Exam V14

Problem 1

a) Calculate pore pressure at the top of the reservoir

$P@OWC = \rho_w g h_w = 1{,}03 \cdot 0.0981 \cdot 1050 = \underline{106\ bar}$

$P@520m = \underline{52\ bar\ \text{(outside res.)}}$

$P@520m = 106\ bar - \rho_o g h_o - \rho_g g h_g$

$= 106\ bar - 0.15 \cdot 0.0981 \cdot (860 - 520)$

$- 0.83 \cdot 0.0981 \cdot (1050 - 860)$

$= 106\ bar - 5\ bar - 15{,}5\ bar$

$= \underline{\underline{85{,}5\ bar\ \text{(inside res.)}}}$

If you are asking for the pressure outside the reservoir, the pressure is 52 bar. Inside the reservoir, the pressure is 85,5 bar

~~b)~~ We need hydrostatic pressure of mud to be 91,5 bar.

$P = \rho_m g h \Rightarrow \rho_m = \dfrac{91.5}{0.0981 \cdot (520 + 24)}$ ← riser air gap

$\rho_m \sim 1{,}715$ s.g

Note that if riser has to be disconected due to stormy wether, the mudweight must be increasl to include riser margin, but 1.715 s.g is the minimum mud weight

b) Reservoir OWC extends down to 1300m

$$P@520\,(\text{inside}) = \rho_w g h_w - \rho_o g h_o - \rho_g g h_g$$

$$85{,}5 = \rho_w g h_w - \rho_o g(1300 - h) - \rho_g g(h - 520)$$

$$85{,}5 = 131{,}4 - \rho_o g\, 1300 + \rho_o g h - \rho_g g h + \rho_g g 520$$

$$= 131.4 + h(\rho_o - \rho_g)g + g(\rho_g 520 - \rho_o 1300)$$

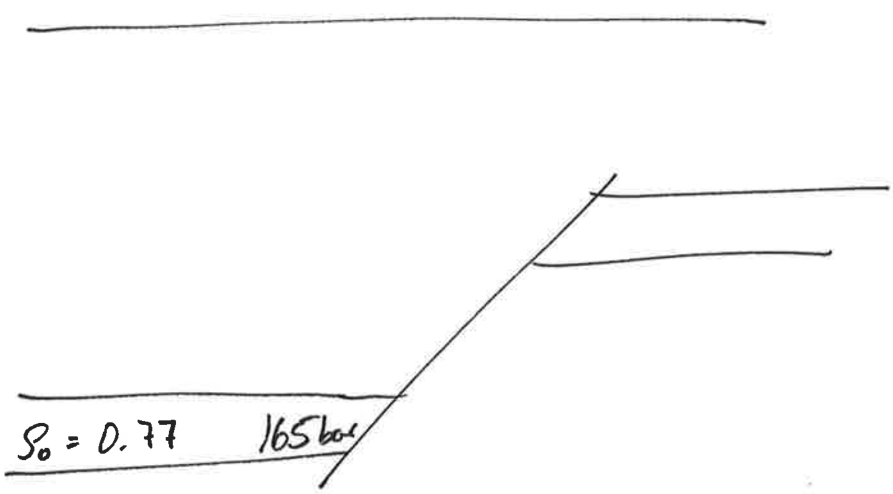
$$\frac{85{,}5 - 131.4 - g(\rho_g 520 - \rho_o 1300)}{(\rho_o - \rho_g)g} = h$$

$$h = \frac{85{,}5 - 131.4 - 0.0981(0.15 \cdot 520 - 0.83 \cdot 1300)}{(0.83 - 0.15) \cdot 0.0981} = \underline{\underline{784.1}}$$

Assuming no overpressure

with 1.715 s.g $\Rightarrow$ $\underline{h = 874}$

c)



i) open fault:

Pressure at B1

165 bar − $\rho_o g h_o$

165 bar − $0.77 \cdot 0.0981 \cdot (1250 - 860)$

165 bar − 29,5 bar

135,5 bar

ii) Same pressure : 165 bar

d) Mud weight, 5 bar overpressure

B1, open fault: $P = \rho_m g h \Rightarrow \rho_m = 1{,}66$ s.g

$\rho_m = 2{,}01$: closed fault

Problem 2

a) Compute the burst strength

P110 ⇒ yield = 110 kpsi
= 7483 bar

$$P_{burst} = 2\sigma_{tensile}\left(\frac{t}{D_o}\right)$$

$$t = \frac{508 - 475,7}{2} = 16,15$$

$$= 2 \cdot 7483 \cdot \frac{16,15}{508} = 475,8 \text{ bar}$$

K55 ⇒ σ = 55 000 psi = 3741,5 bar

$$P_{burst} = 2\sigma_{tensile}\left(\frac{t}{D_o}\right)$$

$$= 2 \cdot 3741,5 \cdot \left[\frac{(346.1 - 314,3)/2}{346.1}\right] = 343,7 \text{ bar}$$

N80 ⇒ σ = 80 000 psi = 5442 bar

$$P_{burst} = 2 \cdot 5442 \cdot \left[\frac{(273 - 245,4)/2}{273}\right] = 550 \text{ bar}$$

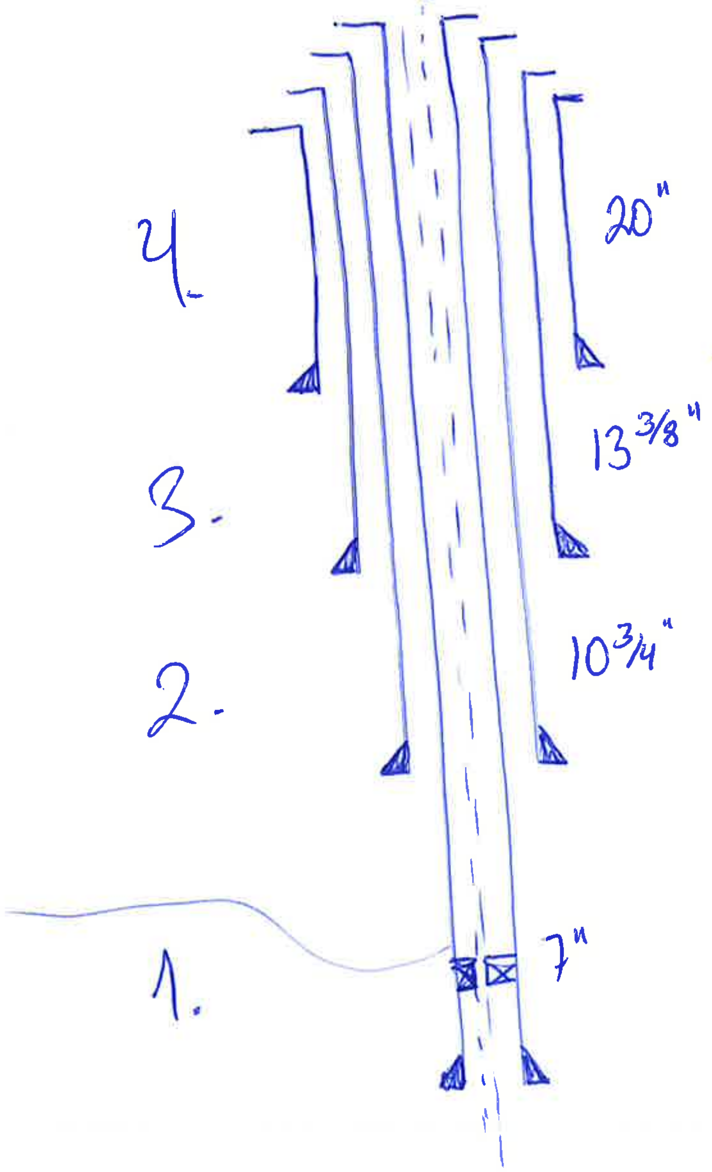
L80

$$P_{burst} = 2 \cdot 5442 \cdot \frac{(177,8 - 164)2}{177,8} = \underline{\underline{422,4 \text{ bar}}}$$

From strongest to weakest

N80 - $10\frac{3}{4}$ - 550
P110 - 20 - 475
L80 - 7 - 422 ⇒ increase strength
K55 - 13 3/8 - 343 ⇒ increase strength

b) Suitable for use in the same well?

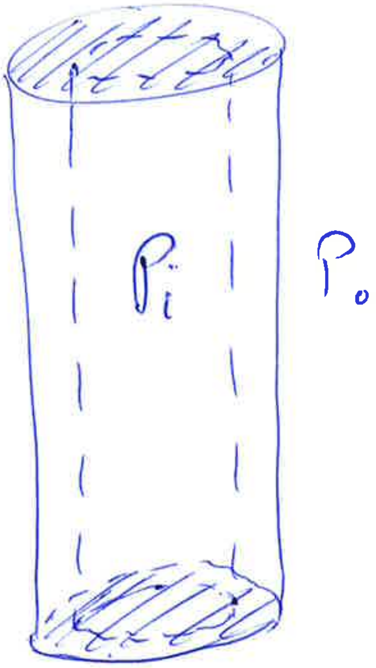


20" - Stronger than P_{frac} @ shoe

13 3/8", 10 3/4" } withstand formation-pressure in next hole section ("gas-filled case")

7" - withstand "Leaking tubing"

c) Pressurized closed pipe

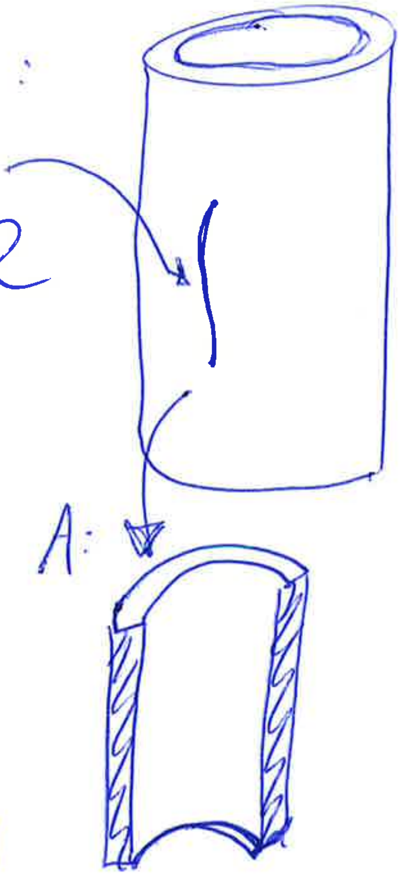


Pressurized from inside

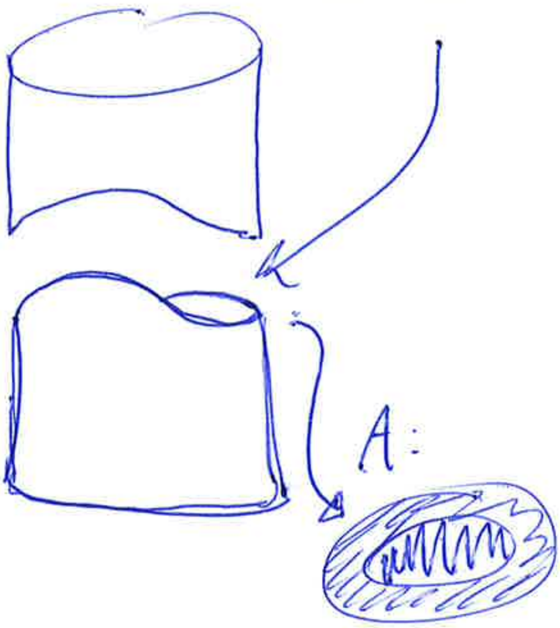
$$P_i \gg P_o$$

Case 1: burst
Case 2: Axial

Case 1:



Case 2

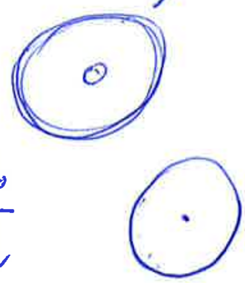


(Assuming inside pressure at 400 bar)

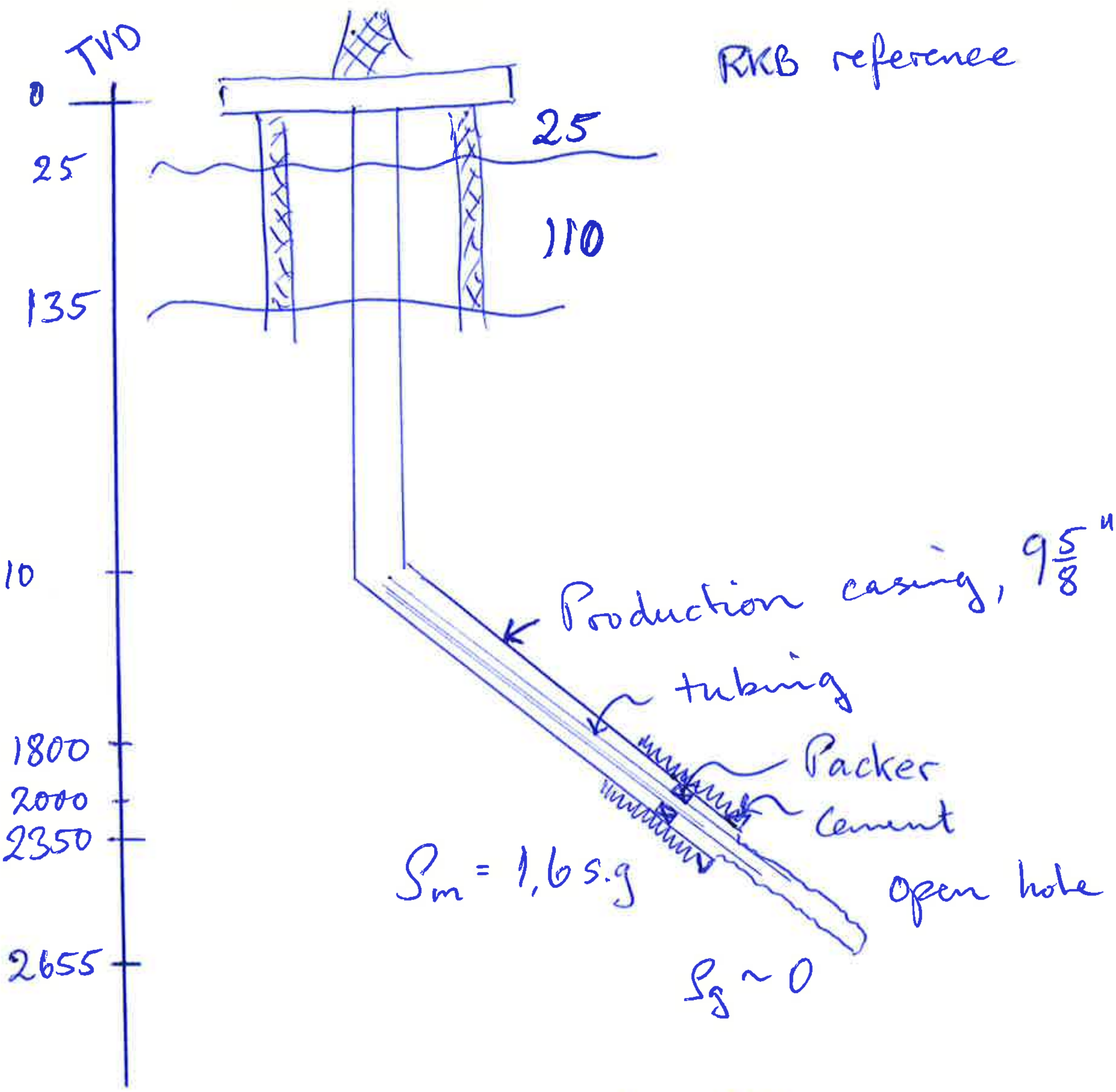
$$P_{burst} = 2\sigma_{tensile} \frac{t}{D_o}$$

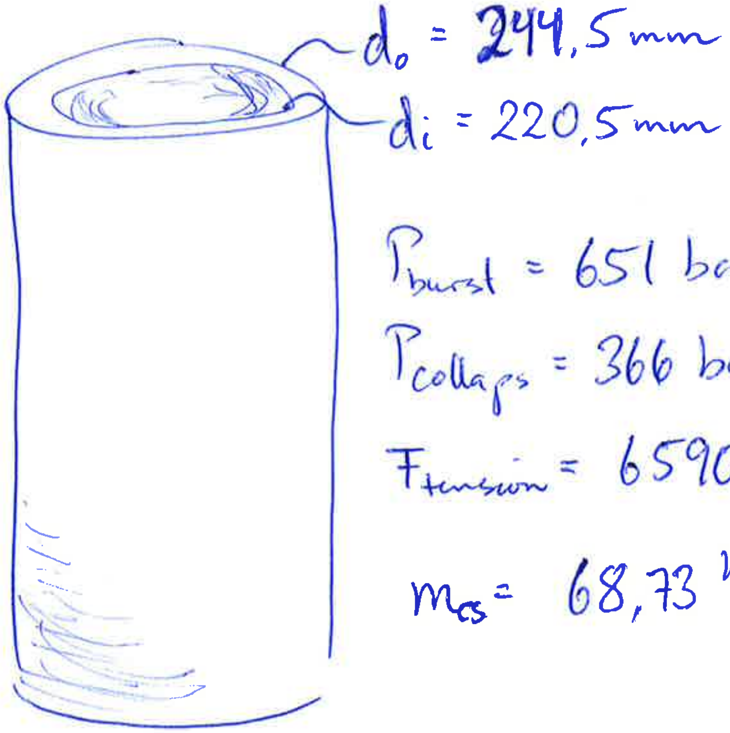
$$P_{tear} = \sigma_{tensile}$$

$$t \geq \frac{D_o}{2}$$



Problem 3





$P_{burst} = 651$ bar

$P_{collaps} = 366$ bar

$F_{tension} = 6590$ kN

$m_{cs} = 68,73$ kg/m

a) Criteria for burst

- Production casing

  - Gas-filled casing
  - Leaking tubing

- Gas-filled casing:

– At wellhead

$P_i = BHP - \rho_g g h_g = BHP = 1.5 \cdot 0.098 \cdot 2350$ (fig 1.)

$= 345.8$ bar

(highest pressure)

$P_o = 0$

$\Delta P = 345,8$ bar

– At casing shoe

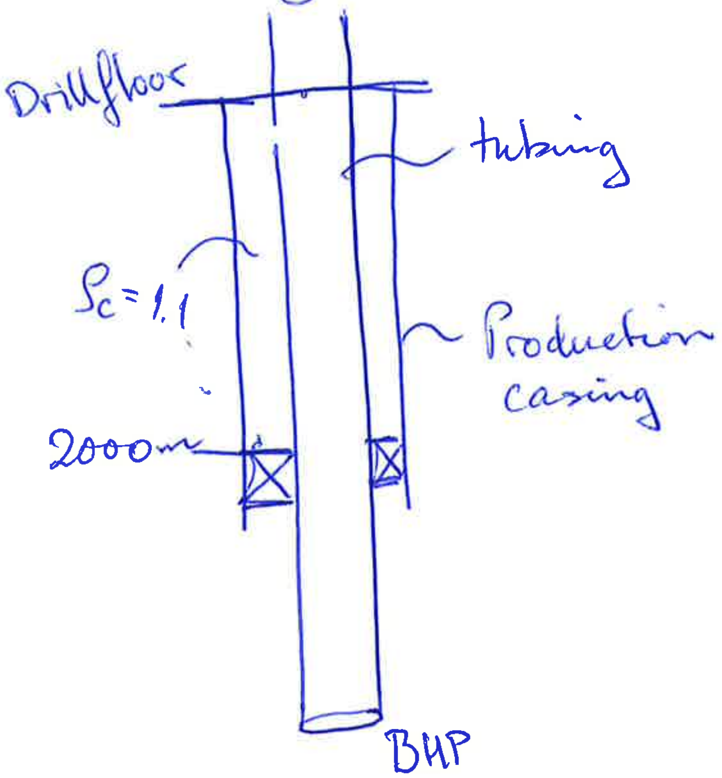
$P_i = 345,8$ bar

$P_o = \rho_w g h_w = 1.03 \cdot 0.0981 \cdot (2350 - 25)$

$= 235$ bar

$\Delta P = 110$ bar

- Leaking tubing



$$P_i = P@Packer = BHP + \rho_c g h_c$$

$$= 345,8 + 1.1 \cdot 0.0981 \cdot 2000$$

$$= \underline{561,6 \text{ bar}}$$

$$P_o = \rho_w g h_w = 1.03 \cdot 0.0981 \cdot (2000 - 25)$$

$$= \underline{200 \text{ bar}}$$

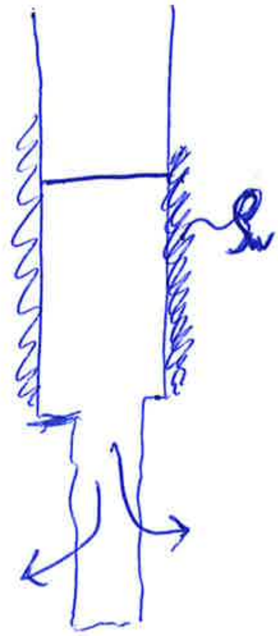
$$\underline{\Delta P = 362 \text{ bar}}$$

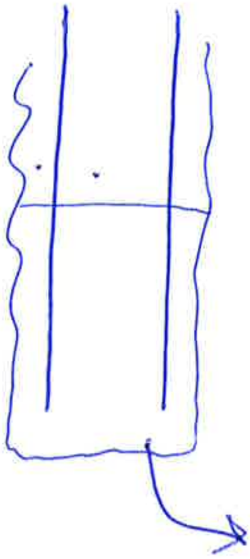
$$DF = \frac{651}{362} = \underline{\underline{1,8}} \Rightarrow ok$$

above 1.18 is recomended.

Collapse

- Loss to thief zone





Assuming poor cement job ⇒ ρ_m outside casing

Frac @ 2350 = 1,615000 s.g

P_{frac} = ~~1.6 · 0.0981 · 2350 = 368,9 bar~~

= 1,62 (1,03) · 0.0981 · (2350 − 25)

= ~~bar~~ = ~~1382~~ = 234,9

Mud in casing must balance frac. pressure.

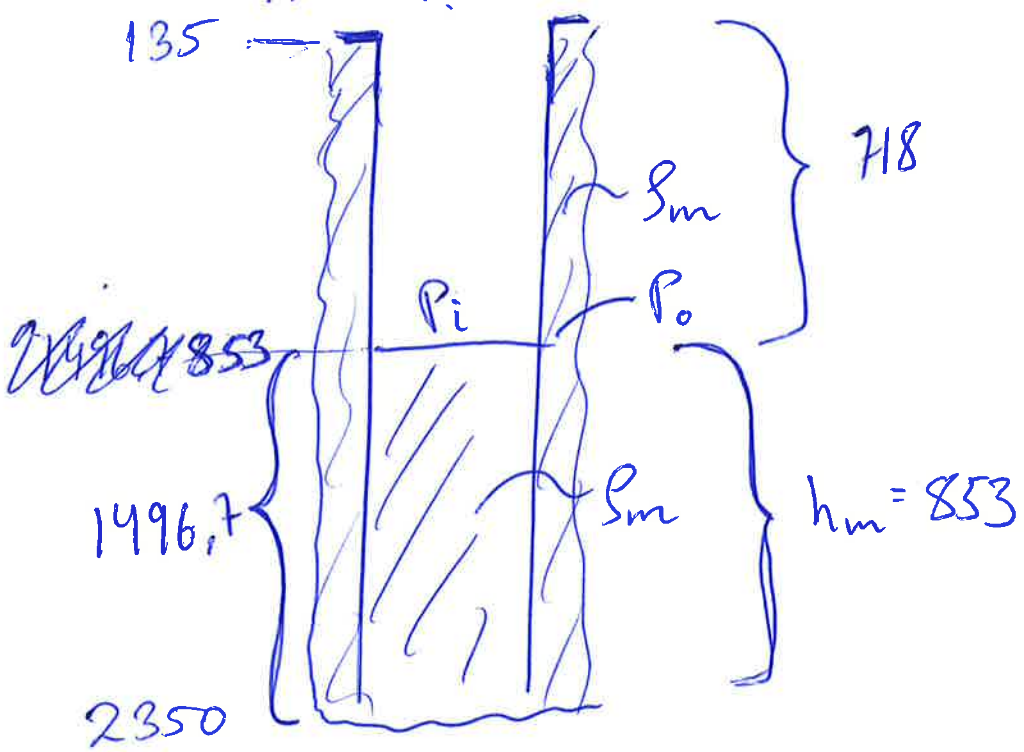
388,0 (345) = $\rho_m g h_m$ ⇒ $h = \frac{239.9}{0.098 \cdot 1.6}$ = 2203 m

h = 1496,7

$P_i = 0$

$P_o = \rho_m g h_m + \rho_w g h_w$

$= 1.6 \cdot 0.0981 \cdot (2350 -$



$P_o = \rho_m g h_m + \rho_w g h_w$

$= 1.6 \cdot 0.0981 \cdot 718 = \underline{112 \text{ bar}}$

$112 + 11 = 123$

$\Delta P = 123$ bar

$DF = \frac{366}{123} = 3 \Rightarrow$ ok

c) Weight in air

$m_{cs} \cdot 9,81 \cdot 2909$

$68,73 \cdot 9,81 \cdot 2909 = \underline{1961,4\,kN}$

Bouyed weight

$\left(1 - \frac{\rho_m}{\rho_s}\right) \cdot W = 1961,4 \cdot ~~kN~~ \left(1 - \frac{1,6}{7.85}\right)$

$= 1561,6\ kN$

$DF = \frac{6590}{1821} = \underline{\underline{3,6}}$

~~$DF = \frac{6590}{1561} = 4,2 \geq$ ok~~

Pressure test, assume wellhead to handle

10000 psi = 680 bar

$A = \frac{\pi}{4} d_i^2$

$= \frac{\pi}{4} \cdot (220,5 \cdot 10^{-3})^2$

$= 3,82\ cm^2$

$P = \frac{F}{A}$

$F = PA$

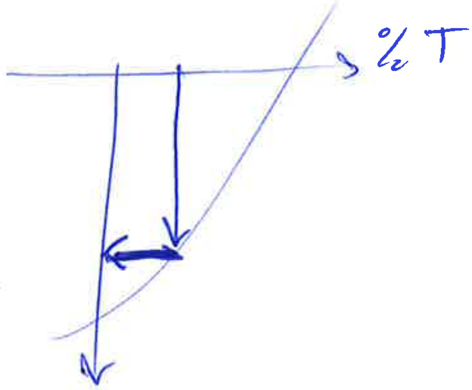
$= 680 \cdot 3,82$

$= 2596\ daN$

$= 259,6\ kN$

$\%T = 23,6\%$

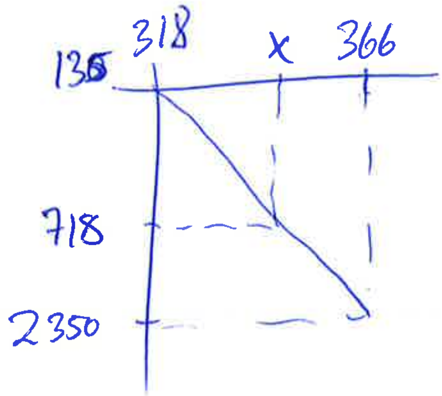
$\%C = -87\%$



$P_{collaps,\,new\ at\ top} = \underline{318}$

$P_{collaps} = 366$

P_{collap} @ 718



$$\frac{366-318}{2350-135} = \frac{x-318}{718-135}$$

$$X = 318 + \frac{366-318}{2350-135}(718-135)$$

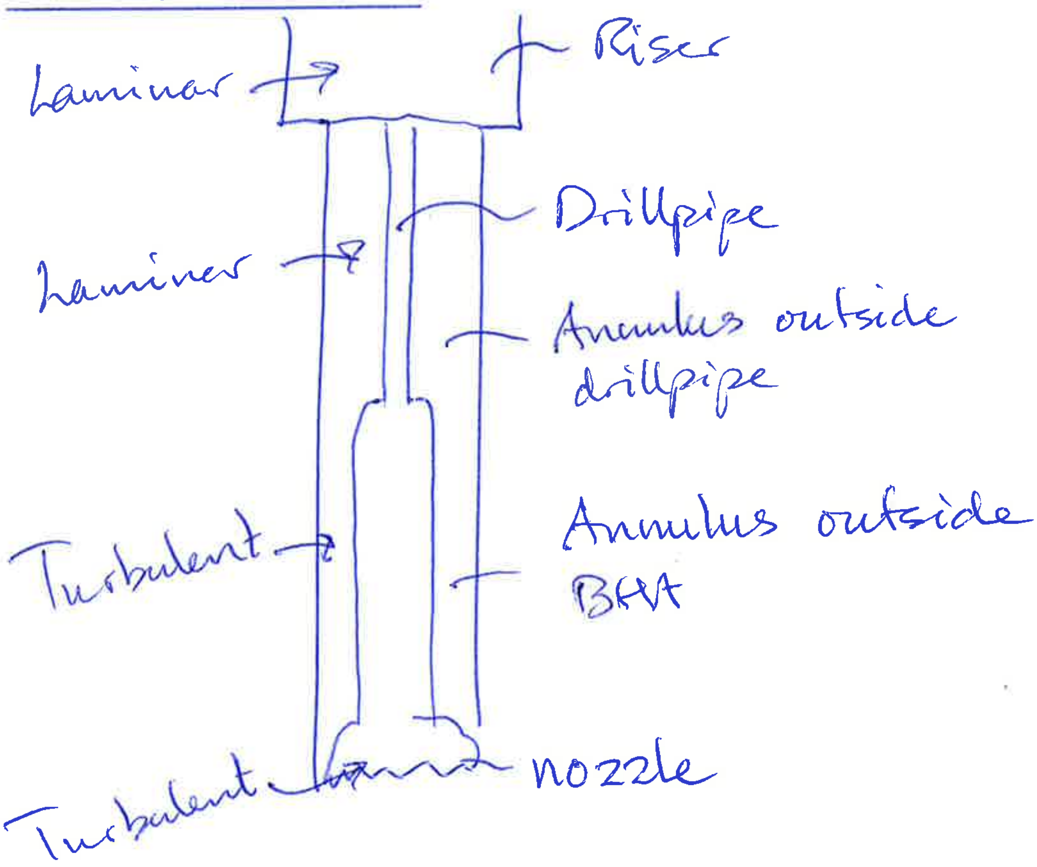
$$\underline{X = 330}$$

$$P_{collaps} = \underline{330}$$

$$DF = \frac{330}{123} = \underline{\underline{2,69}}$$

Problem 4

a)



Most of the length of the well is drillpipe
⇒ Laminar flow is most common.

b) Pressure drop

Laminar : $P \sim \mu q$

Turbulent : $P \sim \rho f q^2$

$\frac{\rho v D}{\mu}$ 16

~~Viscosity, friction against flow~~

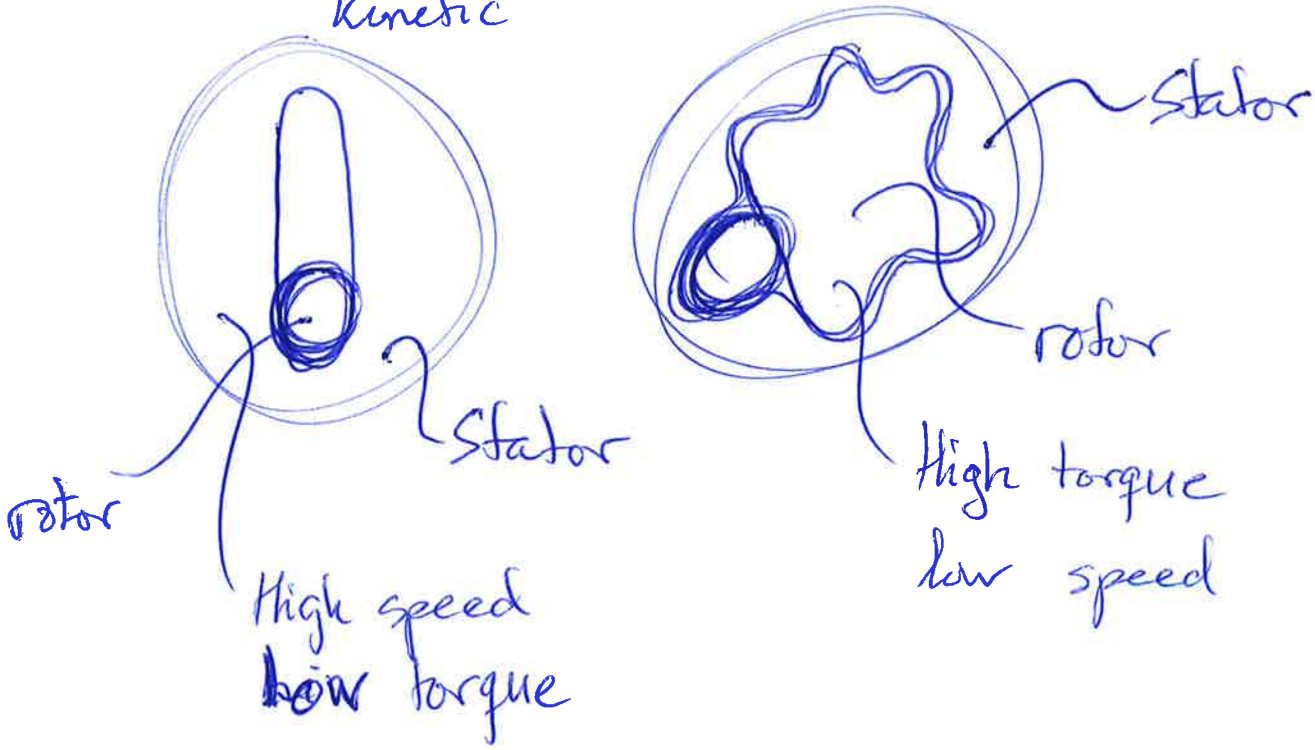
Most of the ΔP in nozzle and annulus outside BHA

⇒ ρ is dominating $P_2 = \frac{\rho q^2}{2A^2 0.95^2}$

c) RSS vs motor

There is a large pressure drop through the motor in order to turn the drillbit

⇒ hydraulic energy is converted to ~~mechaine~~ Kinetic energy.



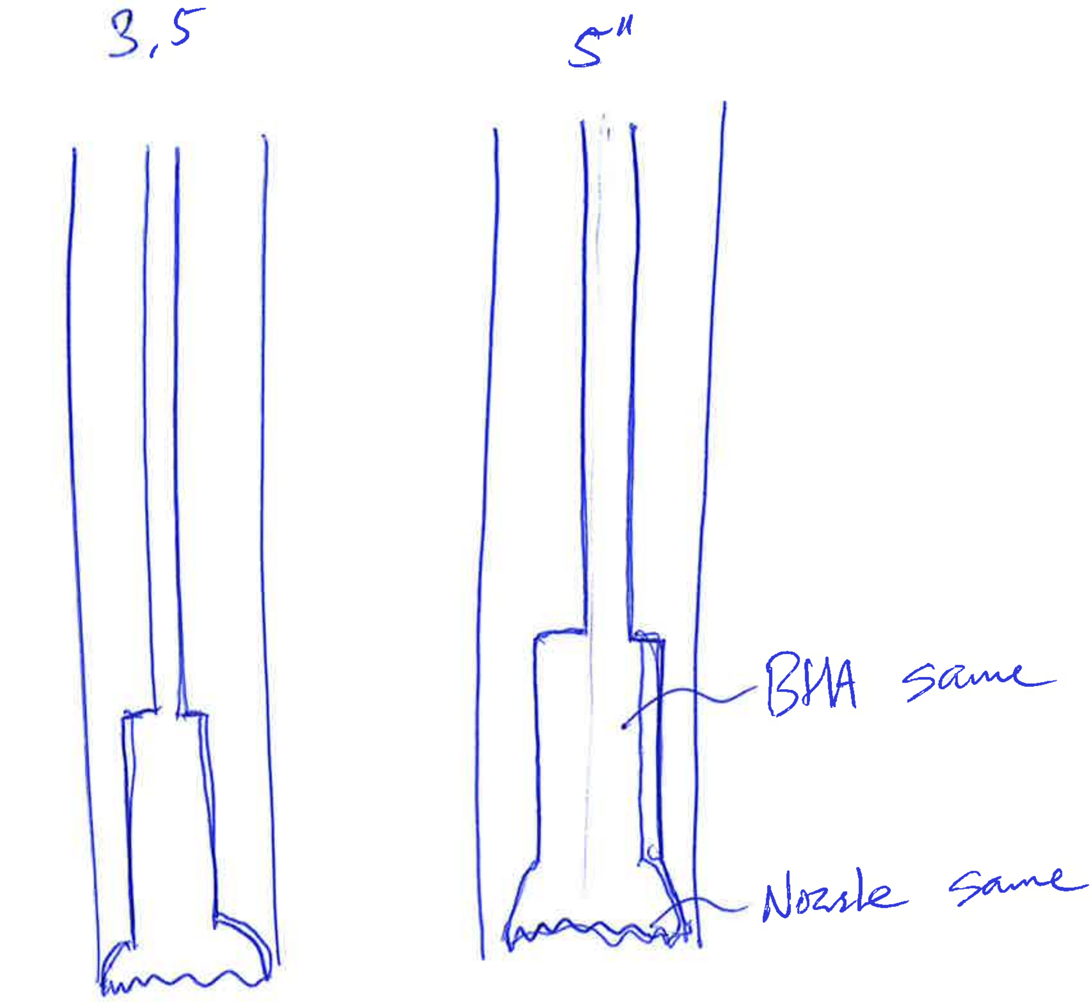
d) 3,5" → 5"   assuming that ID inceases

Three improvements

P_1 = Pump pressure

P_2 = Pressure loss through nozzle

P_3 = paraeitic pressure loss



5" ⇒ ~~more para~~ less parasitic pressure loss inside drillpipe

$P_1 = P_2 + P_3$; P_3 unchanged

P_1 → lower

↳ increased pump capasity

↳ same hydraulic effect through nozzle with lower ~~flow~~ pump pressure

e) Mechanical power

$F_2 = \dot{m}v = \rho q v$ ← fluid velocity

$\dot{m}$ ← mass rate; ρ ← density; q ← flow rate

Hydraulic power

$HP = P_2 q$ ← flow rate

P_2 ← Pressure drop through nozzle

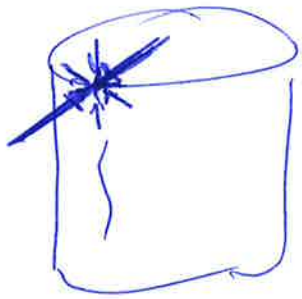
Problem 5

a) Limits for mud weight

- Pore pressure / collapse pressure
- Fracture pressure / LOT

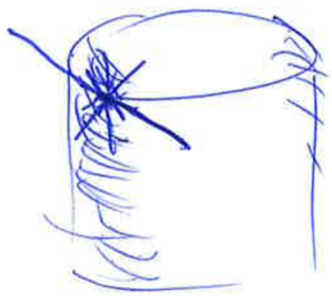
Failure mechanisms

- Tensile
  ↳ too high mud weight



$\sigma_\theta = 2\sigma_a - P_w$

- Tangential / Hoop stress
  ↳ too low mud weight ⇒ collapse



b) Fracture equation

Simplest equation

$P_{wf} = \sigma_a$ No filter cake

$P_{wf} = 2\sigma_a - P_o$ filter cake

$\sigma_a = \frac{1}{2}(P_{wf} - P_o)$; P_o = pore pressure

⇒ Keep the mud weight equal to the in-situ stress

i.e. between the fracture pressure and the pore pressure

This is called "the median line principle"

c) Advantages

- No change in the stress state in the rock.