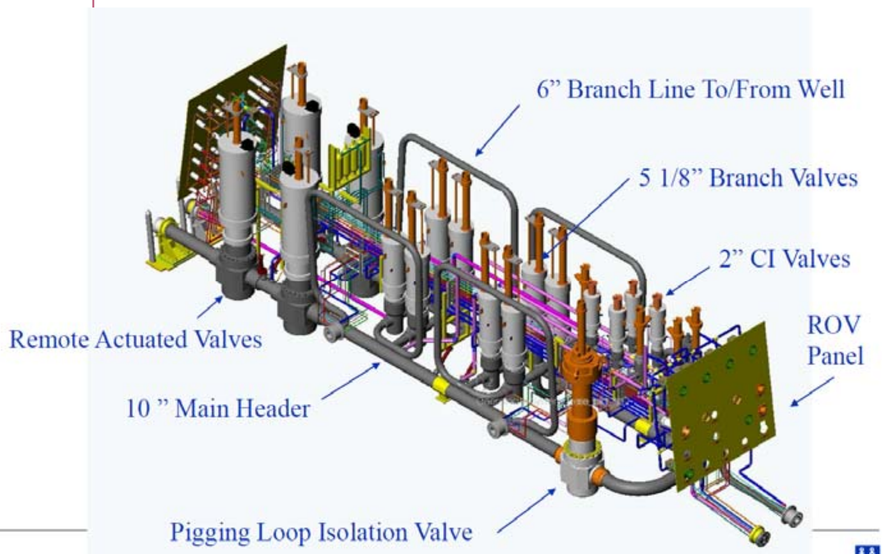

template

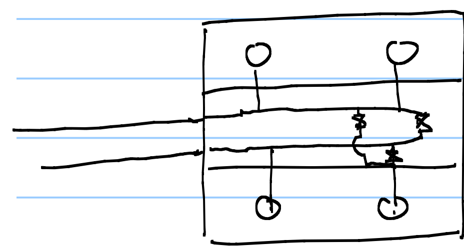
in Norway, UK, Brazil cluster wells



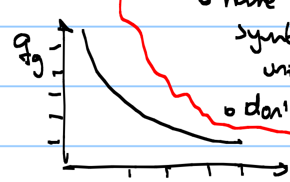


plot format !

- color, tick marks
- font 14-16
- name variable, symbol variable, units
- don't use yellow, pink etc.




Exercise N° 2 Plot $q_g$ local gas rate vs. P.

exercise 3 flow equilibrium → ① bottom-hole equilibrium IPR vs TPR assuming Pwh=40 bara
(IPR: inflow performance relationship)
make plot !
find equilibrium rate and Pwf

② wellhead equilibrium WPR vs Psep assuming Psep = 40bara
find equilibrium rate
make plot

③ perform wellhead equilibrium but including flow line
WPR vs FPR
find equilibrium rate
make plot

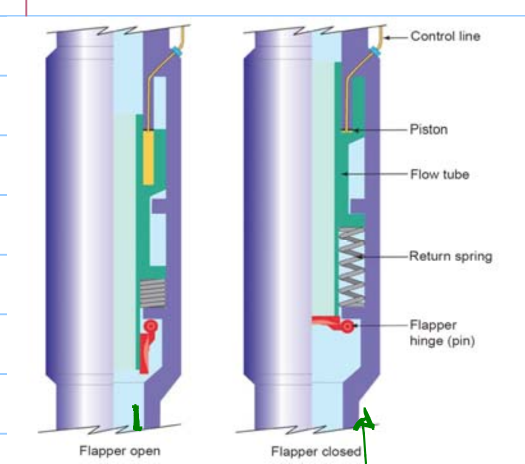
exercises can be delivered ino groups of 3 people

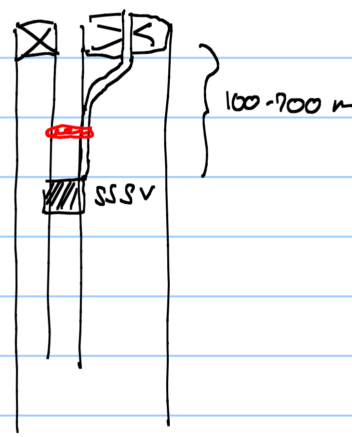
tentative deadline is 18.11.2018

send to my email milan.stanko@ntnu.no

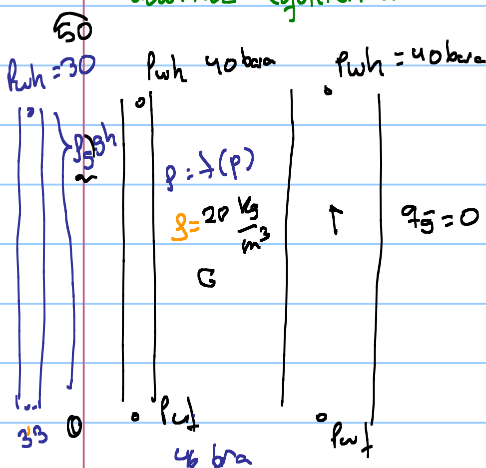
skype: stankome

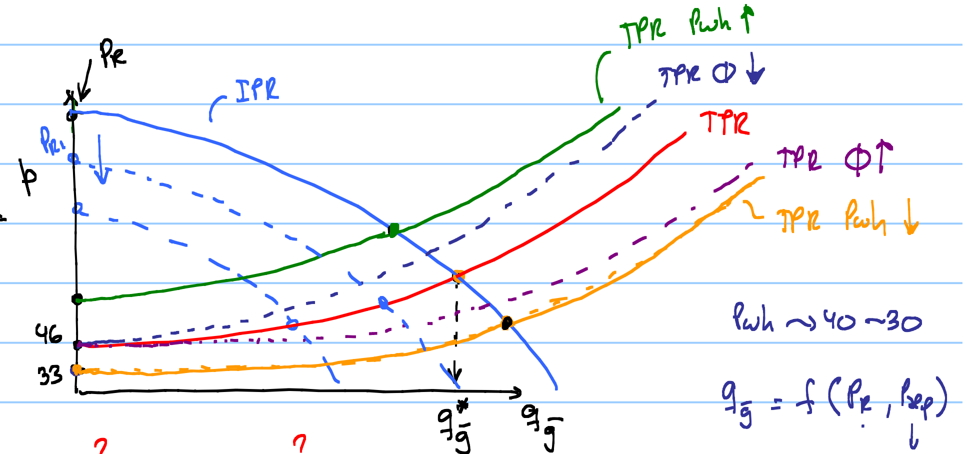
SSSV subsurface safety valve
DHV downhole valve




downhole equilibrium




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

use solver

$$\frac{q_g^2}{C_T^2} = P_{wf}^2 - P_{wh}^2 e^S$$

Pwh ~ 40 ~ 30

$q_g = f(P_R, P_{sep})$

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

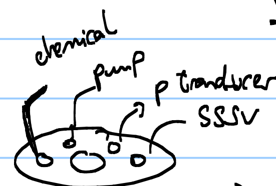
$q_g = 0$

$P_{wf} = P_R$

$$\rho = \frac{P}{RT}$$ (P: 30, 40)

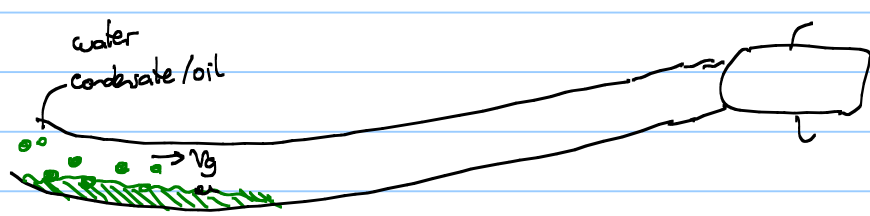
tubing diameter selection

- maximize rate ↑ USD $ ↓ Δp
- minimize cost ↑ Φ ↑ $
- fit production casing
- depends on tubing hanger (structural limitations and space)
- erosion $v_g \leq v_{erosional}$ *
- liquid loading / slugging $v_g \geq v_{loading\ velocity}$ *



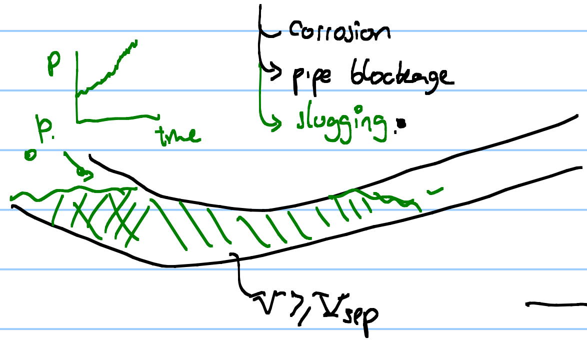

flowline sizing considerations

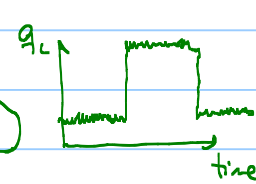
- maximize $q_g$ ↓ Δp
- minimize cost ↓ $
- Liquid transportation.
- hydrate formation (gas)

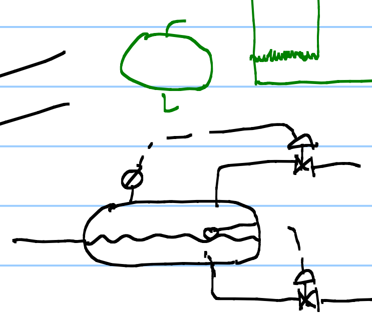



↳ corrosion
↳ pipe blockage
↳ slugging.

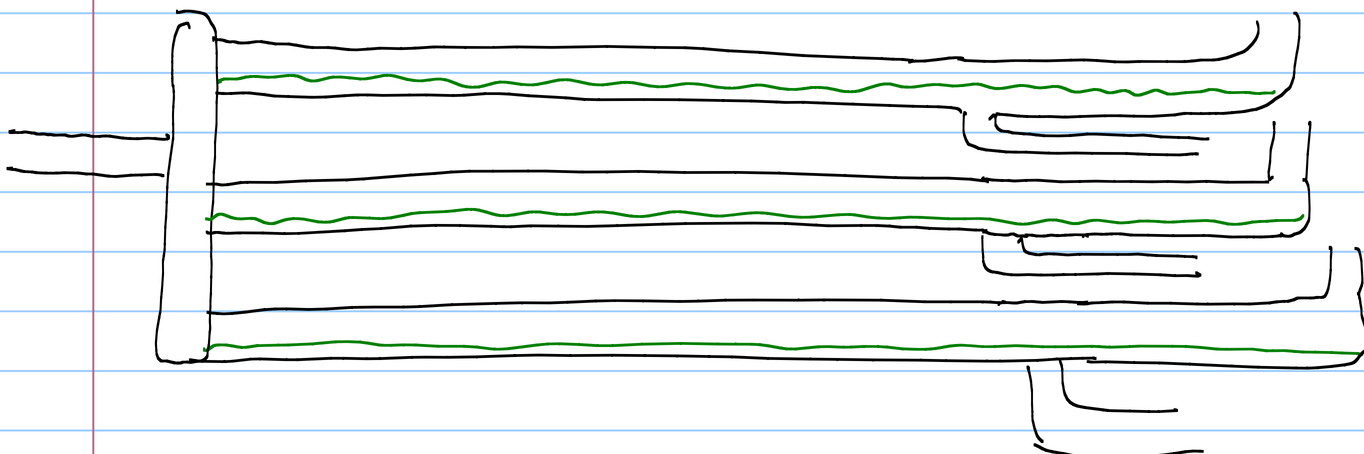
flow assurance
ensuring the uninterrupted flow of hydrocarbons from reservoir to processing facilities



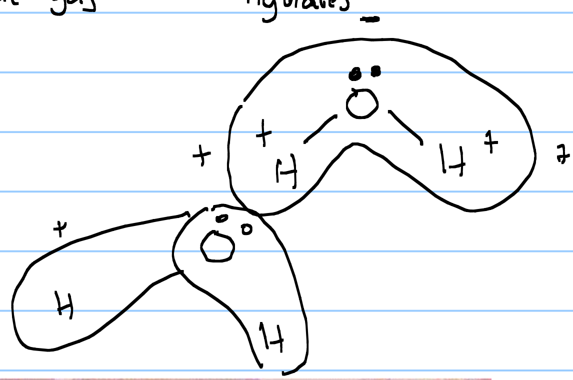



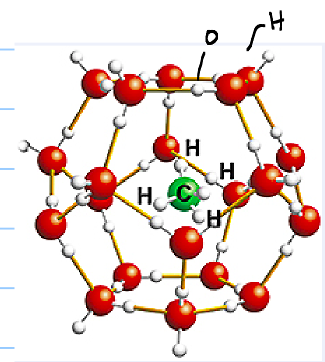



If slugging is unavoidable, a slug catcher is sometimes used instead of a separator



Natural gas Hydrates when T ↓




9 Å

$10^{-10}$ m

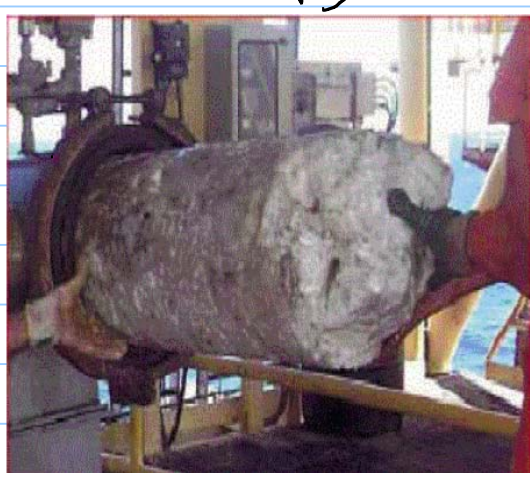
$CH_4$

$C_2H_6$

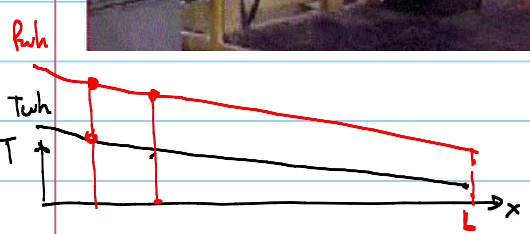
$C_3H_8$

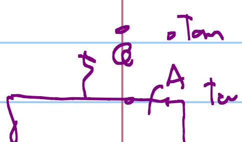
$CO_2$

$N_2$

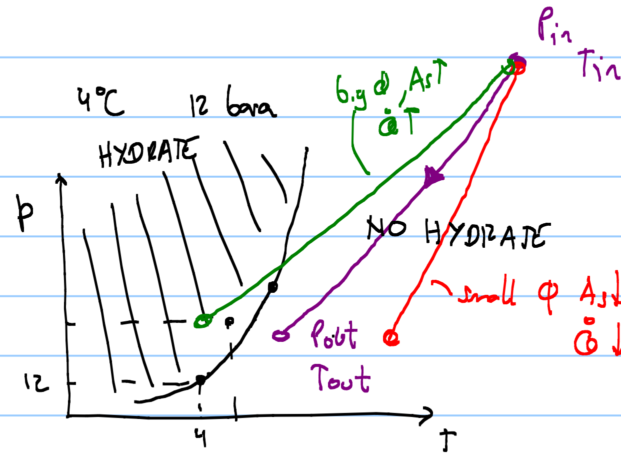


- small HC molecules ($CH_4$, $C_2H_6$, $H_3H_8$)
- free water (liquid)
- ↓T ↑p



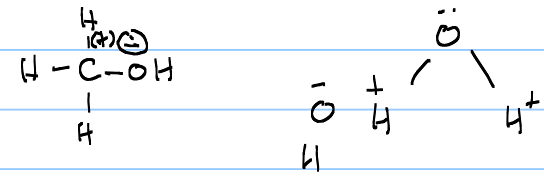




$\dot{Q} = A_s \cdot U (T_w - T_{amb})$

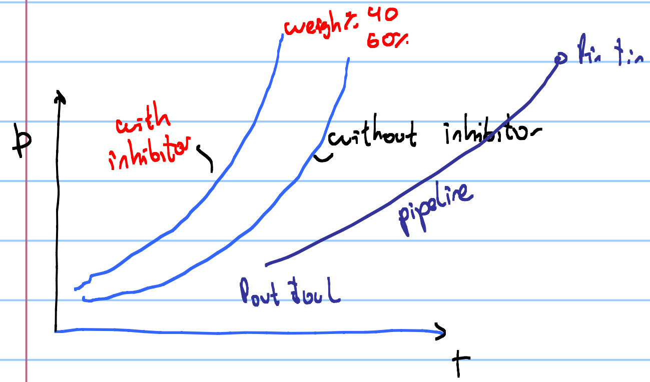


when hydrate zone cannot be avoided then I use hydrate inhibitor

methanol




TEG
MEG
salt




$$\frac{\dot{m}_{inh}}{\dot{m}_{inh} + \dot{m}_{water}} = [0.4 - 0.6]$$

range

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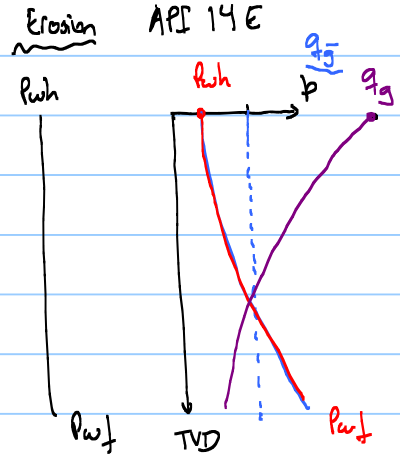
Erosion API 14E




$$v_g \leq \frac{C}{\sqrt{\rho_m}}$$

C — (100–120) [ft/s]

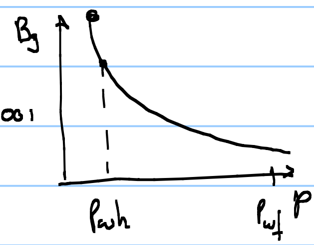
$\rho_m$ → [lb/ft³]

→ should include solids (ppm)

$$q_g = q_{\tilde{g}} \cdot B_g(p,T)$$

$q_{\tilde{g}}$ @sc.

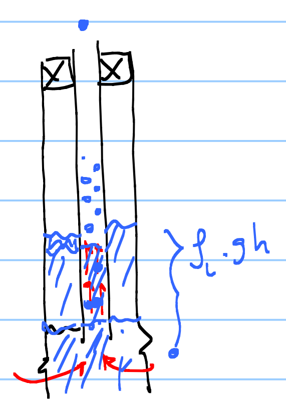
$B_g$: 0.01–0.001



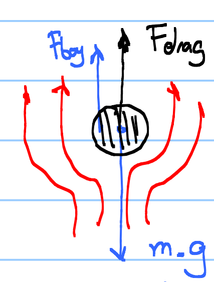

$$v_g = \frac{q_g}{A} = \frac{4\, q_g}{\pi\, \phi^2}$$

$v_g$ maximum?

Liquid loading



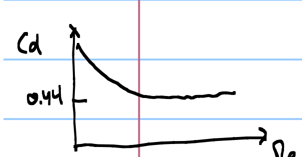

liquid loading criteria Turner




$$F_{drag} + F_{buoyan} = F_{weight}$$

$$V_d = \frac{\pi \phi^3}{6}$$

$$A_d = \frac{\pi \phi^2}{4}$$




$$F_d = \frac{1}{2} \rho_g\, C_d\, A_d\, v_g^2$$

critical gas velocity

$$\frac{1}{2} \rho_g\, C_d\, v_g^2 A_d + V_d\, \rho_g\, g = V_d \cdot \rho_L \cdot g$$

$$v_g = \sqrt{\frac{\pi \phi^3}{6} (\rho_L - \rho_g)\, g \,\frac{2}{\rho_g} \frac{1}{C_D} \frac{4}{\pi \phi^2}} \quad (1)$$

turbulent regime

drag coefficient $\approx 0.44$

$$v_g = \sqrt{\frac{4}{3} \frac{(\rho_L - \rho_g)}{\rho_g} \frac{\phi g}{0.44}} \qquad \rho_g = \frac{p}{RT}$$

Hinze max droplet $d_{max}$ Weber number $= \left( \frac{\rho_g u_g^2 \phi_{max}}{\sigma} \right)$ (2)

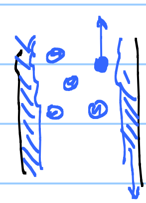
weber number = 30

substitute eq (2) in (1)

$$v_{g_{crit}} = 5.46 \left[ \frac{\sigma^{0.25} (\rho_L - \rho_g)^{0.25}}{\rho_g^{0.5}} \right] \quad [m/s]$$

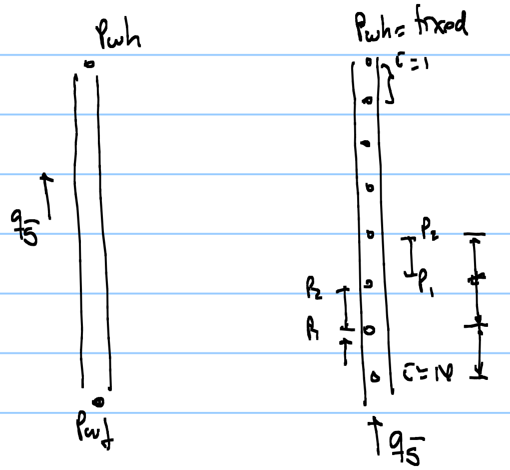
$\rho$ in $[kg/m^3]$ $\sigma\ [N/m]$

$v_g \geq v_{g_{crit}}$



pressure traverse calculations in tubing ($p, q_g, v_g, \rho_g$, along the tubing !)

$$p_{wf}^2 = p_{wh}^2 e^{s_i} + \frac{q_{\bar{g}}^2}{C_{T_i}^2}$$



| | |
|---|---|
| Gas gravity | 0.55 |
| Twf [K] | 378 |
| Twh [K] | 360 |
| pR [bara] | 304 |
| friction factor [-] | 0.012 |
| qg [Sm^3/d] | 2.85E+06 |
| liquid density [kg/m^3] | 8.97E+02 |

| TVD | T | Tav | passumed | Pav | Zav | S | Ct | p | Z | Bg | qg_local |
|---|---|---|---|---|---|---|---|---|---|---|---|
| [m] | [K] | [K] | [bara] | [bara] | [-] | [-] | [Sm^3/bar] | [bara] | [-] | [m^3/Sm^3] | [m^3/d] |
| 0 | 360.0 | 360.9 | 40.0 | 43.3 | 0.966 | 0.031 | 1.29E+05 | 40.0 | 0.9678 | 0.031 | 8.71E+04 |
| 284 | 361.8 | 362.7 | 46.5 | 49.5 | 0.962 | 0.031 | 1.29E+05 | 46.4 | 0.9642 | 0.026 | 7.53E+04 |
| 567 | 363.6 | 364.5 | 52.5 | 55.2 | 0.960 | 0.030 | 1.29E+05 | 52.1 | 0.9612 | 0.024 | 6.71E+04 |
| 851 | 365.4 | 366.3 | 58.0 | 60.5 | 0.958 | 0.030 | 1.29E+05 | 57.5 | 0.9589 | 0.021 | 6.10E+04 |
| 1135 | 367.2 | 368.1 | 63.1 | 65.6 | 0.956 | 0.030 | 1.29E+05 | 62.5 | 0.9570 | 0.020 | 5.62E+04 |
| 1418 | 369.0 | 369.9 | 68.1 | 70.4 | 0.954 | 0.030 | 1.29E+05 | 67.3 | 0.9554 | 0.018 | 5.24E+04 |
| 1702 | 370.8 | 371.7 | 72.8 | 75.1 | 0.953 | 0.030 | 1.28E+05 | 71.9 | 0.9542 | 0.017 | 4.92E+04 |
| 1986 | 372.6 | 373.5 | 77.4 | 79.6 | 0.952 | 0.030 | 1.28E+05 | 76.4 | 0.9532 | 0.016 | 4.65E+04 |
| 2269 | 374.4 | 375.3 | 81.9 | 84.1 | 0.952 | 0.030 | 1.28E+05 | 80.8 | 0.9524 | 0.015 | 4.41E+04 |
| 2553 | 376.2 | 377.1 | 86.2 | 88.4 | 0.951 | 0.030 | 1.28E+05 | 85.1 | 0.9519 | 0.015 | 4.21E+04 |
| 2837 | 378.0 | | 90.5 | | | | | 89.3 | 0.9516 | 0.014 | 4.03E+04 |