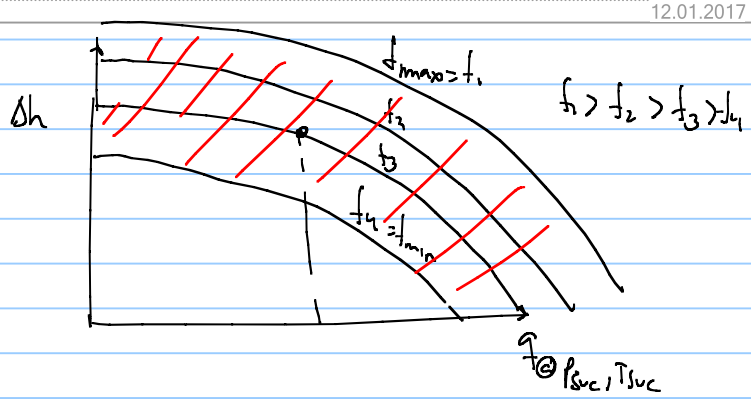
20180320 Lead $\Delta h = \frac{\Delta p}{\rho \cdot g}$

pure oil $\rho_o = 790\ kg/m^3$

$\Delta p = \Delta h \cdot 790\ kg/m^3$

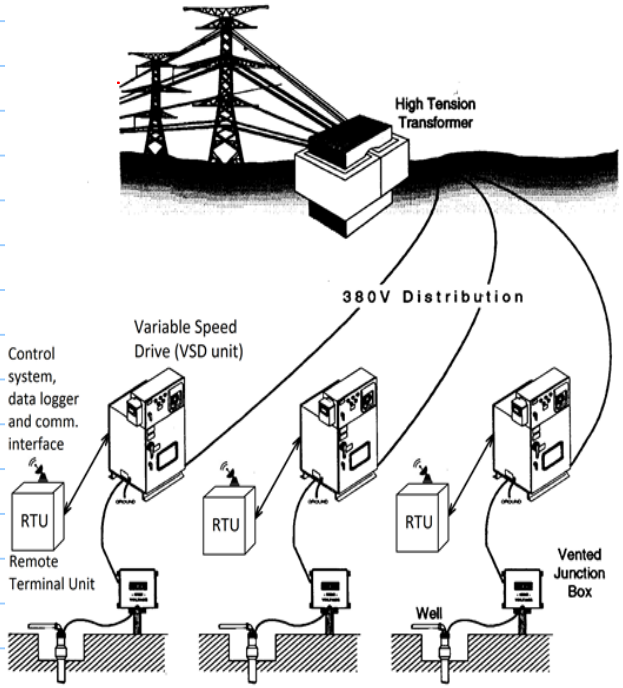
pure water $\rho_w = 1024\ kg/m^3$

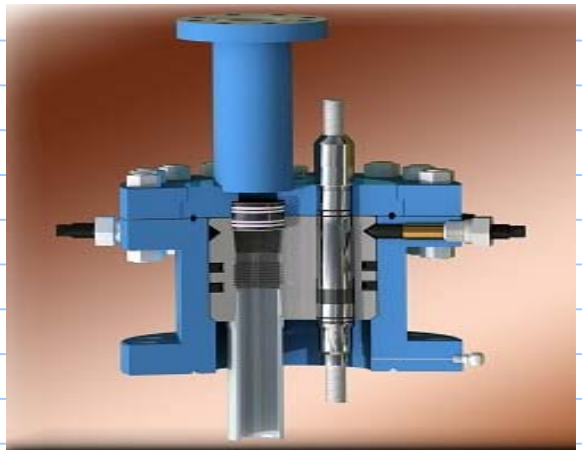
$\Delta p_{water} = \Delta h \cdot 1024\ kg/m^3$



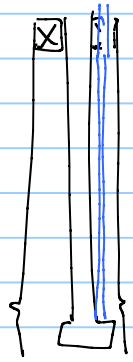
$f_1 > f_2 > f_3 > f_4$

to control performance ESP one can change the rotational speed of pump (impeller) frequency h_z 30 - 70

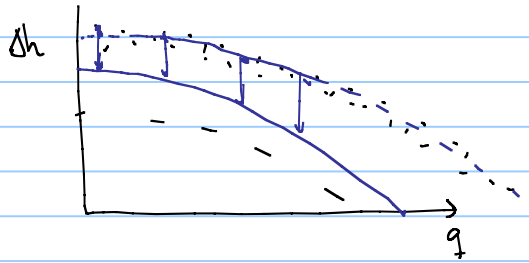




power, P, T transducer



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



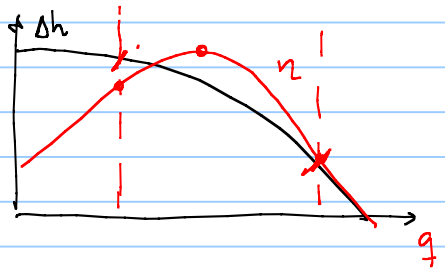
manufacturers usually measure for a ref fluid (water) at reference frequency (60 hz)

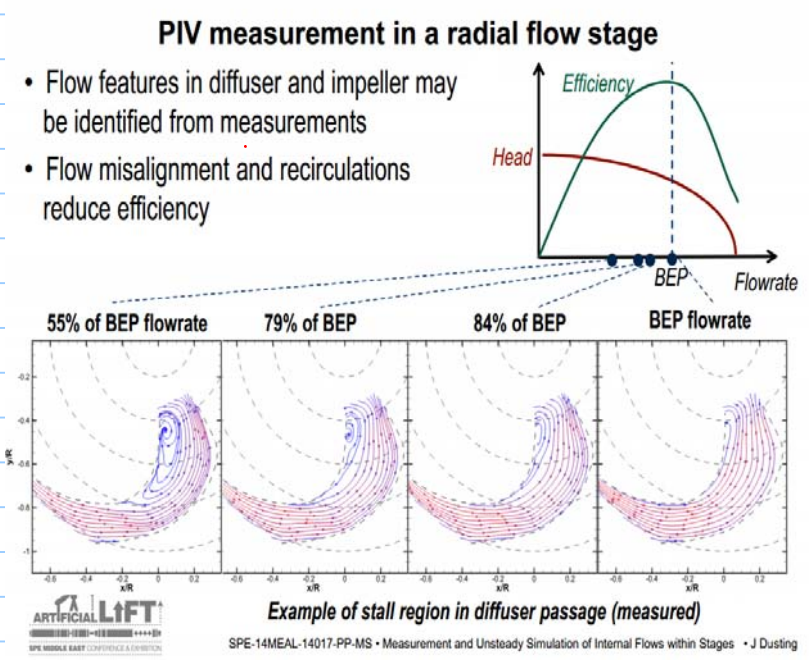
$$\frac{\Delta h_1}{\Delta h_{ref}} = \left(\frac{f_1}{f_{ref}}\right)^2 \qquad \frac{q_1}{q_{ref}} = \frac{f_1}{f_{ref}} \qquad q_{ref} = q_1\left(\frac{f_{ref}}{f_1}\right)$$

$$\Delta h_{@f} = \left(a\,q^4 + b\,q^3 + c\,q^2 + d\,q + e\right)\left(\frac{f}{f_{ref}}\right)^2$$

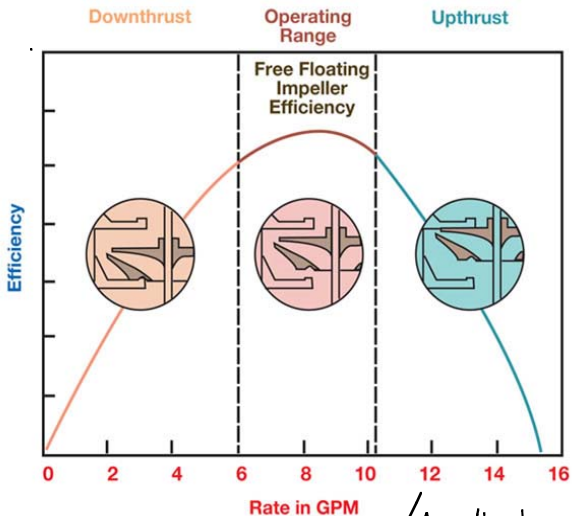
$$\Delta h_{@f} = a\left[q_1\left(\frac{f_{ref}}{f_1}\right)\right]^4 + b\left[q_1\frac{f_{ref}}{f_1}\right]^3 + c\left[q_1\frac{f_{ref}}{f_1}\right]^2 + d\left[q_1\frac{f_{ref}}{f_1}\right] + e$$

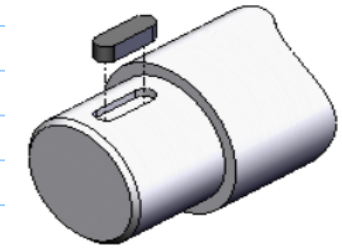
other operational constraints :

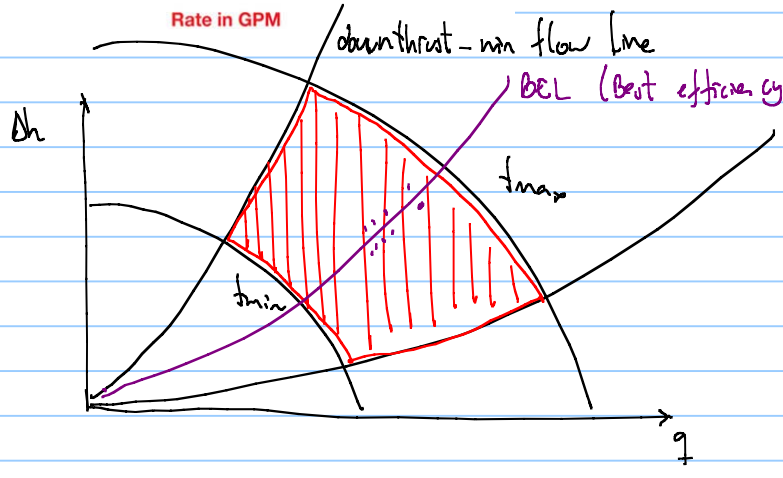




upthrust and downthrust

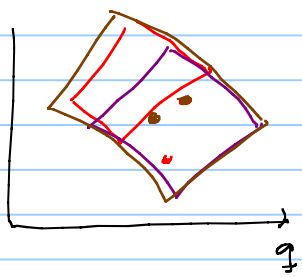


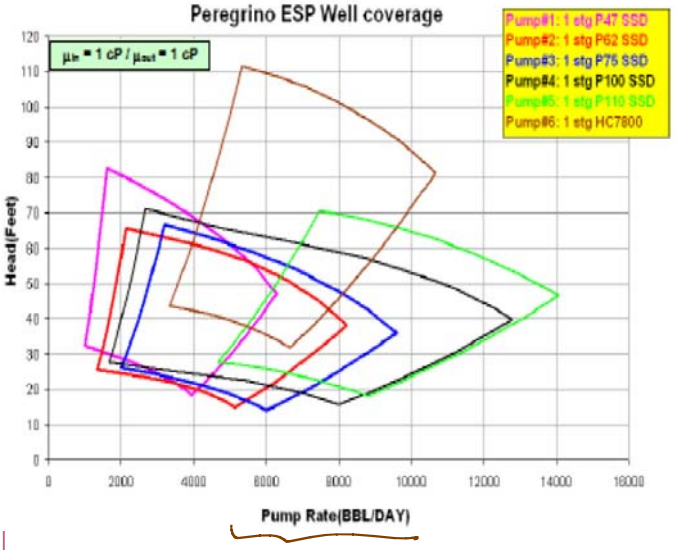




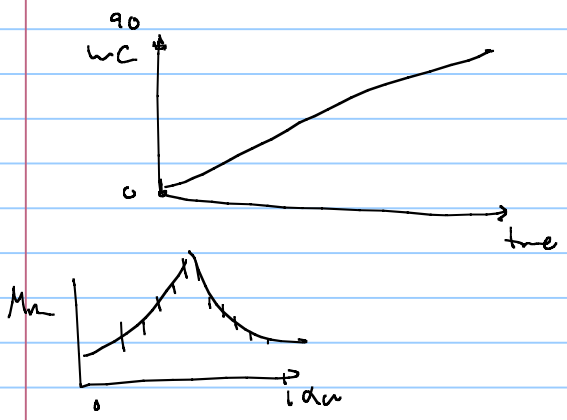
if I haven't selected an ESP yet

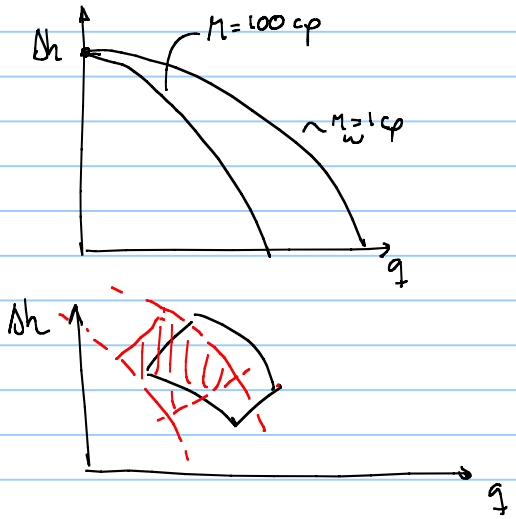
t_1 q_1
t_2 q_2
t_3 q_3





the performance of ESP is reduced by increased viscosity !

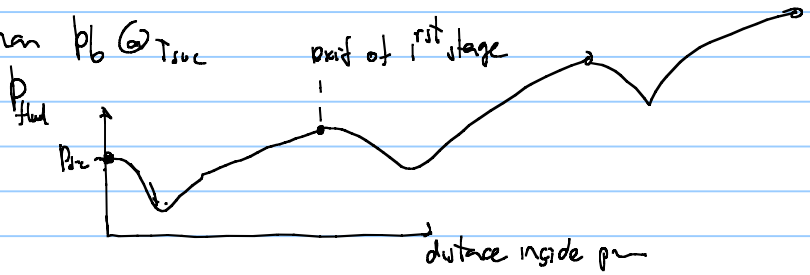




to estimate performance for a different viscosity → measurements

→ American national standard (Hydraulic Institute) ANSI/HI 9.6.7 - 2015

- $P_{suction}$ has to be greater than p_b @ T_{suc}

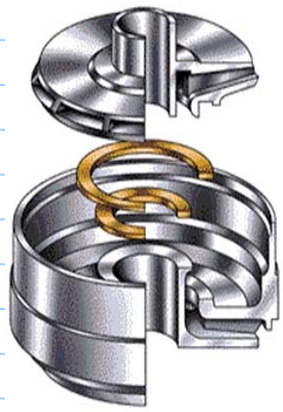


$P_{suc} > F \cdot p_b$ @ T_{suc}

safety factor

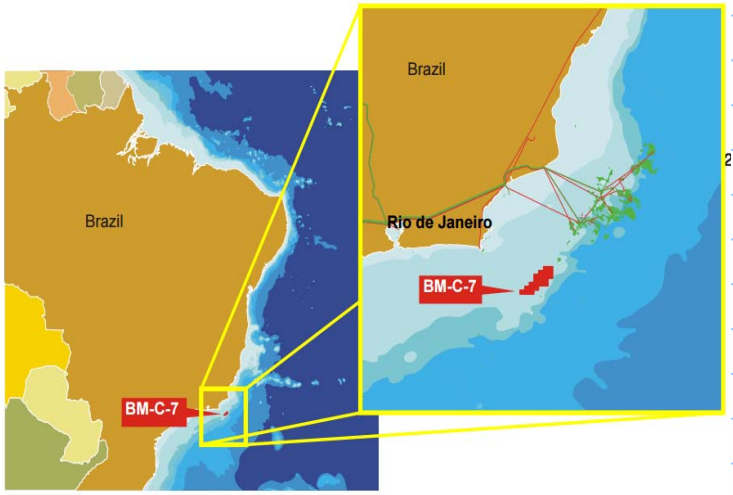
- Power ≤ Power capacity motor

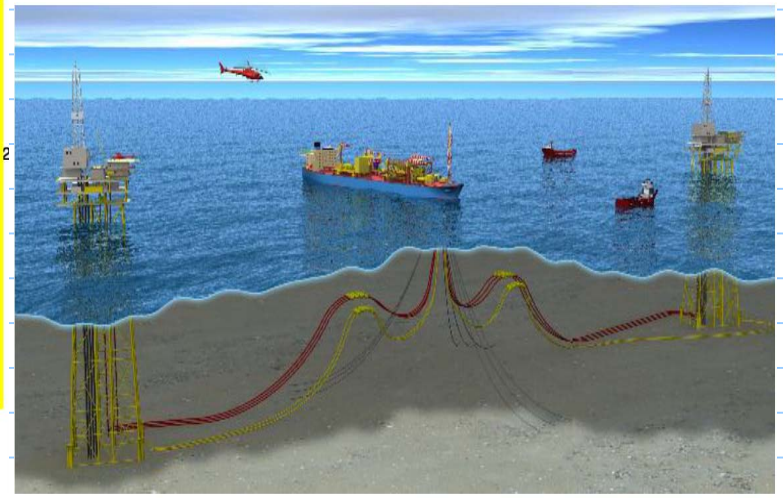
$$Power_{pump} = \frac{\Delta p \cdot q}{\eta_m \eta_H}$$

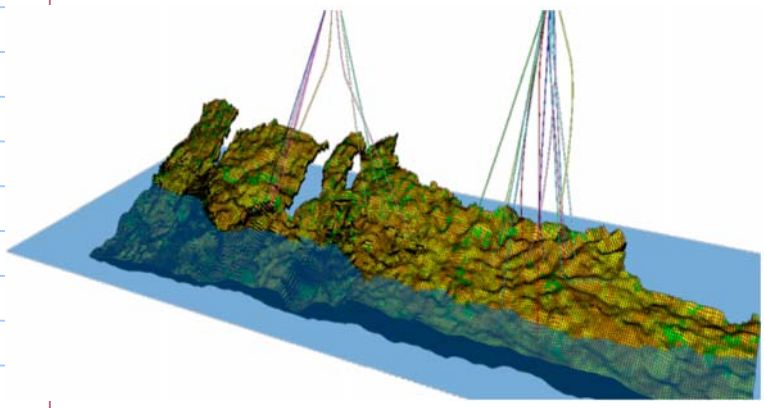


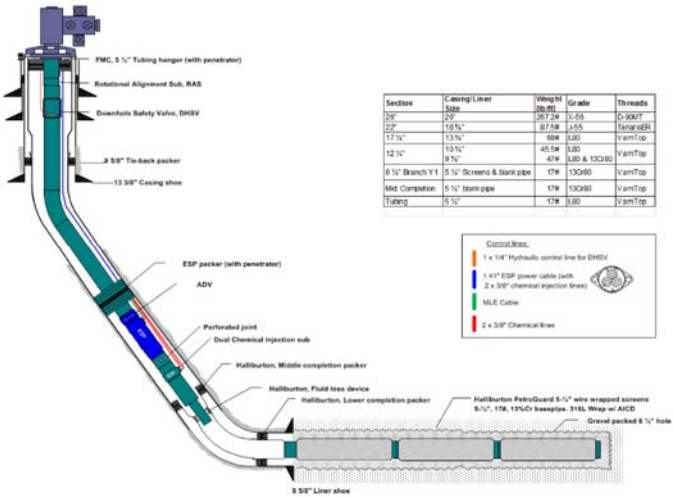
Class exercise:

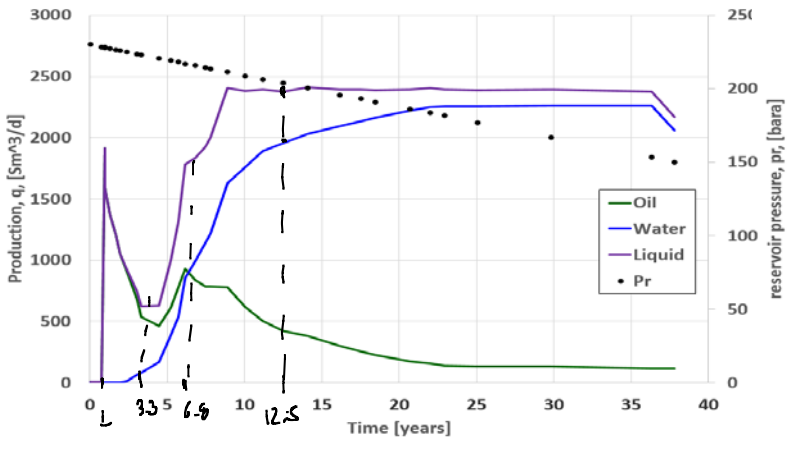
http://folk.ntnu.no/stanko/Courses/TPG4230/2018/Class_files/20180320/









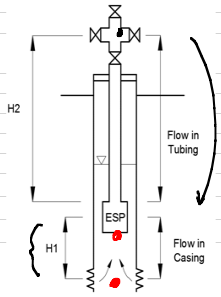


2018.03.20, TPG4230, Class Exercise, M. Stanko

Wells	p_R	J, for total liquid flow	h1	h2	d1	d2	Pumpname	Stages
-	bara	Sm^3/d/bar	m	m	m	m	-	-
1	231	14	380	1960	0.24	0.14	Centrilift 675	78

	Water	Oil	
Fluid Density	1025	897	[kg/m^3]
Richardson Emul. exp.	13	3.215	
Viscosity	1.00E-03	0.1	[Pa s]
α_w cut off	0.60		
Roughness tubing and lines	0.00010	m	
Bubble point pressure [bara]	30	[bara]	

Required pressure at pump intake 36



$(p_{du} - p_{suc})$

Mechanic efficiency 0.95
Max pump power [hp] 760

Date [years]	p_R bara	WC [-]	Average density kg/m^3	Effective viscosity Pa s	q_{tot} Sm^3/d	p_{wf} bara	q_o Sm^3/d	q_w Sm^3/d	p_{suc} bara	p_{disc} bara	Δp_{ESP} bara	Δh_{ESP} m	p_{wh} bara	Pump power [hp]	Hydraulic Effic [%]	frequency Hz
1.0	230	0.00			1912								7			
3.3	223	0.13			621								7			
6.8	216	0.54			1833								7			
12.5	204	0.82			2379								7			

IPR

$q_{\bar{L}} = J_L (p_R - p_{wf})$

$h_1 = h_2 + \Delta h_1$

$p_{in}(-,-,-)$ Δp ρg

Function Pout(qt, ID, den, visc, Length, teta, pin, roughness)

assume $B_o \approx 1$

$B_w \approx 1$

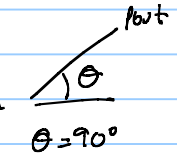
$q_{\bar{o}} = q_{o@p,T}$

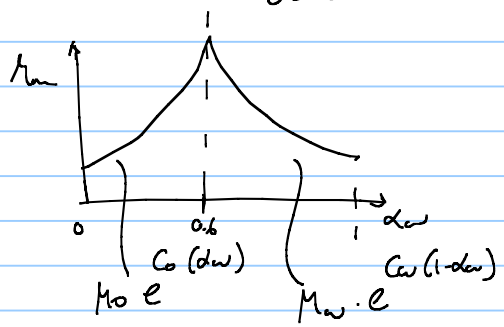
$q_{\bar{w}} = q_{w@p,T}$

$WC = \frac{q_{\bar{w}}}{q_{\bar{o}} + q_{\bar{w}}} = \alpha_w = \frac{q_w}{q_o + q_w}$

$\rho_m = \alpha_w \rho_w + (1-\alpha_w)\rho_o$

Function Avprop(WC, Po, Pw)





Rich_emul_visc(muo, muw, alphaw, expo, expw, alphaw_cutoff)

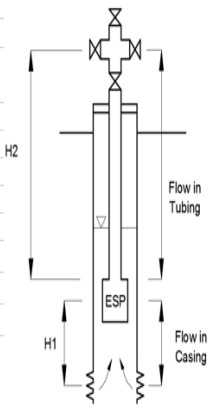
final operating points after adjustments

2018.03.20, TPG4230, Class Exercise, M. Stanko

Wells	p_R	J, for total liquid flow	h1	h2	d1	d2	Pumpname	Stages
-	bara	Sm^3/d/bar	m	m	m	m	-	-
1	231	14	380	1960	0.24	0.14	Centrilift 675	78

	Water	Oil	
Fluid Density	1025	897	[kg/m^3]
Richardson Emul. exp.	13	3.215	
Viscosity	1.00E-03	0.1	[Pa s]
α_w cut off	0.60		
Roughness tubing and lines	0.00010	m	
Bubble point pressure [bara]	30	[bara]	

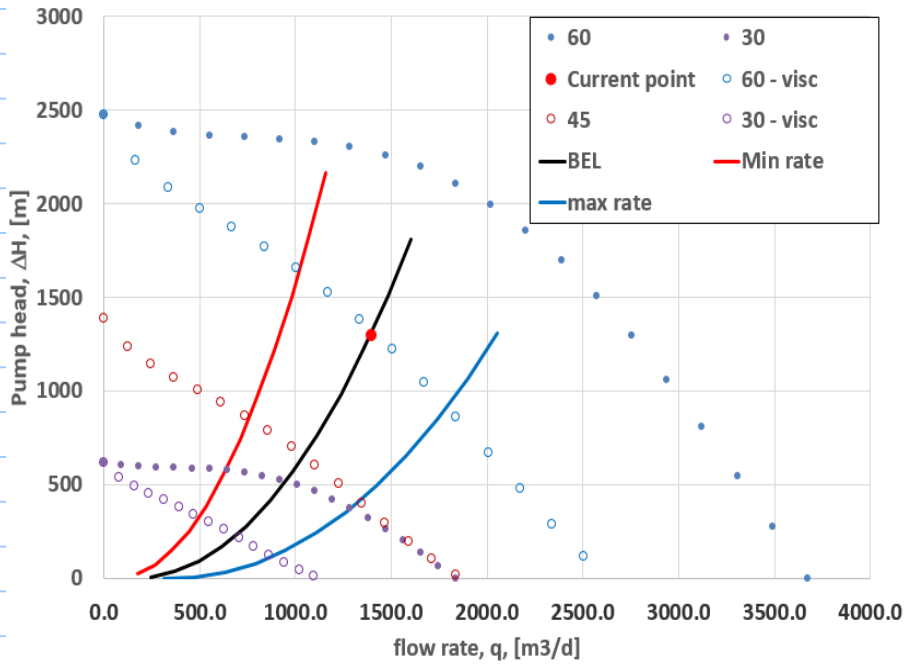
Required pressure at pump intake 36



Mechanic efficiency 0.95
Max pump power [hp] 760

Date [years]	p_R bara	WC [-]	Average density kg/m^3	Effective viscosity Pa s	q_{tot} Sm^3/d	p_{wf} bara	q_o Sm^3/d	q_w Sm^3/d	p_{suc} bara	p_{disc} bara	Δp_{ESP} bara	Δh_{ESP} m	p_{wh} bara	Pump power [hp]	Hydraulic Effic [%]
1.0	230	0.00	897	0.100	1912	93			59.9	186	127	1439	7		
3.3	223	0.13	914	0.153	621	179			144.5	184	40	442	7		
6.8	216	0.54	966	0.572	1400	116			79.5	202	123	1298	7		
12.5	204	0.82	1002	0.010	1800	75			37.7	203	166	1684	7		

for year 6.8 :


3000
2500
2000
1500
1000
500
0
Pump head, ΔH, [m]
0.0
500.0
1000.0
1500.0
2000.0
2500.0
3000.0
3500.0
4000.0
flow rate, q, [m3/d]
60
30
Current point
60 - visc
45
30 - visc
BEL
Min rate
max rate