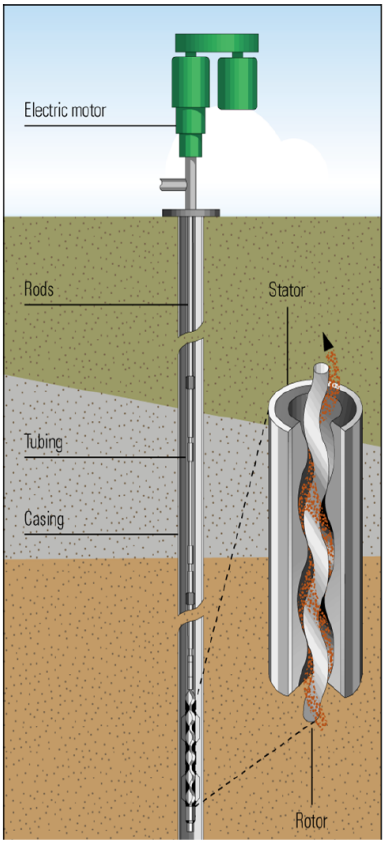
Note Title 14.03.2016

# Artificial lift methods:

- Gas lift
- Electric submersible pump (ESP)
- PCP progressive cavity pump → M↑
- Rod pump ↓ q




← positive displacement principle

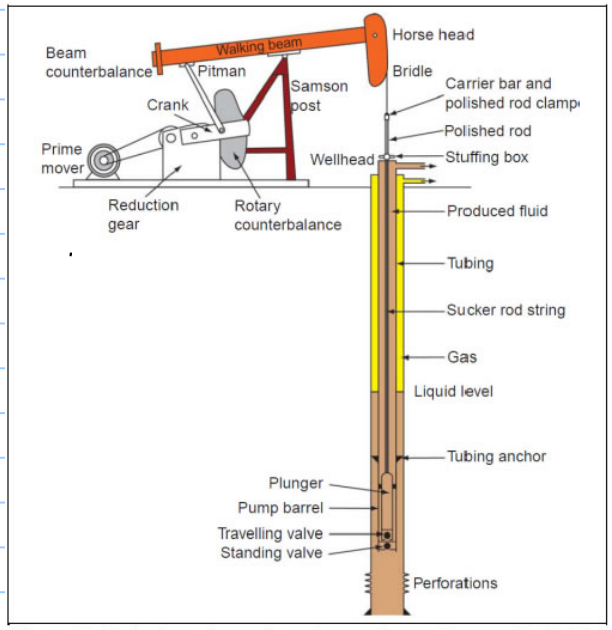
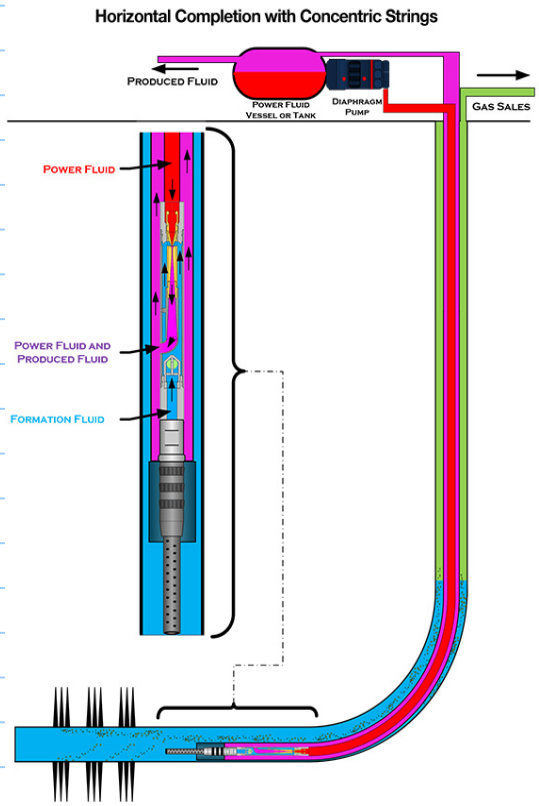
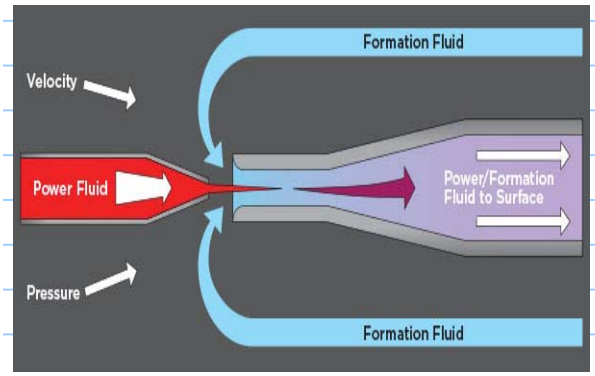
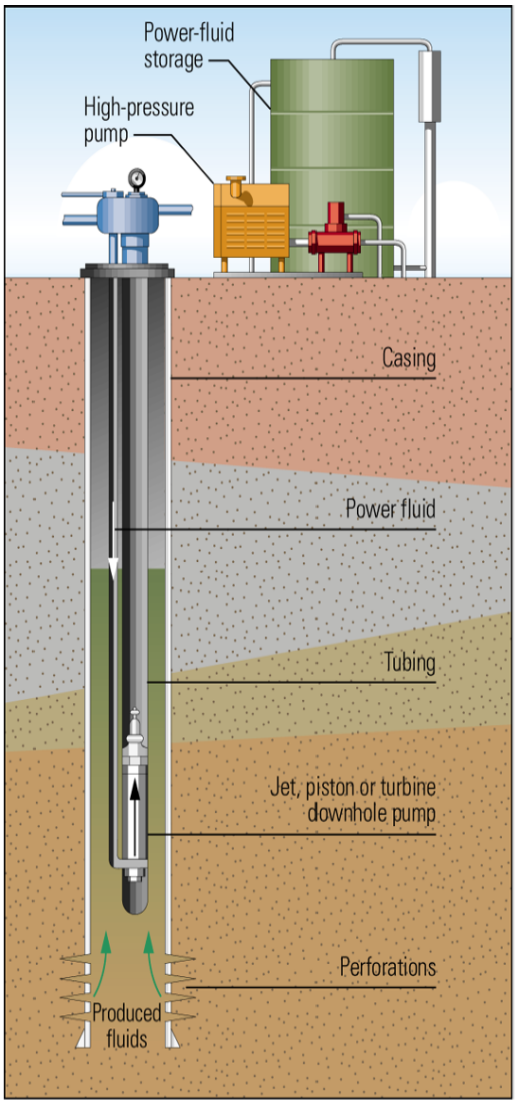



**Figure 2. Typical configuration of a sucker rod pump (Bellarby, 2009).**

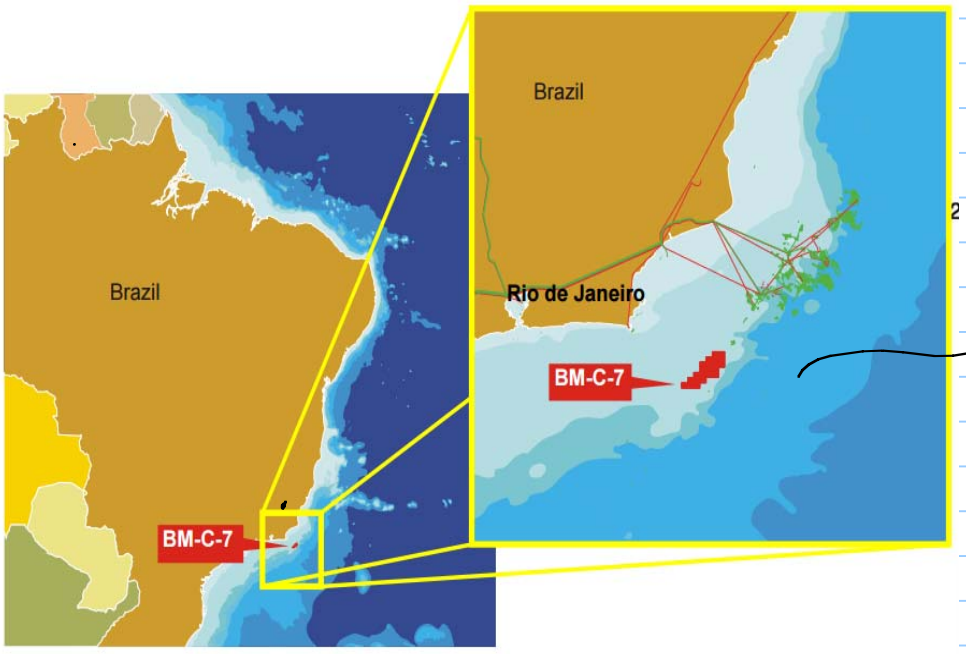
- Jet pump






Peregrino field



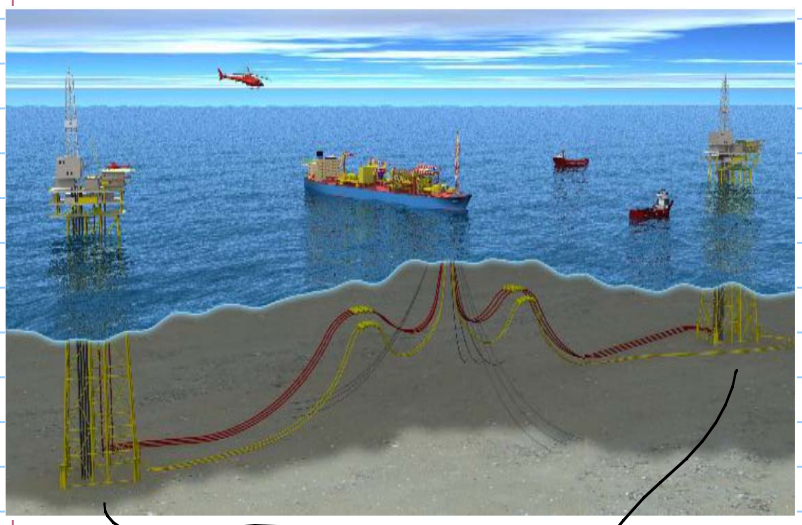

100 m

API : 14

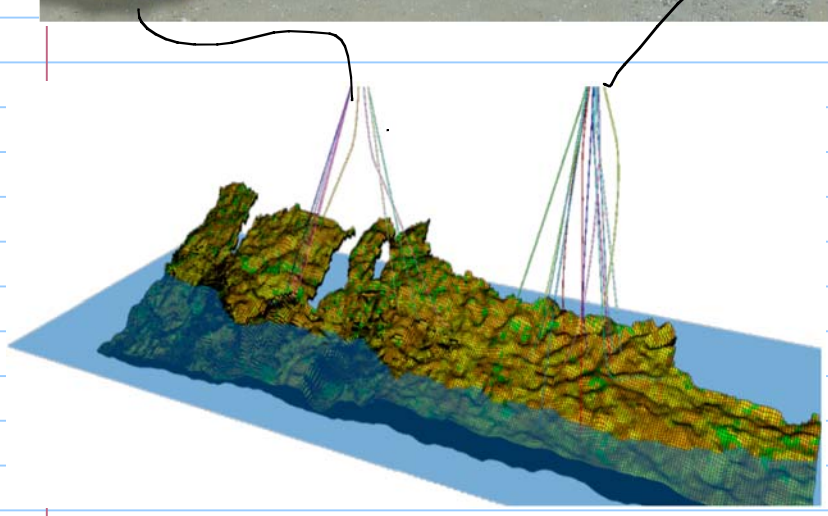
$\mu_o$ = 120 - 200 cp @ $T_R$

GOR ≈ 100 $S_{m^3}/S_{m^3}$

aquifer and water reinjection

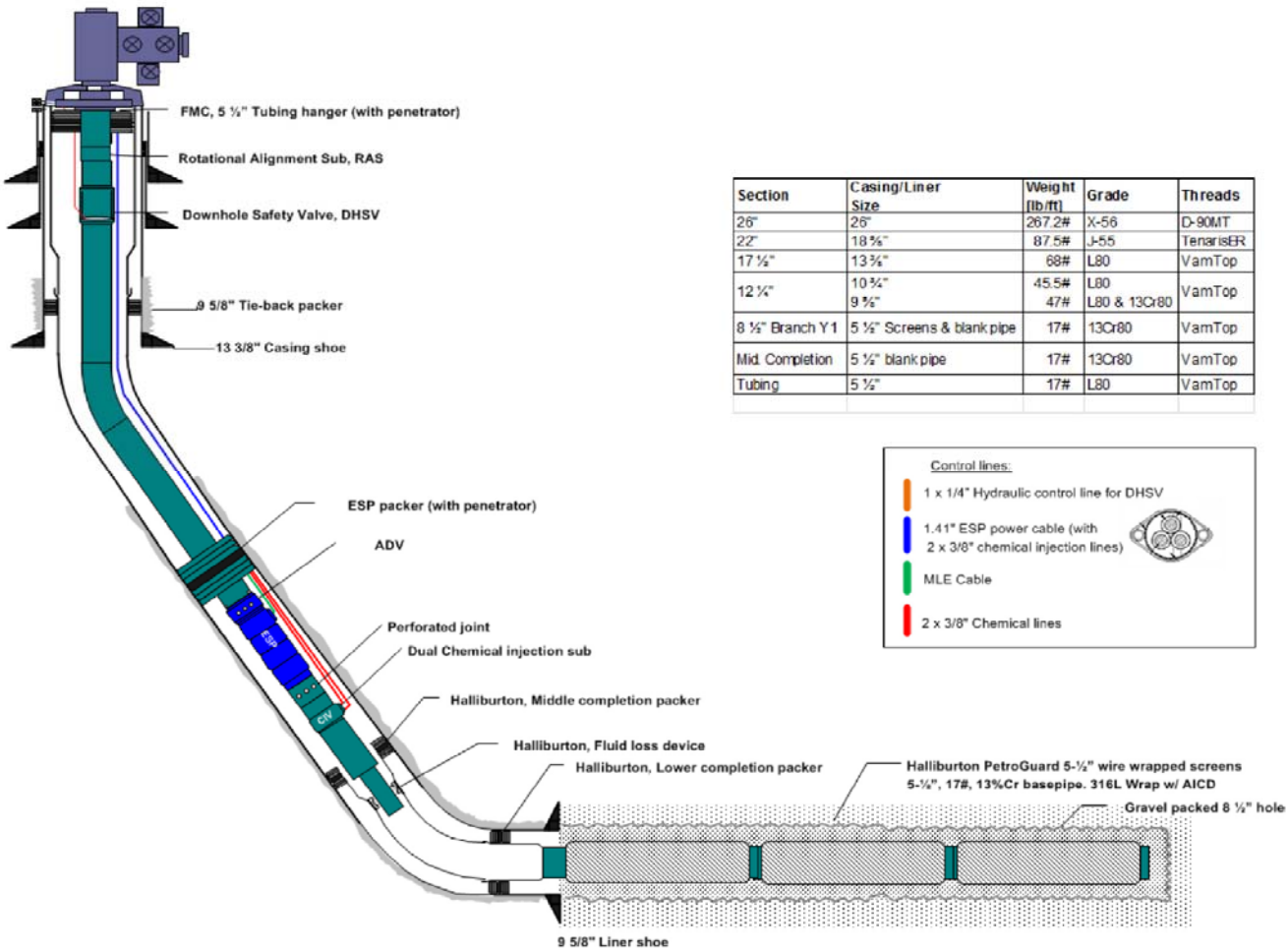


- LQ
- Drilling module
- Movable drill rig
- Electrical plant
- Wellheads
- Booster pumps
- Water Injection
- Uptime 99% bracket



typical life of ESP (5 years)
medium life (2 years – 1 year)

- frequent startups ~ shutdowns hurt the life of the pump.
- Sand production

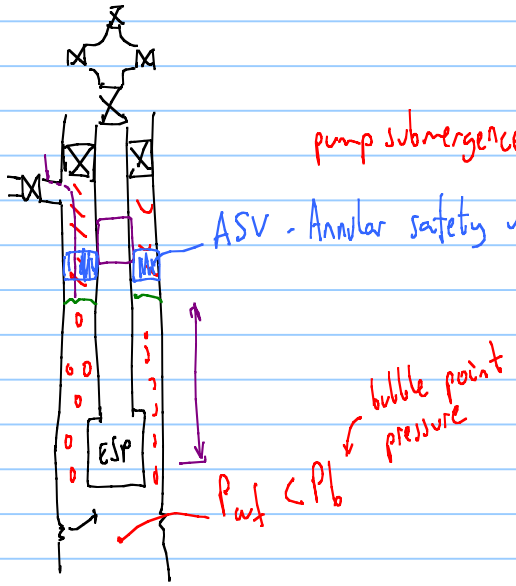


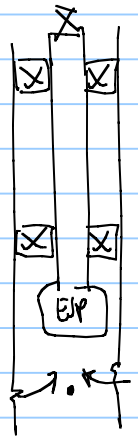

| Section | Casing/Liner Size | Weight [lb/ft] | Grade | Threads |
|---|---|---|---|---|
| 26" | 26" | 267.2# | X-56 | D-90MT |
| 22" | 18 ⅝" | 87.5# | J-55 | TenarisBR |
| 17 ½" | 13 ⅜" | 68# | L80 | VamTop |
| 12 ¼" | 10 ¾"<br>9 ⅝" | 45.5#<br>47# | L80<br>L80 & 13Cr80 | VamTop |
| 8 ½" Branch Y1 |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

Control lines:
- 1 x 1/4" Hydraulic control line for DHSV
- 1.41" ESP power cable (with 2 x 3/8" chemical injection lines)
- MLE Cable
- 2 x 3/8" Chemical lines

# ESP lifted wells

- Liquid through tubing, gas through annulus
- Liquid and gas (if any) through tubing




gas affects negatively the performance of the pump
- performance
- vibration
- cooling
- frequent failures

$P_{suc} \geq F_s \cdot P_b$

$P_{suc} \geq 1.05\ P_b$

$\geq 1.05\ 30$ bar

GVF → gas volume fraction

$GVF = \frac{q_g}{q_L + q_g} \leq 0.3$ ← local

$q_L = J_L \cdot (P_R - P_{wf})$ ← initial

| 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 | | 78 |

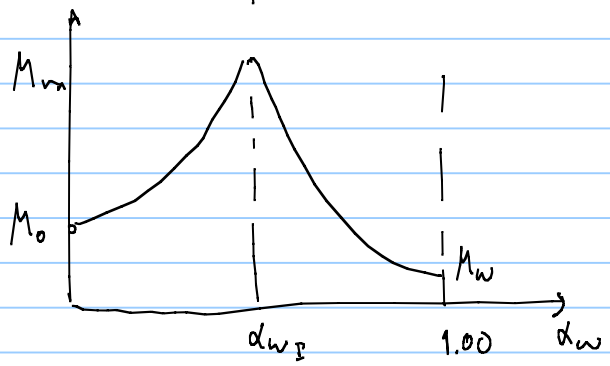
| | Water | Oil | |
|---|---|---|---|
| Fluid Density | 1025 | 897 | [kg/m^3] |
| Richardson Emul. exp. | 3.089 | 3.215 | |
| Viscosity | 1.00E-03 | 0.1 | [Pa s] |
| $\alpha_w$ cut off | 0.60 | | |
| Roughness tubing and lines | 0.00010 | m | |
| Bubble point pressure [bara] | 30 | [bara] | |

$h_1$ .. distance from sand phase to pump suction

$h_2$ .. distance from pump discharge to well head


| Wells | $p_R$ | WC | Average density | Effective viscosity | $q_{tot}$ | $p_{wf}$ | $q_o$ | $q_w$ | $p_{suc}$ | $p_{disc}$ | $\Delta p_{ESP}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| - | bara | [-] | kg/m^3 | Pa s | Sm^3/d | bara | Sm^3/d | Sm^3/d | bara | bara | bara |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

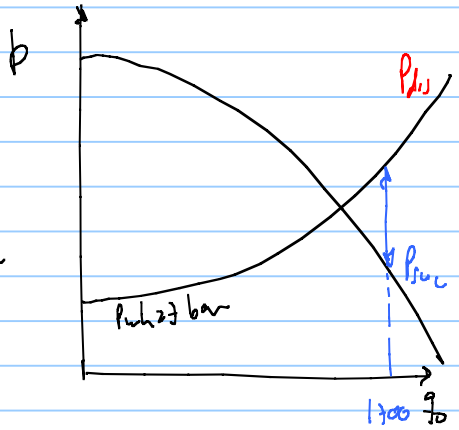
dispersion
mixture of oil and water




$q_{target} = 1700\ Sm^3/d$ oil


$\Delta p_{pm}\ (P_{cv} - P_{suc})$ @ $q_o = 1700\ Sm^3/d$

Re $q_{\bar{o}}$




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

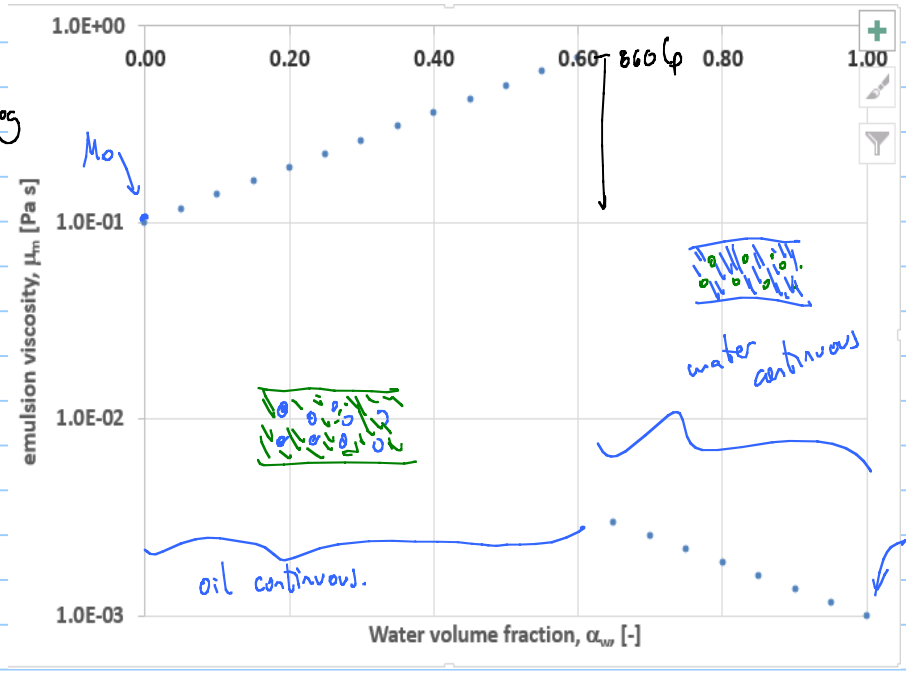
assumption

the oil and water are incompressible

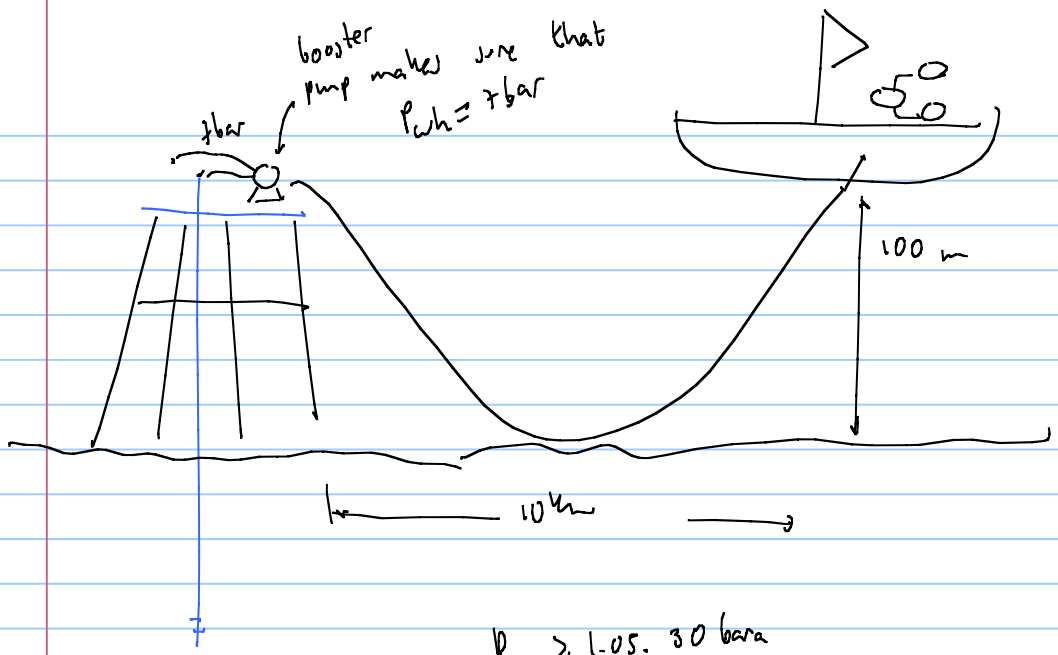
$q_{\bar{o}} = q_o(P,T)$

$q_{\bar{w}} = q_w(P,T)$

$\alpha_w(P,T) = wc$




emulsion behavior.




$P_{suc} \geq 1.05 \cdot 30$ bara

$P_{suc} \geq 31.5$ bara

Power capacity → casing size limits the maximum power capacity

↘ $

300 hp → 1500 hp

minimum maximum

600 hp → comes from the experts


$$P_{Hydraulic} = \frac{(P_2 - P_1)\, q}{\eta_{eff}}$$

$\eta_{eff}$ → ? ↗ 50% → 70%

↘ above 60%

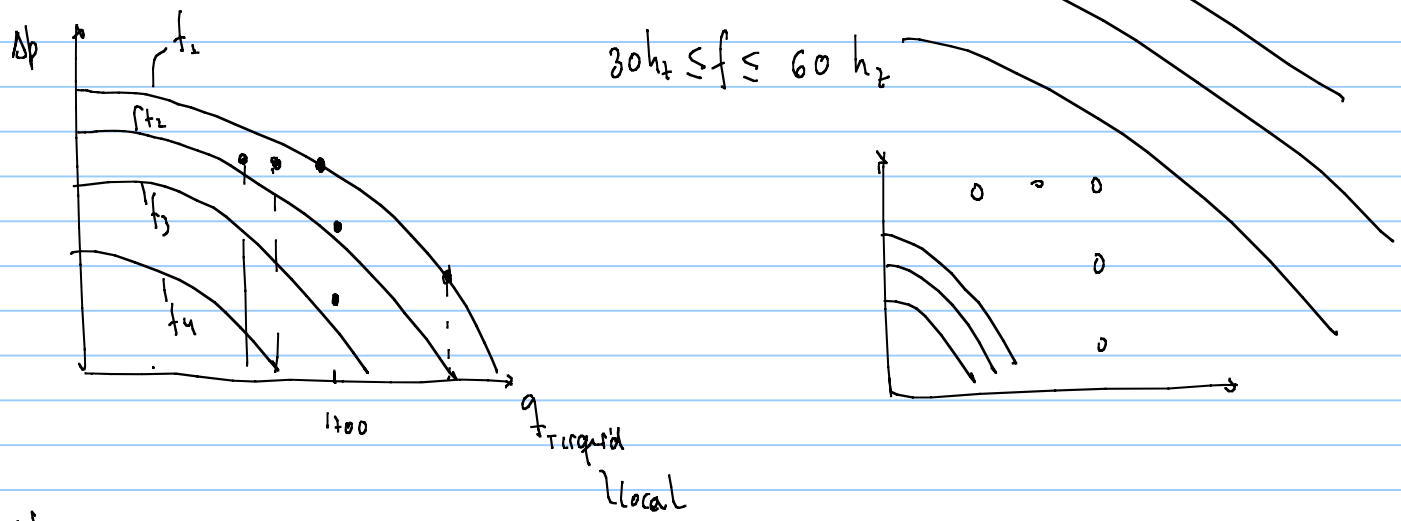
$$w = \frac{J}{s} = \frac{N \cdot m}{s} =$$

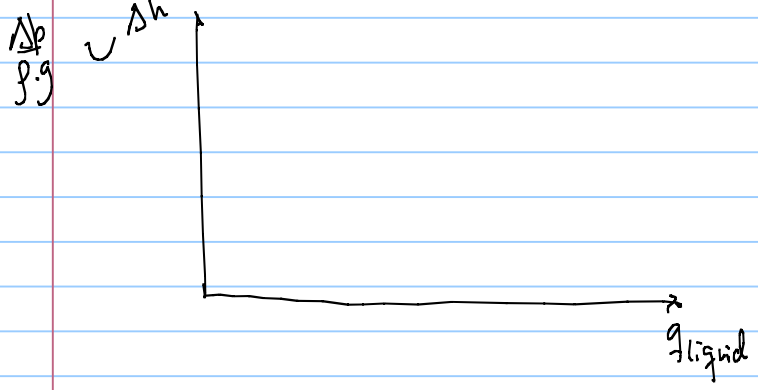
$$Pa \cdot m^3/s = \frac{N}{m^2} \frac{m^3}{s} = \frac{J}{s}$$

| - | bara | Sm^3/d/bar | m | m | m | m | - | - | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 231 | 14 | 380 | 1960 | 0.24 | 0.14 | | 78 | | | |

| | Water | Oil | |
|---|---|---|---|
| **Fluid Density** | 1025 | 897 | **[kg/m^3]** |
| **Richardson Emul. exp.** | 3.089 | 3.215 | |
| **Viscosity** | 1.00E-03 | 0.1 | **[Pa s]** |
| **$\alpha_w$ cut off** | 0.60 | | |
| **Roughness tubing and lines** | 0.00010 | m | |
| **Bubble point pressure [bara]** | 30 | [bara] | |

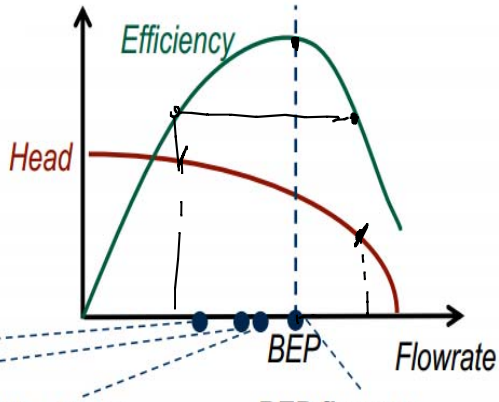
| **Wells** | **$p_R$** | **WC** | **Average density** | **Effective viscosity** | **$q_{tot}$** | **$p_{wf}$** | **$q_o$** | **$q_w$** | **$p_{suc}$** | **$p_{disc}$** | **$\Delta p_{ESP}$** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| - | bara | [-] | kg/m^3 | Pa s | Sm^3/d | bara | Sm^3/d | Sm^3/d | bara | bara | bara |
| | 231 | 0.00 | 897 | 0.100 | 1700 | **110** | 1700 | 0 | 76 | 185 | 10 |
| | 215 | 0.00 | 897 | 0.100 | 1700 | **94** | 1700 | 0 | 60 | 185 | 12 |
| | 200 | 0.00 | 897 | 0.100 | 1676 | **80** | 1676 | 0 | 47 | 185 | 13 |
| | 175 | 0.00 | 897 | 0.100 | 1527 | **66** | 1527 | 0 | 32 | 184 | 15 |
| | 150 | 0.00 | 897 | 0.100 | 1190 | **65** | 1190 | 0 | 31.5 | 183 | 15 |

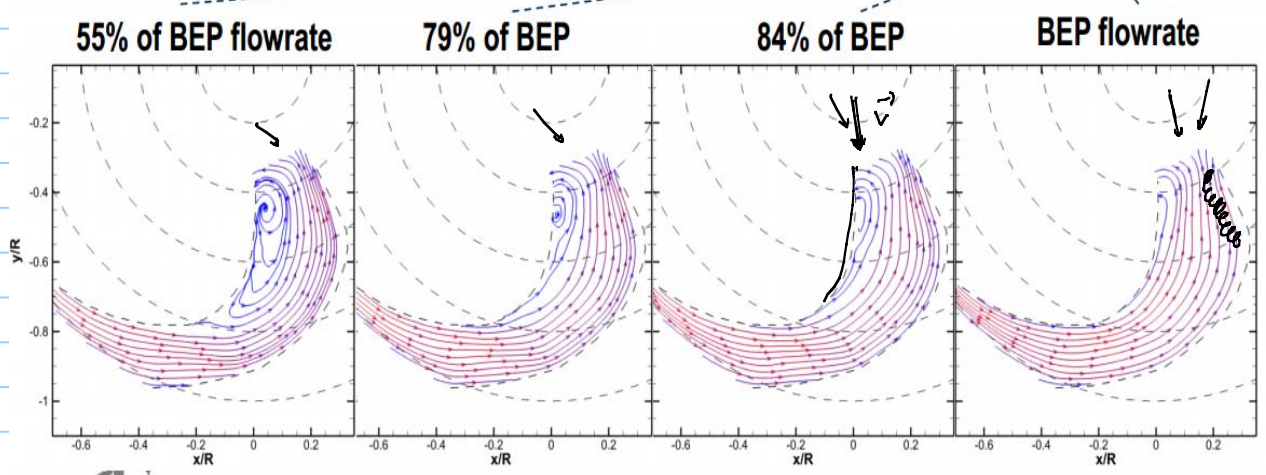


# PIV measurement in a radial flow stage

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




*Example of stall region in diffuser passage (measured)*

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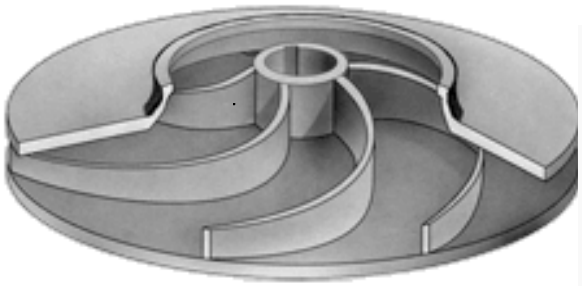
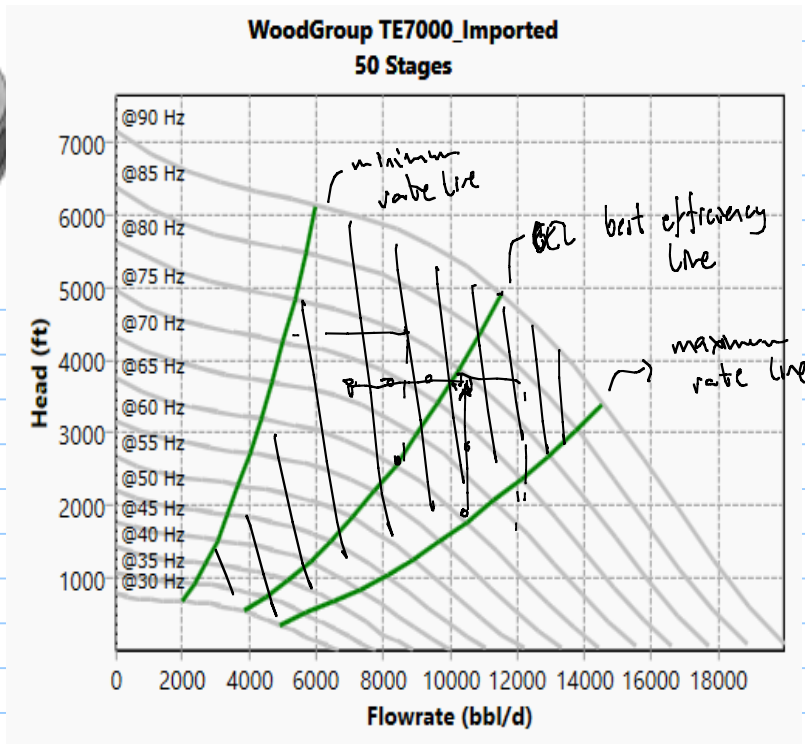
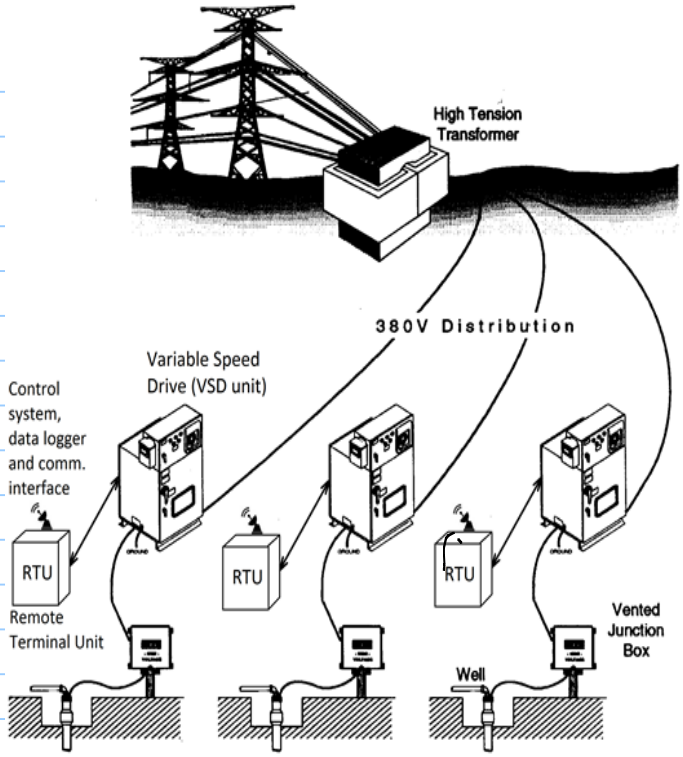
BEP when the flow is aligned with the the vane angle






High Tension
Transformer
380V Distribution
Variable Speed
Drive (VSD unit)
Control
system,
data logger
and comm.
interface
RTU
Remote
Terminal Unit
RTU
RTU
Vented
Junction
Box
Well

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