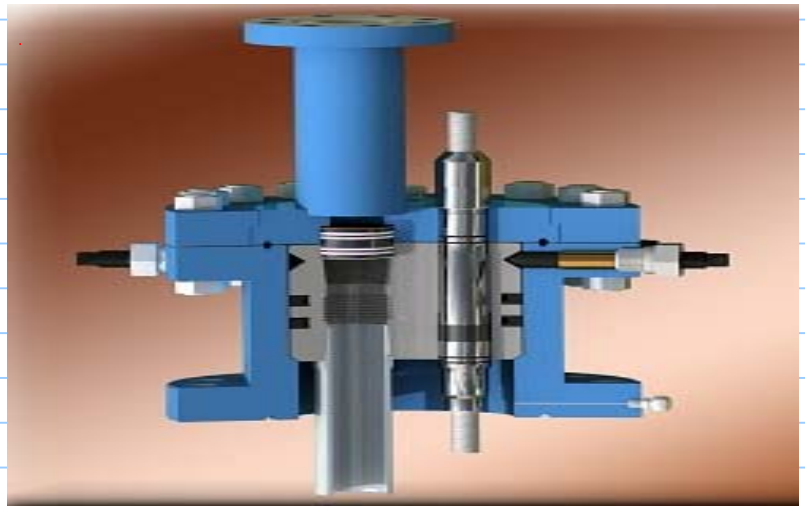
04.04.2017 . Multiphase subsea boosting
06.04.2017 . Production optimization
20.04.2017 . Course wrap-up



Operational limitations of ESP's so far

↳ $30Hz \leq f \leq 70Hz$

$P_{suc} > f \cdot P_b$

$$P_{Pump} = \Delta p \cdot q \cdot \frac{1}{\eta_H \cdot \eta_{mech}}$$

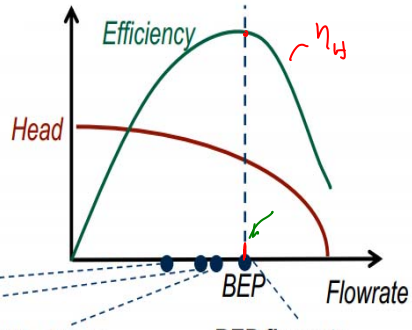
$\Delta p = P_{dis} - P_{suc}$

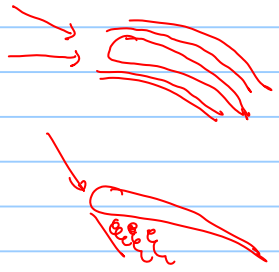
q ~ local conditions

η_H ~ fluid friction

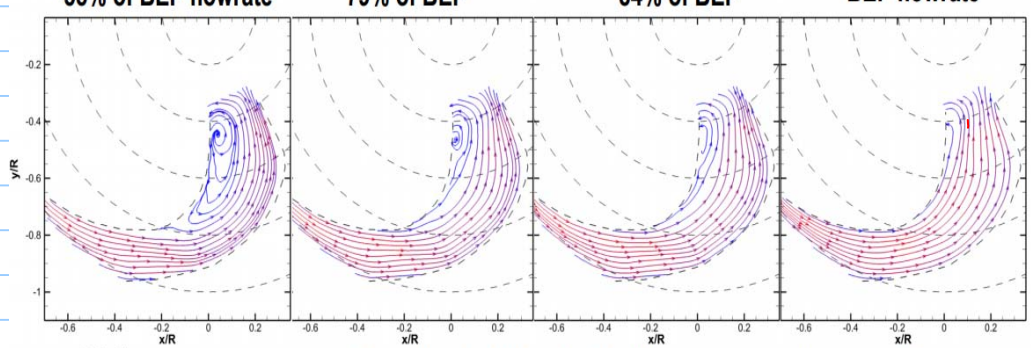
PIV measurement in a radial flow stage

- Flow features in diffuser and impeller may be identified from measurements
- Flow misalignment and recirculations reduce efficiency



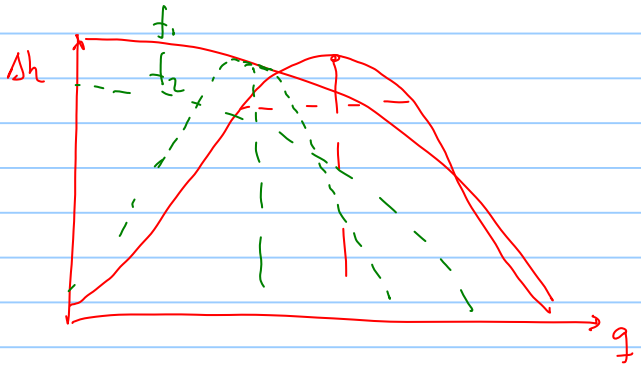


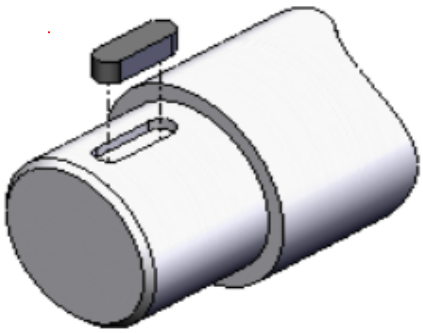
55% of BEP flowrate | 79% of BEP | 84% of BEP | BEP flowrate



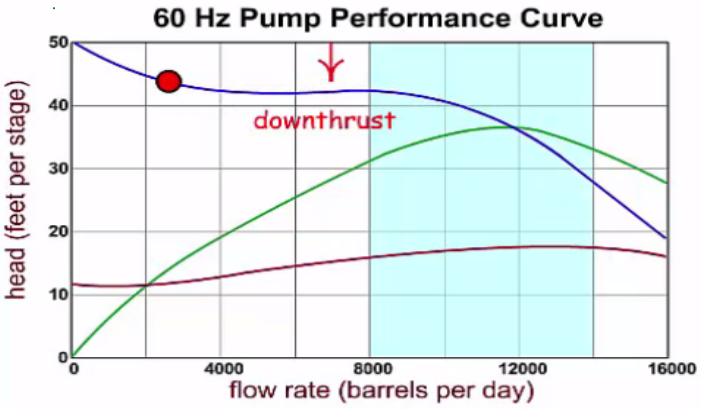
Example of stall region in diffuser passage (measured)

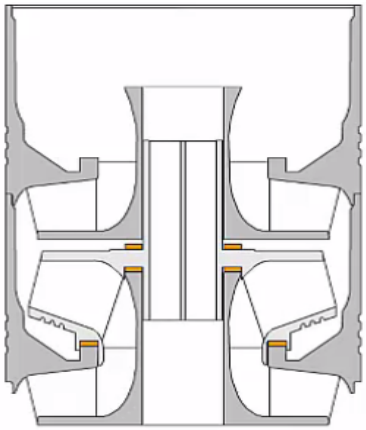
SPE-14MEAL-14017-PP-MS • Measurement and Unsteady Simulation of Internal Flows within Stages • J Dusting



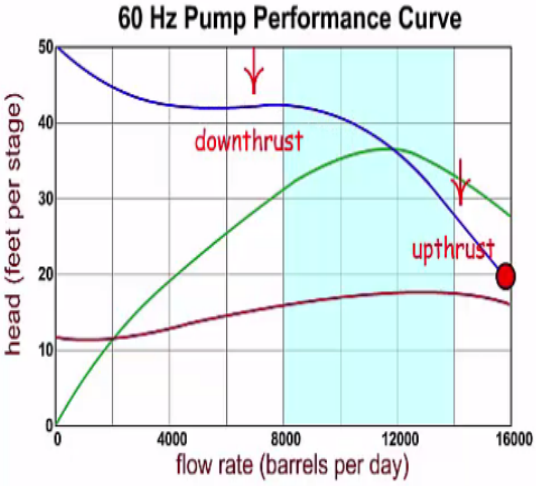


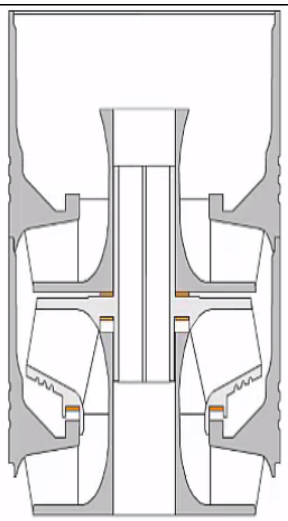
In mechanical engineering, a **key** is a machine element used to connect a rotating machine element to a shaft.



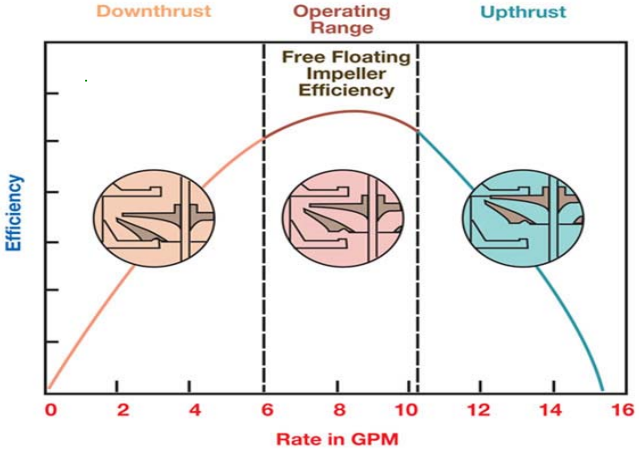


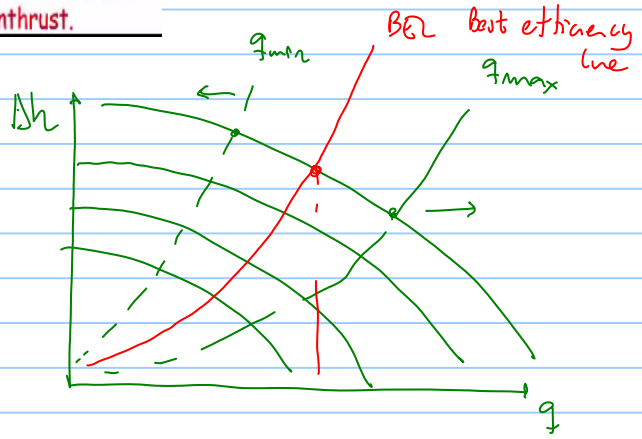
Until it reaches a certain point on the curve where it goes in to downthrust.

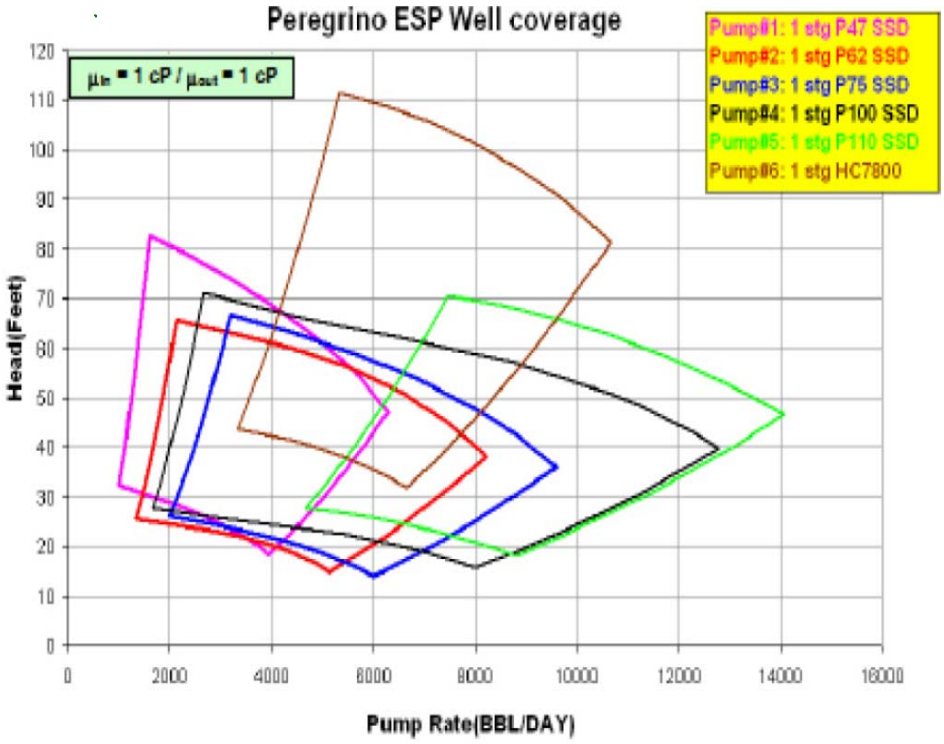


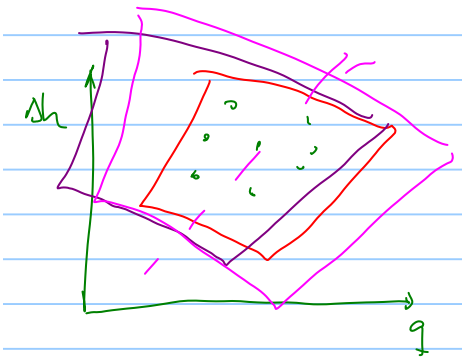


It will not go into upthrust at the same point it went into downthrust.









- maximum power capacity of motor (100 hp ~ 1600 hp)

$$P = \frac{\Delta p\, q}{\eta_H \eta_m} \leq \text{Power installed}$$

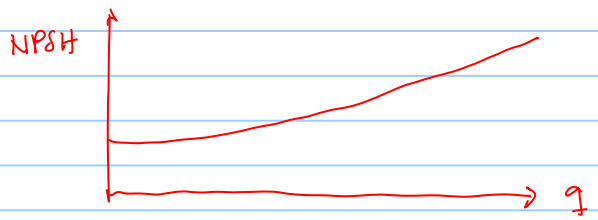
- Cavitation

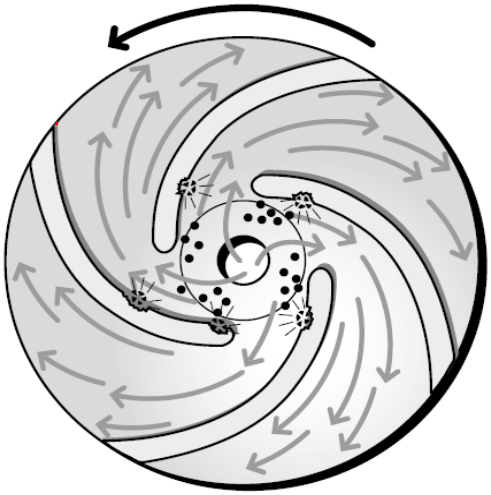
distance along the flowpath from pump inlet to pump outlet

p_{suct} > that limit

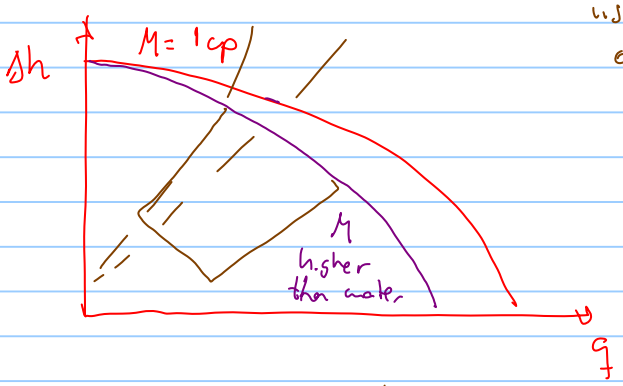
NPSH net positive suction head [m]

(Δp Δh with ρ change to bara)





Effect of viscosity

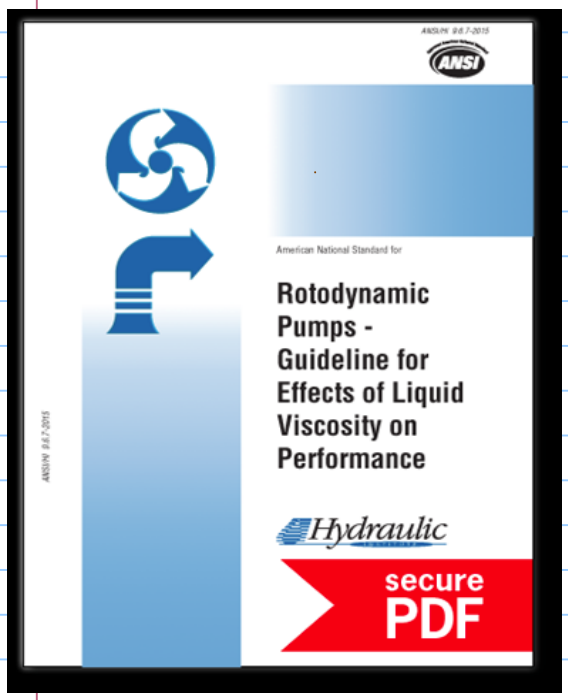


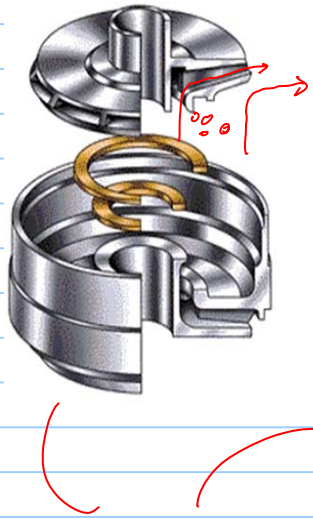
viscosity reduces the operational envelope of pump!

how to estimate pump performance with viscosity

↳ lab testing

↳ hydraulic institute method not 100% accurate!



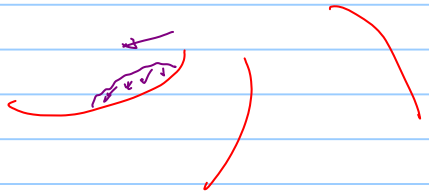


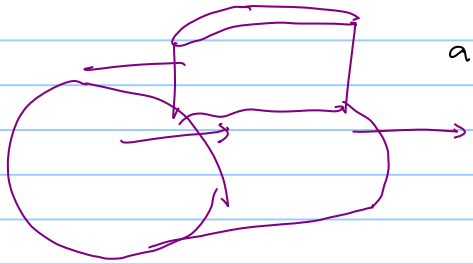
mixed flow
↳ axial
radia

Δp per stage is
usually.

very tolerant to gas

GVF ≈ 10%
gas volume fraction
↳ actual cond.
local cond





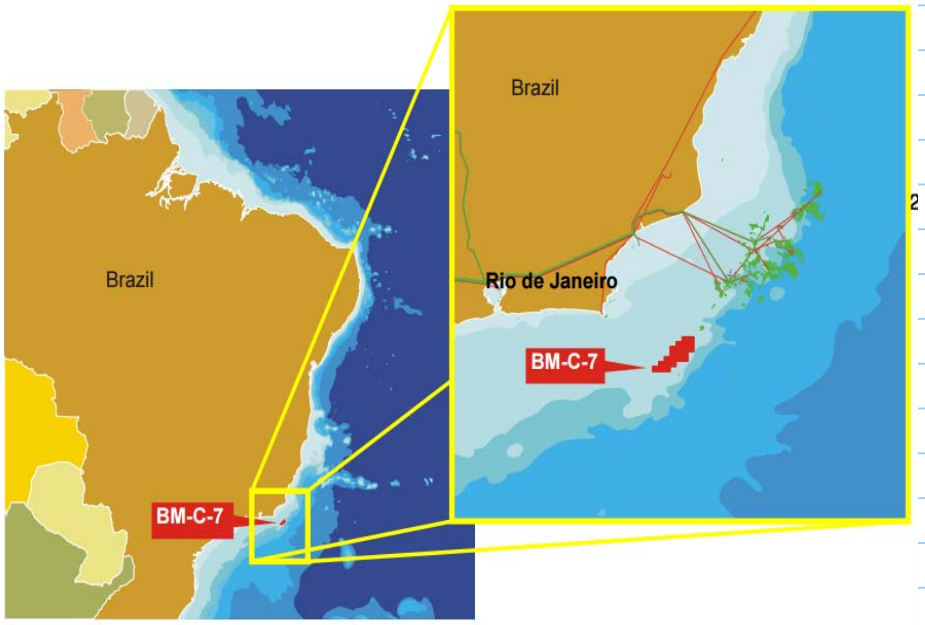
axial impeller. not used
in ESPs.

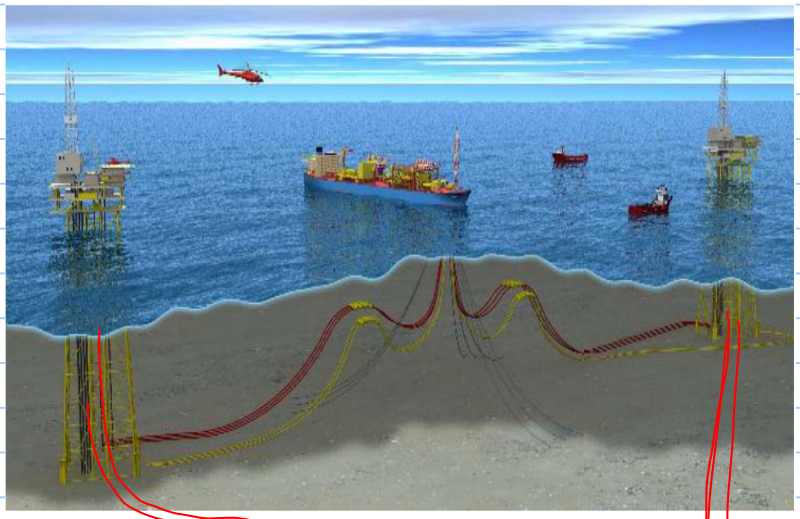
//

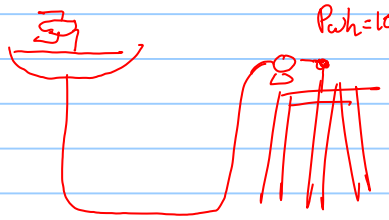
Class exercise

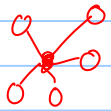
http://folk.ntnu.no/stanko/Courses/TPG4230/2017/Class_files/20170330/

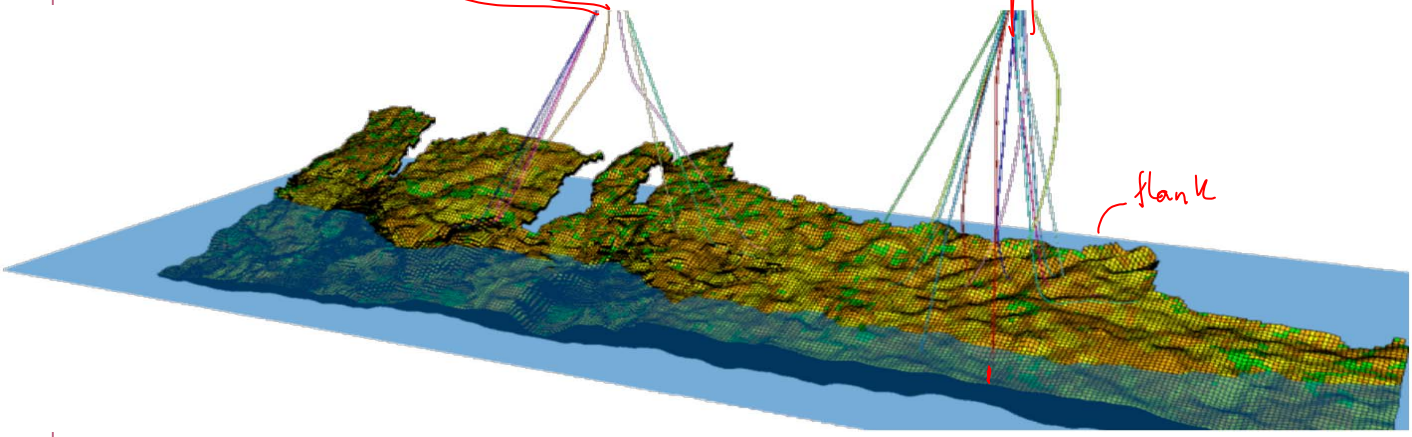
the Peregrino field :



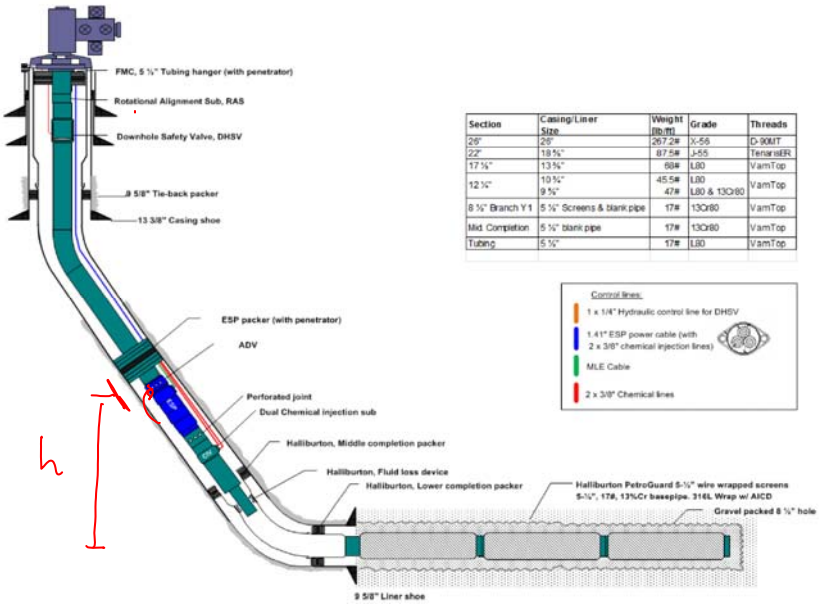




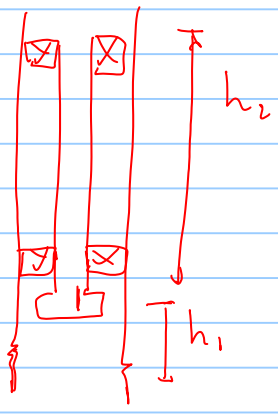




- LQ — living quarters
- Drilling module
- Movable drill rig
- Electrical plant
- Wellheads
- Booster pumps
- Water Injection
- Uptime 99% bracket



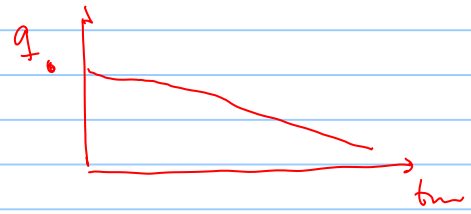
Section	Casing/Liner Size	Weight lbs/ft	Grade	Threads
26"	26"	267.2#	X-56	D-90MT
22"	18 ⅝"	87.5#	J-55	TenarisBR
17 ½"	13 ⅜"	68#	L80	VamTop
12 ¼"	10 ¾"	45.5#	L80	VamTop
	9 ⅝"	47#	L80 & 13Cr80	
8 ½" Branch Y1	5 ½" Screens & blank pipe	17#	13Cr80	VamTop
Mid. Completion	5 ½" blank pipe	17#	13Cr80	VamTop
Tubing	5 ½"	17#	L80	VamTop

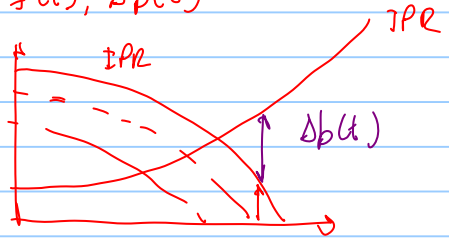


Design process of ESP for the field lifetime

Reservoir department → Production department

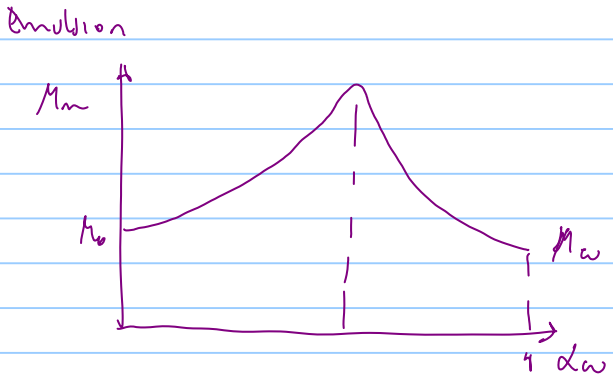
$q_i^w(t)$, P_{wf}^i → $q(t)$, $\Delta p(t)$

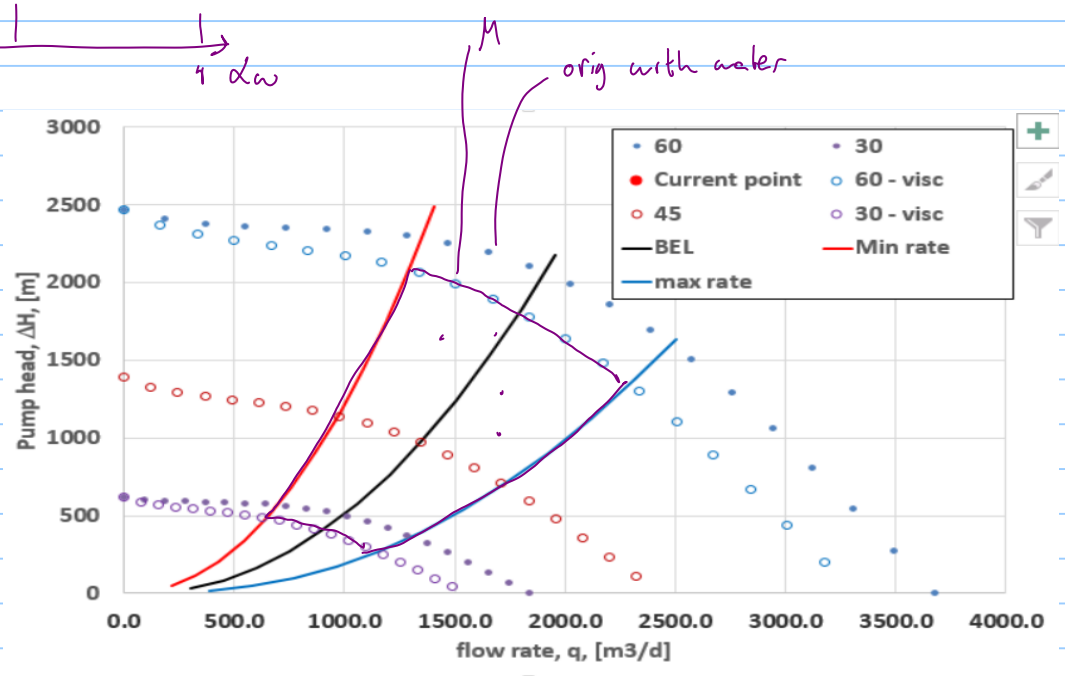




find an equipment such that covers Δp, $q(t)$ for most of lifetime with high efficiency not gas at inlet at affordable price

↳ you : select an ESP model to produce $t_1 - t_3$ but you cannot produce in this interval $t_3 - t_5$





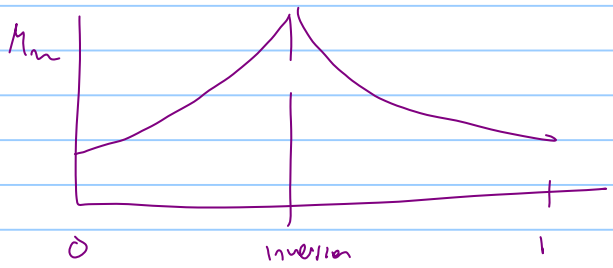
$q_o = q_o$ no dissolved gas

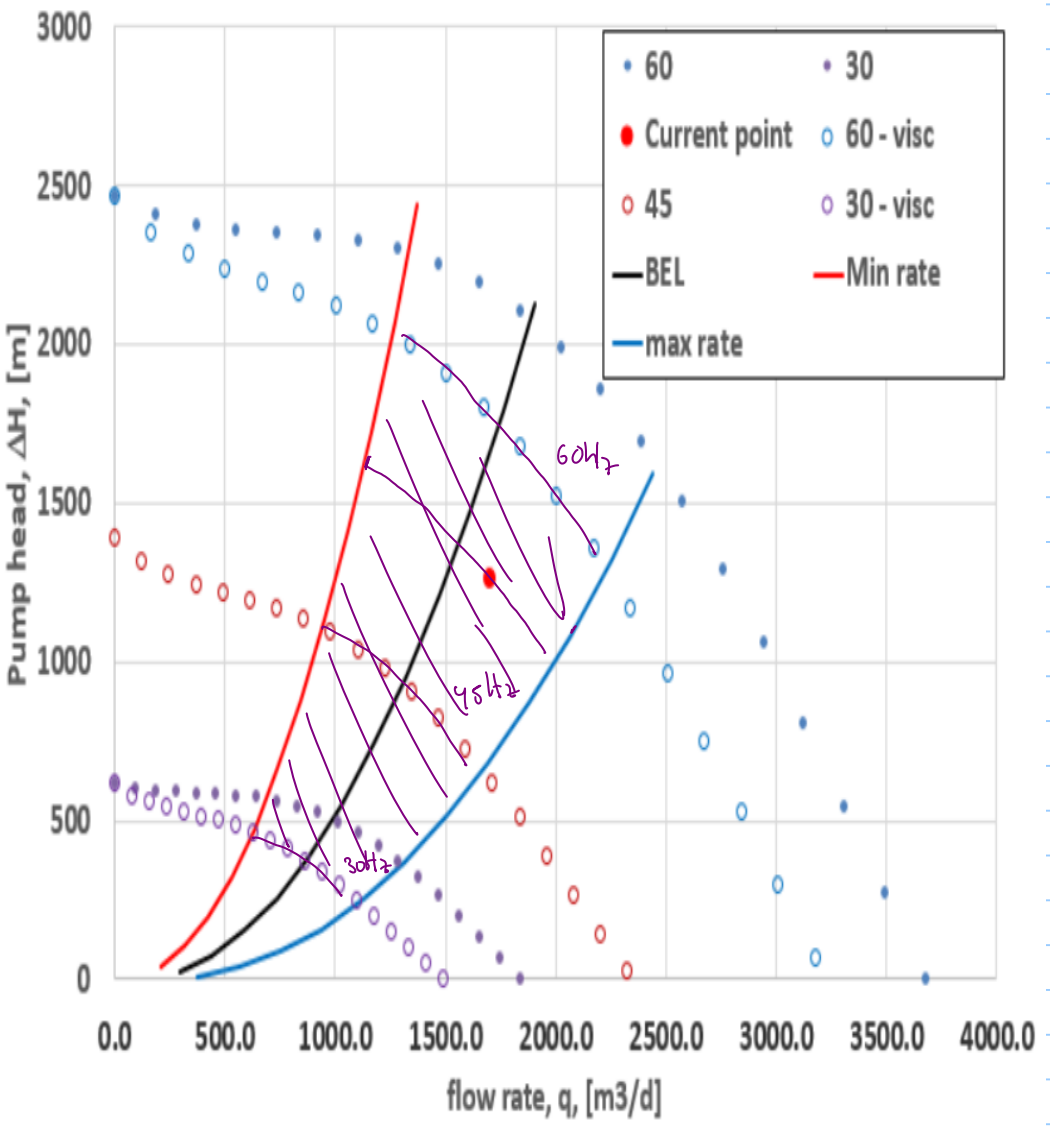
$q_w = q_w$

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

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

$\mu_m = \mu_{cont} e^{c \cdot \alpha_{dispersed}}$





$q = 1700\ Sm^3/d$

$\Delta p = 111$ bara

$\mu = 0.138$ Pa.S

$\rho = 910\ kg/m^3$

$f \simeq 52.5\ Hz$

$P = \frac{\Delta p \cdot q}{\eta_H \eta_{mech}}$

2017.03.30, 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

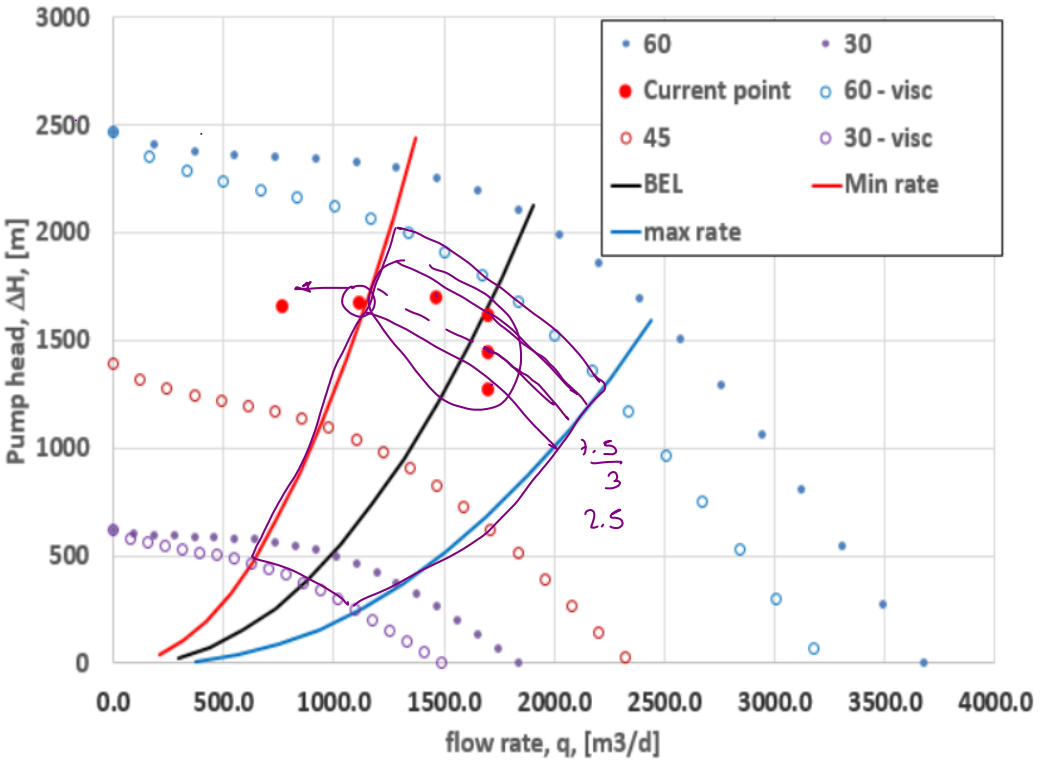
	Water	Oil	
Fluid Density	1025	897	[kg/m^3]
Richardson Emul. exp.	13	3.215	
Viscosity	1.00E-03	0.1	[Pa s]
α_w cut off	0.60		
Roughness tubing and lines	0.00010	m	
Bubble point pressure [bara]	30	[bara]	

Required pressure at pump intake: 36

Mechanic efficiency: 0.95

Max pump power [hp]: 760

Wells	p_R	WC	Average density	Effective viscosity	q_{tot}	p_{wf}	q_o	q_w	p_{suc}	p_{disc}	Δp_{ESP}	Δh_{ESP}	p_{wh}	Pump power	Hydraulic Effic	frequency
-	bara	[-]	kg/m^3	Pa s	Sm^3/d	bara	Sm^3/d	Sm^3/d	bara	bara	bara	m	bara	[hp]	[%]	Hz
	231	0.10	910	0.138	1700	110	1530	170	75.6	188	113	1265	7	402.4	74.06	52.5
	215	0.10	910	0.138	1700	94	1530	170	59.6	188	129	1445	7	465.1	73.15	55.0
	200	0.10	910	0.138	1700	79	1530	170	44.6	188	144	1613	7	526.0	72.20	57.5
	175	0.10	910	0.138	1470	70	1323	147	36.0	187	151	1693	7	496.3	69.47	56.0
	150	0.10	910	0.138	1120	70	1008	112	36.0	185	149	1673	7	406.5	63.86	53.5
	125	0.10	910	0.138	771	70	694	77	36.0	184	148	1656	7	325.9	54.25	52.5



52.5
55
57.5