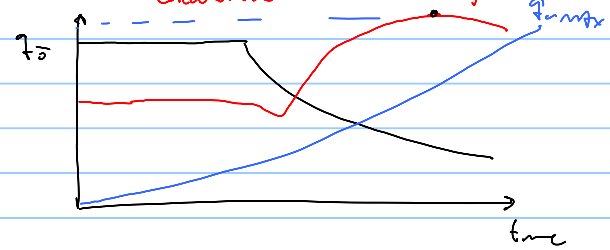
CAPEX of topside processing facilities: $\underbrace{f(q_{\bar o}(t), q_g(t), q_w(t))}_{\text{usually calculated with a reservoir model}}$



during production actual profiles can be different than the profiles predicted during the design phase → GOR, WC

Be sure ! $q_{\bar g}$ fixed $\leq q_{\bar g}$ max Processing facilities

$q_{\bar w}$ fixed $\leq q_{\bar w}$ max

$q_{\bar i}$ fixed $\leq q_{\bar i}$ max → $q_{\bar w}$ occupies space that could potentially be used for oil.

the only way to ensure this is choking production.

we could use optimization for this.
Ranking method

well usually have different GOR WC

choosing which well to choke and which well to produce.

Determining optimum P of second stage separator to increase liquid recovery.

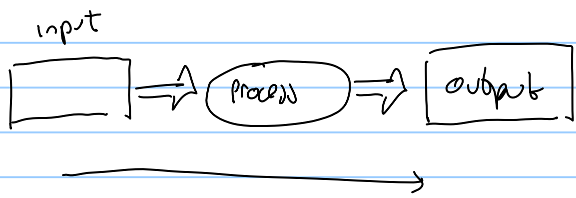
Hysys → simulating processes → processing facilities

→ compositional simulator EoS { Peng Robinson, SRK }

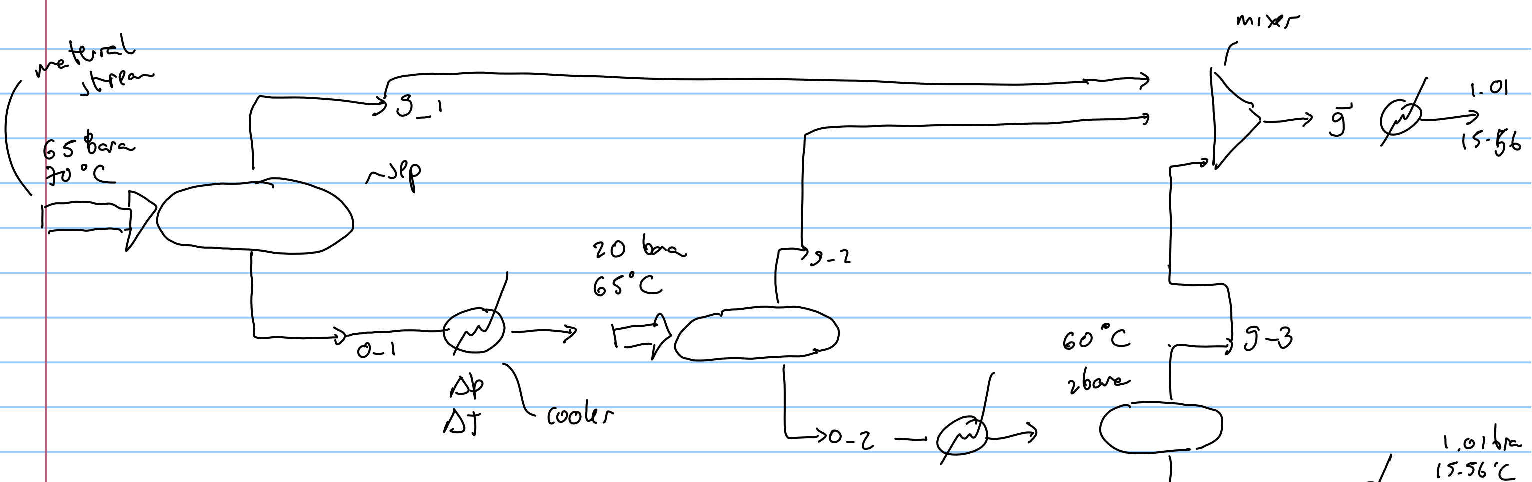
→ Aspentech

Honeywell → UNISIM (same source code as Hysys but developed by another company).

http://folk.ntnu.no/stanko/Courses/TPG4230/2017/Class_files/20170328/ Class exercise.



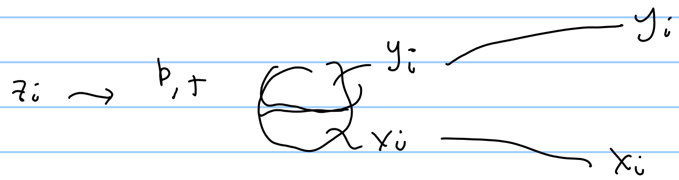
co-current
always downstream
always along the direction of flow

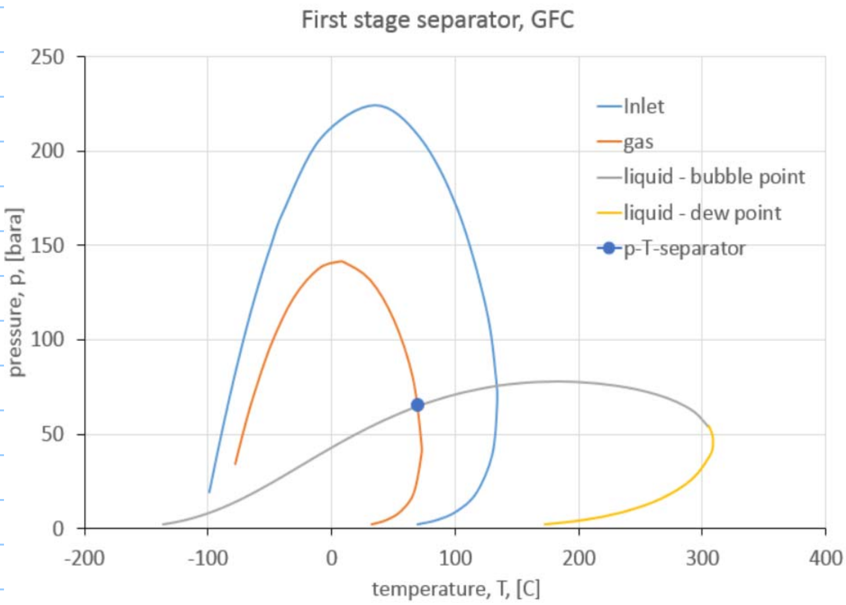


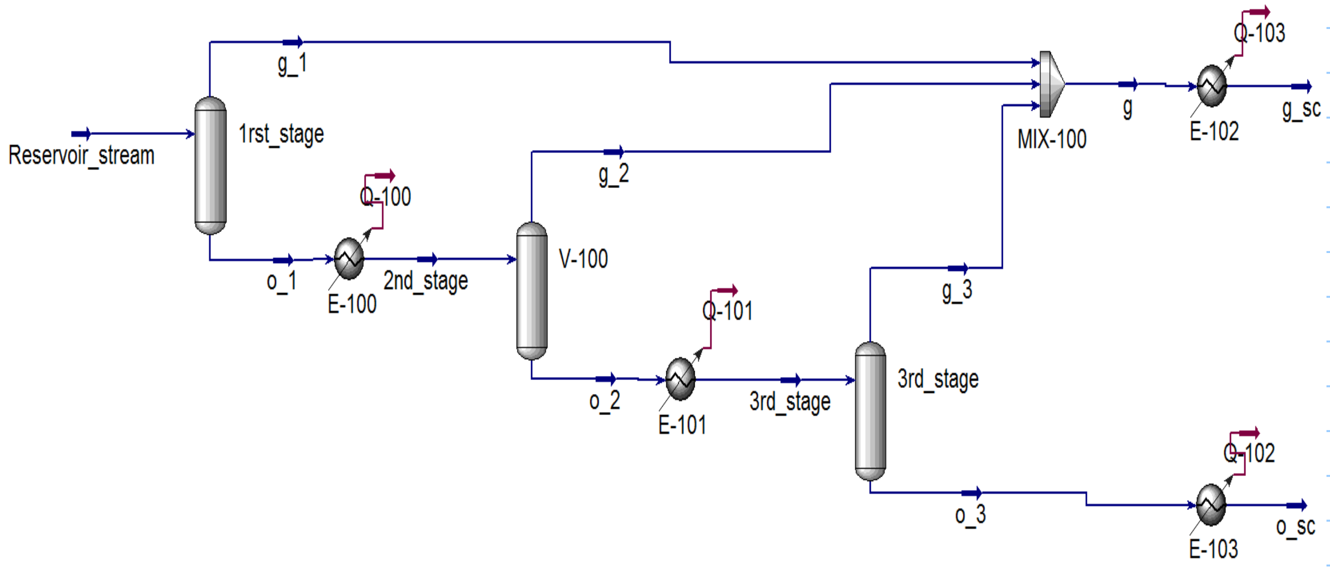
$GOR : \left[\frac{Sm^3}{Sm^3}\right]$

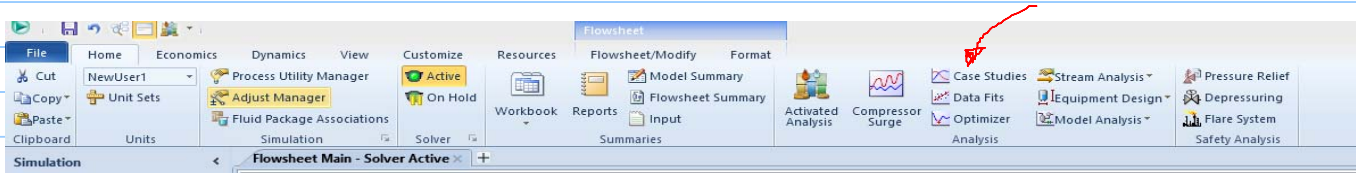
$p = 1.01325$ bara

$T = 15.56$ °C









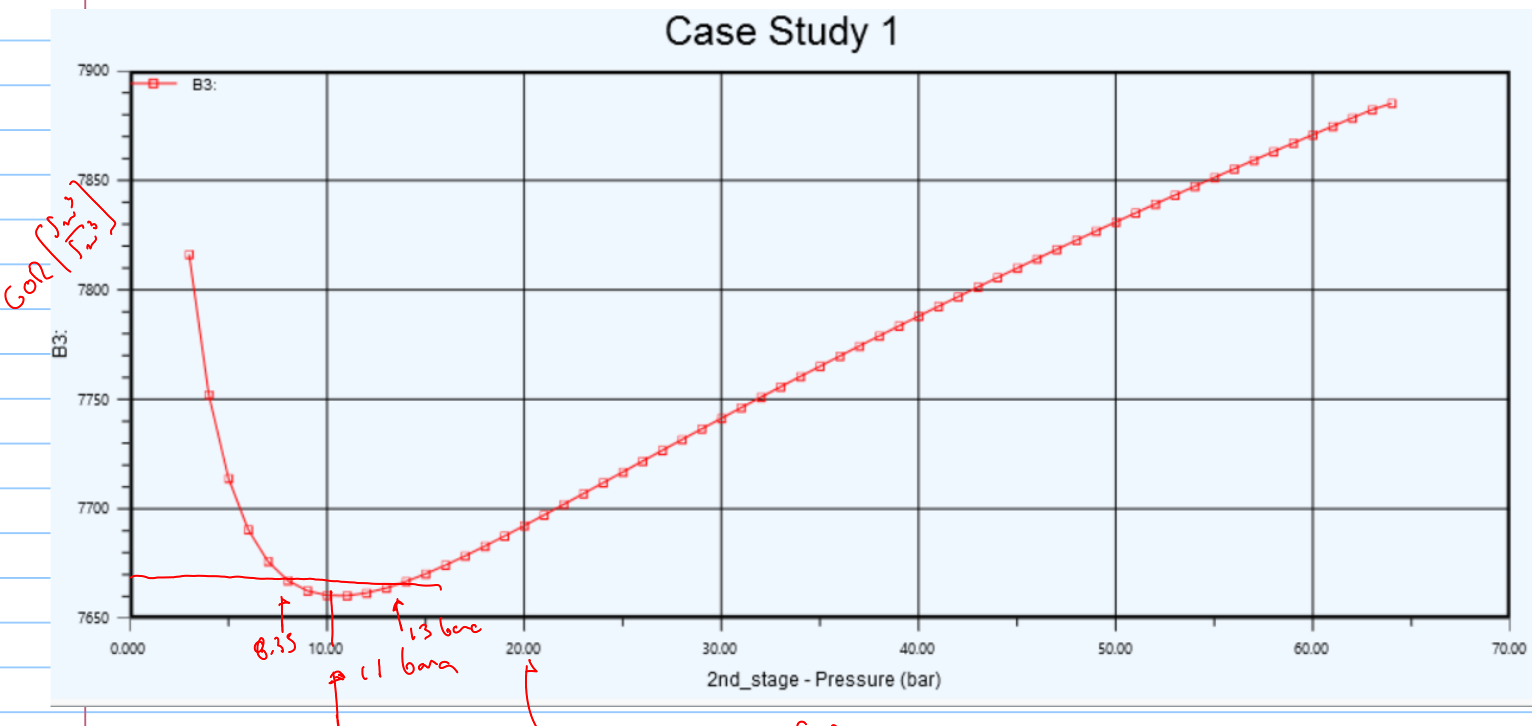
Case studies

Object	Variable	Independent	Include
2nd_stage	Pressure	Yes	☑
SPRDSHT-1	B3:	No	☑

x y

$y = f(x)$

$GOR = f(P_{msep})$



$GOR = 7692\ Sm^3/Sm^3$

$GOR = 7660\ Sm^3/Sm^3$

if $q_{g\,fed} = 7E6\ Sm^3/d$

$P_{msep} = 20$ bara $\quad q_{liquid} = 910.04\ Sm^3/d$

$P_{msep} = 11$ bara $\quad q_{liquid} = 913.83\ Sm^3/d$

$3.8\ Sm^3/d$

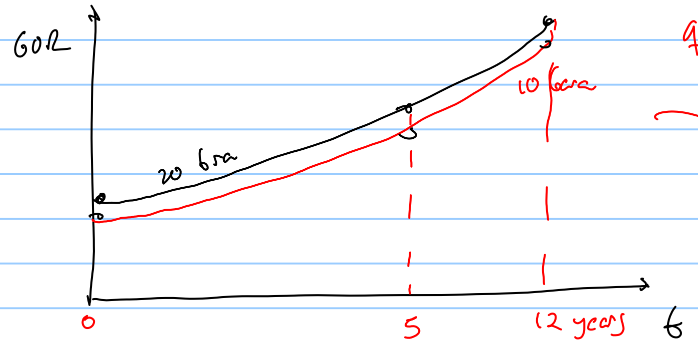
$24\ stb/d$

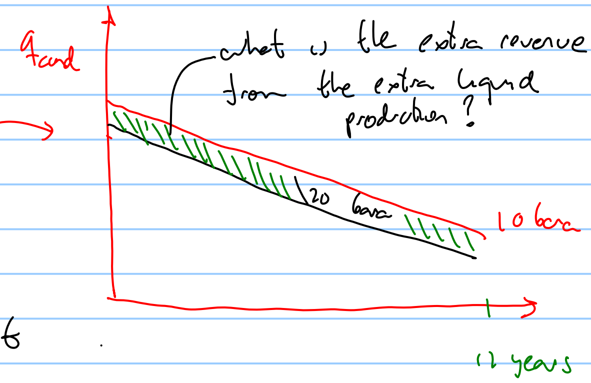
@ 50 usd/bbl $\approx$ 1200 usd/d

to compare the two options $P_{2nd\,stage} = 20$ bara vs. 10 bara

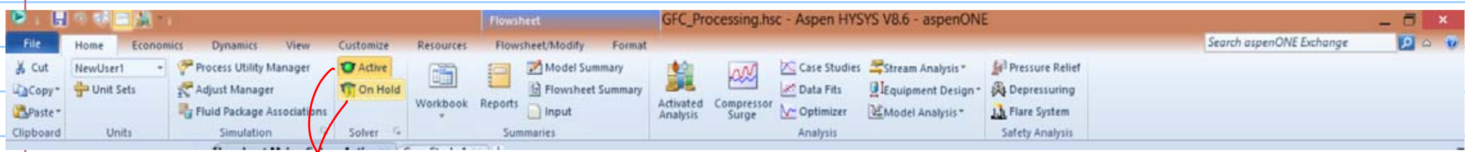
$$q_{cond} = \frac{q_{g\,fed}}{GOR}$$

Compute GOR for all years





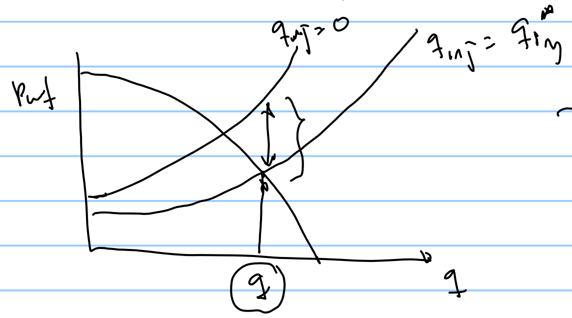
Other Hysys tricks



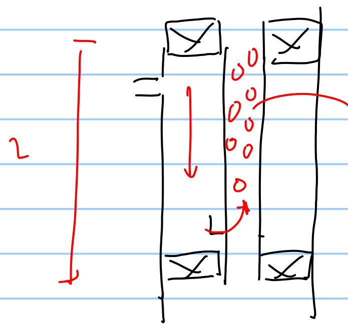
calculates everything all the time

doesn't calculate

Artificial lift: methods deployed in well to increase production aid natural flow



→ gas lift
reduce the density of the flowing mixture in the tubing by injecting gas

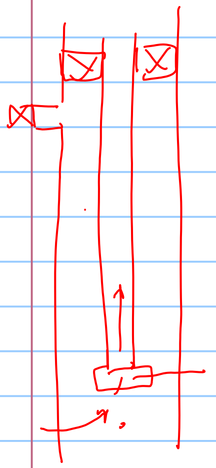


$$\rho_{mix} = \alpha \rho_g + (1-\alpha)\rho_L$$

$$\alpha = \frac{q_g}{q_o + q_g}$$

$$\Delta p = \rho \cdot L g$$

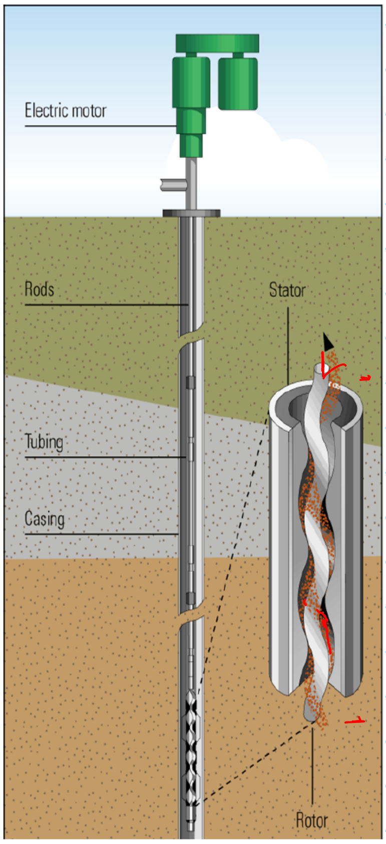
• PCP Progressive cavity pump



pump {ESP, PCP, rod pump

if $P_{wf} \leq P_b$
then gas should be produced through annulus

if $P_{wf} \geq P_b$
single phase at pump suction



• rod pumping

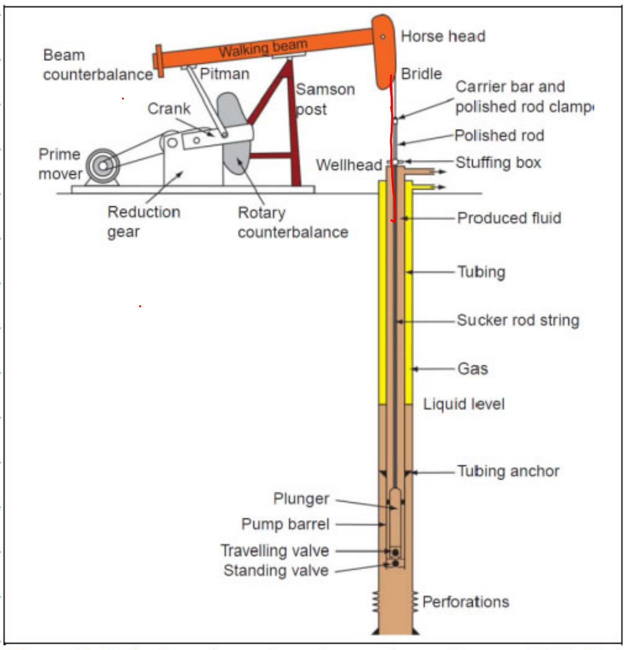
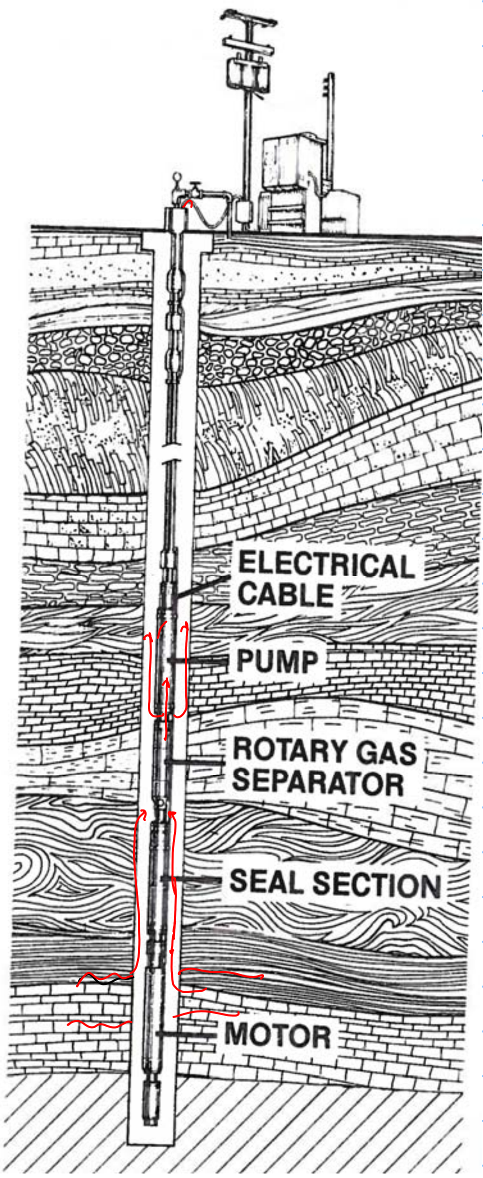


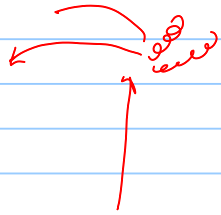
Figure 2. Typical configuration of a sucker rod pump (Bellarby, 2009).

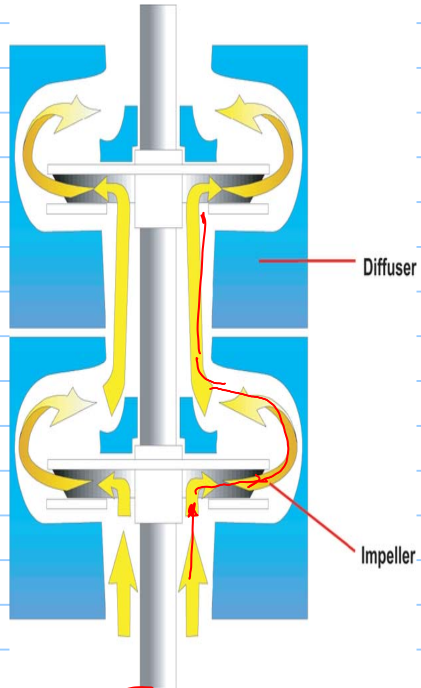
- ESP Electric submersible pump. Russian engineer (Armais Arutunoff

centrifugal pump installed in the wellbore
driving electrical motor is also in the wellbore

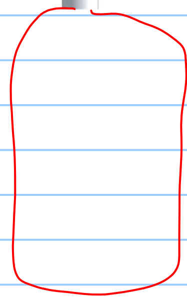
50 - 100 stages

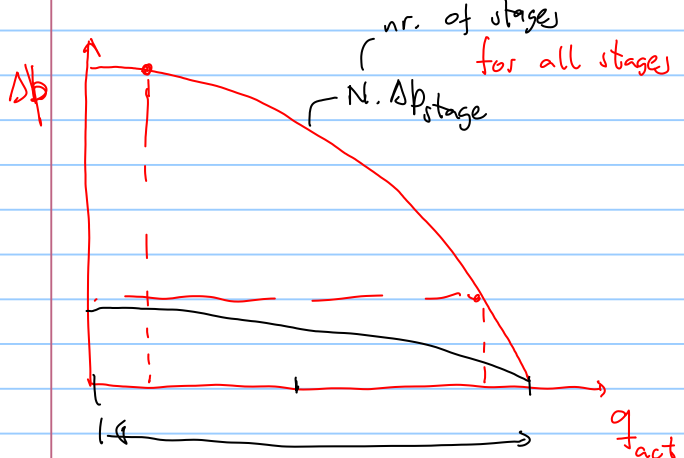






$p_{wf} < p_b$





with $q_{required}$ and $\Delta p_{required}$ the $N_{stages} = \frac{\Delta p_{required}}{\Delta p_{stage}} \cdot F$

pancake factors

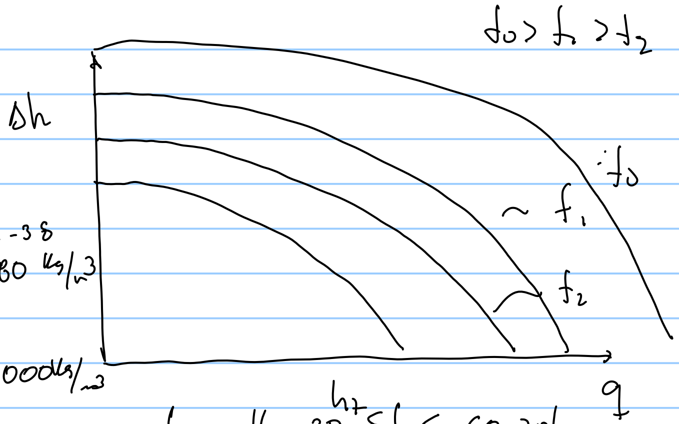
$\Delta h = \frac{\Delta p}{\rho_{fluid}\, g}$

head

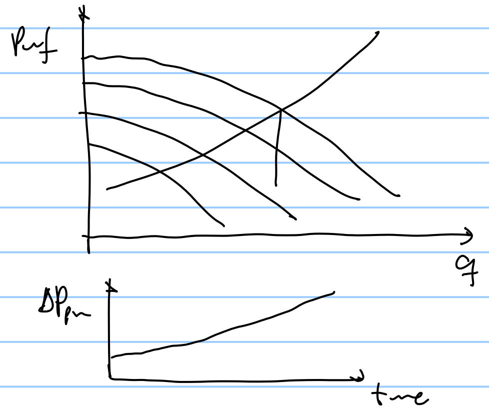
API ~ 32-38

780 kg/m^3

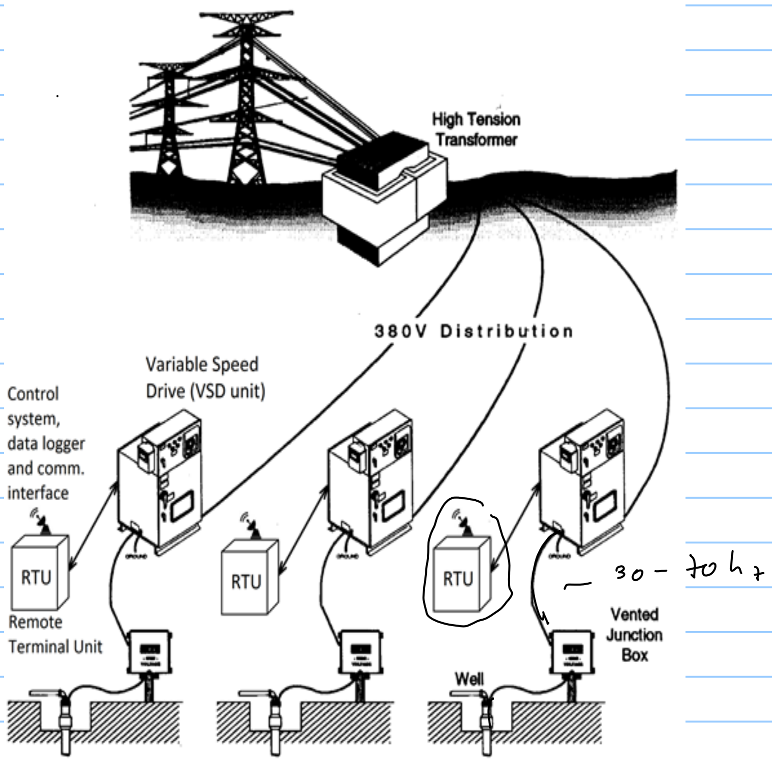
10 ~ 1000 kg/m^3

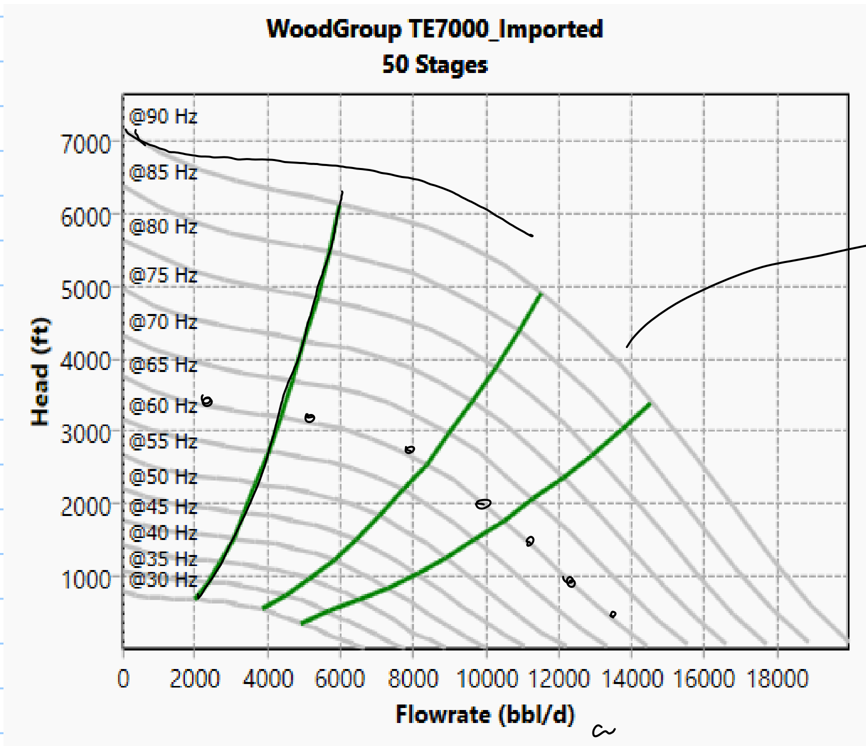


typically 30 hz ≤ f ≤ 60-70 hz



change the rotational speed of pump





usually represented with a polynome

$$\Delta h = a q^4 + b q^3 + c q^2 + d q + e$$

tune a, b, c, d, e to measured data @ reference frequency $\begin{cases} 60hz \\ 50hz \end{cases}$

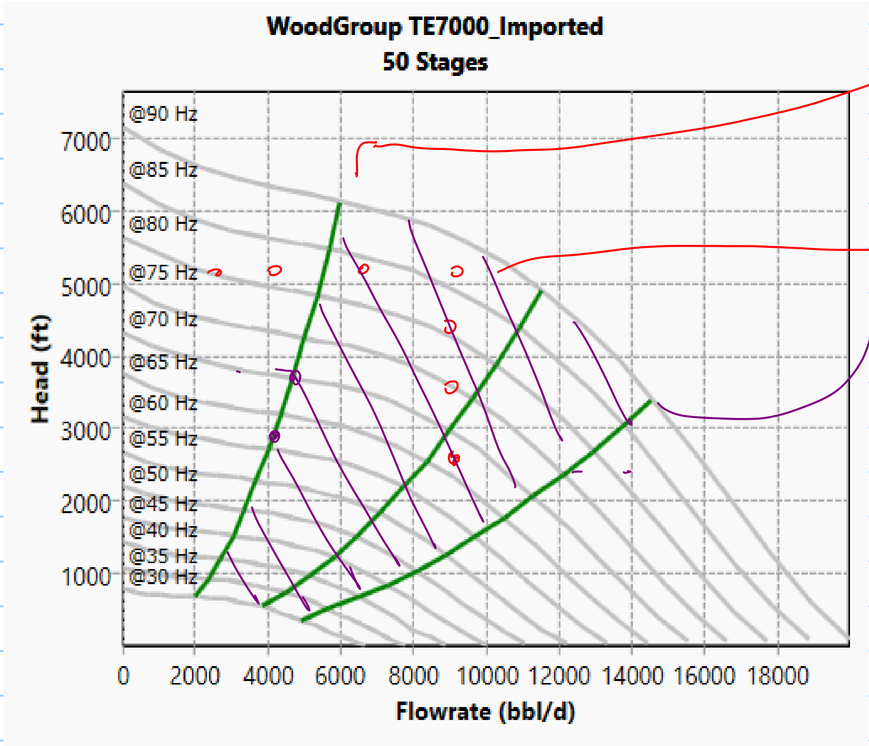
for another speed one use similarity law.

$$\frac{\Delta h @ f_1}{\Delta h @ \underset{60hz}{f_2}} = \left(\frac{f_1}{f_2}\right)^2$$

calculated for 60 hz

$$\Delta H = \left(a_4 \cdot \left(\frac{60\,hz}{f}\right)^4 \cdot q^4 + a_3 \cdot \left(\frac{60\,hz}{f}\right)^3 \cdot q^3 + a_2 \cdot \left(\frac{60\,hz}{f}\right)^2 \cdot q^2 + a_1 \cdot \left(\frac{60\,hz}{f}\right) \cdot q + a_0 \right) \cdot \left(\frac{f}{60\,hz}\right)^2$$

$$\frac{q_{@f_1}}{q_{@f_2}} = \left(\frac{f_1}{f_2}\right)$$



minimal flow rate line

maximum flow rate line

time	q	Δp
1	q_1	Δp_1
2	q_2	Δp_2
3	q_3	Δp_3
4		
1		

$q_{min}(f) \leq q \leq q_{max}(f)$ for every frequency

if not pump life is reduced dramatically !

typical pump life ≈ 2 years
5 years

not favorit for subsea installations due to increased maintenance frequency !

typical intervention time in subsea systems is 5 years.