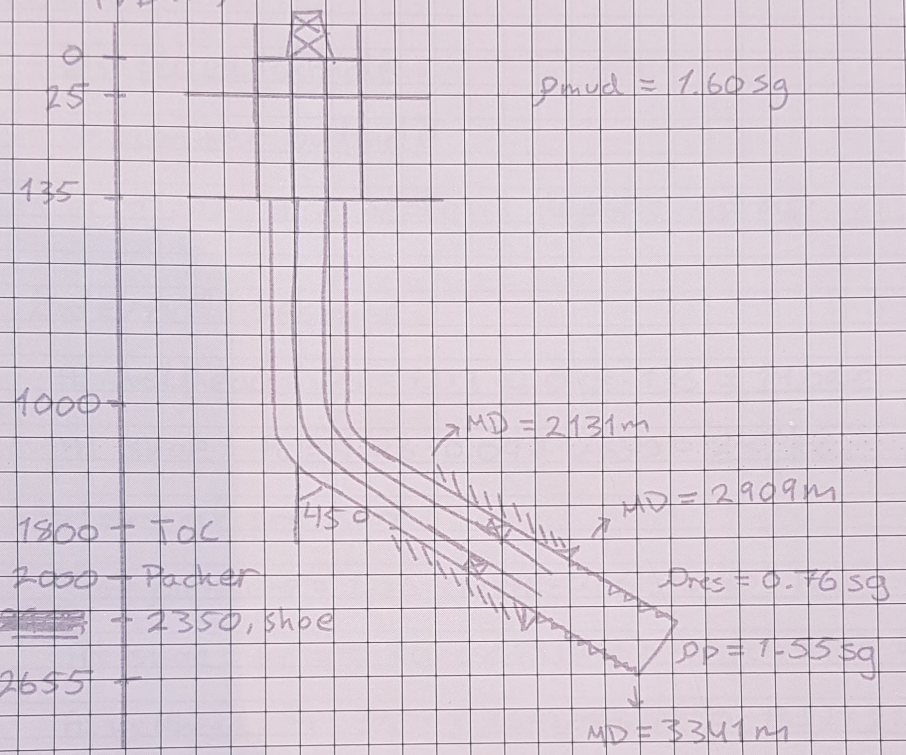
Skriv her. Bruk kulepenn. Ved feilskrift - bruk overstrykning. *Write here. Use a ballpoint pen. Cross out any mistakes.*

1 Production casing: 9 5/8 in

a)



Assumptions:

- 110m water depth
- Riser and BOP installed
- Use vertical depth for burst and collapse, and MD for tension.
- Neglect bending

Oil-filled casing

Assumptions:

- res. fluid inside
- seawater outside
- vertical, use vertical depths, not MD

① External pressure

At wellhead: $P_o = 1.03 - 0.098 \cdot 135 = 14$ bar

At shoe: $P_o = 1.03 \cdot 0.098 \cdot 2350 = 237$ bar

② Internal pressure

Pore pressure $= 1.55 \cdot 0.098 \cdot 2655 = 403$ bar

At shoe: $P_i = -0.76 \cdot 0.098 (2655 - 2350) + 403 = 380$ bar

At wellhead: $P_i = 380 - 0.76 \cdot 0.098 (2350 - 135) = 215$ bar

③ Burst load

At wellhead: $P_i - P_o = 215 - 14 = 201$ bar

At shoe: $P_i - P_o = 380 - 237 = 143$ bar

④ Design factor

$$DF = \frac{651}{201} = 3.24$$

Skriv her. Bruk kulepenn. Ved feilskrift - bruk overstrykning. *Write here. Use a ballpoint pen. Cross out any mistakes.*

Tubing leak

Assumptions

- res. fluid in tubing
- seawater outside
- packer fluid (1.10sg) above packer
- use vertical depths

① External pressure

At wellhead: $P_o = 1.03 \cdot 0.098 \cdot 135 = 14\,bar$

At packer: $P_o = 1.03 \cdot 0.098 \cdot 2000 = 202\,bar$

② Internal pressure

Pore pressure $= 1.55 \cdot 0.098 \cdot 2655 = 403\,bar$

At wellhead: $P_i = 403 - 0.76 \cdot 0.098 \cdot (2655 - 135) = 215\,bar$

At packer: $P_i = 215 + 1.1 \cdot 0.098 \cdot 2000 = 431\,bar$

③ Burst load

At wellhead: $P_i - P_o = 215 - 14 = 201\,bar$

At packer: $P_i - P_o = 431 - 202 = 229\,bar$

④ Design factor

$$DF = \frac{651}{229} = 2.84$$

Skriv her. Bruk kulepenn. Ved feilskrift - bruk overstrykning. *Write here. Use a ballpoint pen. Cross out any mistakes.*

b) Mud loss to thief zone

Assumptions

- mud outside
- use vertical depth

① ~~External pressure~~ Mud loss level

$1.03 \cdot 0.098 (2350-25) = 1.6 \cdot 0.098 (2350-h)$

$h = 2350 - \frac{1.03}{1.60}(2350-25) = 853\,m$

② External pressure

At wellhead: $P_o = 1.60 - 0.098 \cdot 135 = 21\,bar$

At h: $P_o = 1.60 - 0.098 \cdot 853 = 134\,bar$

At shoe: $P_o = 1.60 - 0.098 \cdot 2350 = 368\,bar$

③ Internal pressure

At wellhead: $P_i = 0$

At h: $P_i = 0$

} Due to air inside

At shoe: $P_i = 1.6 - 0.098 \cdot (2350 - 853) = 235\,bar$

④ Collapse load

At wellhead: $P_o - P_i = 21 - 0 = 21\,bar$

At h: $P_o - P_i = 134 - 0 = 134\,bar$

At shoe: $P_o - P_i = 368 - 235 = 133\,bar$

⑤ Design factor

$DF = \frac{366}{134} = 2.73$

Skriv her. Bruk kulepenn. Ved feilskrift - bruk overstrykning. *Write here. Use a ballpoint pen. Cross out any mistakes.*

c) Use MD now

① Weight in air

$W = 68.73 kg/m \cdot 9.81 \cdot (2909 - 735) = 187 \cdot 10^3 daN$

② Buoyed weight in mud

$W_b = \left(1 - \frac{1.6}{7.8}\right) 187 \cdot 10^3 daN = 149 \cdot 10^3 daN$

③ Test pressure

Lower part of the well $\Rightarrow P_t = P_{burst}$

$P_t = 651 bar$

④ Force from pressure test

$F = P_t \cdot A = 651 \cdot \frac{\pi}{4} \cdot 22.05^2 = 249 \cdot 10^3 daN$

⑤ Design factor

$DF = \frac{659}{149 + 249} = 1.66$

d) Place max allowable burst strength at the wellhead and calculate pressure at the casing shoe

- Assume fracture gradient at shoe: 1.7 sg

$P_{shoe} = 651 + 0.76 \cdot 0.098 \cdot 2350 = 826$ bar

Gradient at shoe:

$$\frac{826}{0.098 \cdot 2350} = 3.59$$

$3.59 > 1.70$

=> weak point is the casing shoe

2 a) $\Delta P = \left(\frac{-1}{c}\right)\frac{\Delta V}{V}$, $\frac{\Delta V}{V} = \frac{1}{2}\alpha\Delta T$

$\Rightarrow \Delta P = -\frac{\alpha}{c}\frac{1}{2}\Delta T$

ΔP: Pressure change

ΔT: Temperature change

α: Thermal expansion coefficient

c: Compressibility coefficient

Conditions:

- Constant mass
- Density and viscosity can be neglected

b) $\Delta P = -\frac{1}{2}\frac{\alpha}{c}\Delta T = -\frac{1}{2}\left(\frac{3\cdot10^{-4}}{-3\cdot10^{-5}}\right)\cdot 150°$

$\Delta P = 750$ bar

The pressure increase is 750 bar

Skriv her. Bruk kulepenn. Ved feilskrift - bruk overstrykning. *Write here. Use a ballpoint pen. Cross out any mistakes.*

3 a) $P_{wf} = 2\sigma_h - P_o$

$\sigma_h = \frac{1}{2}(P_{wf} - P_o)$

Using this equation will give you the mid point between the pore pressure and the fracture pressure, to find mudweight. This is called "The median line principle"

b) $P_{wf}(\gamma) = P_{wf}(0) + \frac{1}{3}(P_o - P_o^*)\sin^2\gamma$

$P_{wf}(0) = P_{wf}(\gamma) - \frac{1}{3}(P_o - P_o^*)\sin^2\gamma$

Assume P_o^* is constant at 2.09sg

Depth	LOT
890m	1.51sg
1124m	1.42sg
1540m	1.37sg

$P_{wf,1124} = 1.35 - \frac{1}{3}(1.21 - 2.09)\sin^2(30) = \underline{1.42\,sg}$

$P_{wf,1540} = 1.27 - \frac{1}{3}(1.30 - 2.09)\sin^2(39) = \underline{1.37\,sg}$

Skriv her. Bruk kulepenn. Ved feilskrift - bruk overstrykning. *Write here. Use a ballpoint pen. Cross out any mistakes.*

c) $\sigma_n = \frac{1}{2}(\sigma_T + P_0)$

890 → $\sigma_n = \frac{1}{2}(1.51 + 1.03) = 1.27\,sg$

1124 → $\sigma_n = \frac{1}{2}(1.42 + 1.21) = 1.32\,sg$

1540 → $\sigma_n = \frac{1}{2}(1.37 + 1.30) = 1.34\,sg$

This is for an isotropic process ↑ only valid

4

1 → A, Inertial/viscous forces

2 → C, Energy

3 → B, Turbulent flow

4 → A, Laminar flow

5 → B, Turbulent

6 → B, Turbulent

7 → A, Laminar

8 → B, More nozzle press.

Skriv her. Bruk kulepenn. Ved feilskrift - bruk overstrykning. *Write here. Use a ballpoint pen. Cross out any mistakes.*

5 a) The authorities are making laws and regulations in order to reduce danger to people (injuries, accidents) and the material/equipment in use. It is to ensure/help companies in the oil and gas industry to uphold and reduse HSE risks (health, safety and environmental risk).

PSA is underneath and related to the Petroleum directorate (~~Petroleum~~ Petroleums direktoratet). They used to be joined together as one, but was eventually divided into the two sections we have today.

b) PSA's laws and regulations are based on experience, history and tradition. They go through all of the different parts of an operation, such as: cementing and pressure testing.
In order to reduce risk of an operation, it is important to make sure that all steps are done correct. The regulations have requirements that will help with this.

Skriv her. Bruk kulepenn. Ved feilskrift - bruk overstrykning. *Write here. Use a ballpoint pen. Cross out any mistakes.*

One example of this can be the primary and secondary barriers of both a drilling operation and during production. NORSOK-D10 contains information of the barriers, and illustrates with a figure where they should be placed. If this is followed, it will reduce risk, too few barries related to

c) Risk assesment prior to all well activities might reduce the risks during the operation, but also prepare the workers of what might come, and how to handle it.

Example: risk assesment prior to drilling through a certain formation can give insight to what might come, which risk to look out for, and make a plan on how to handle it.

laws and regulations can be used for this, testing a section before continue drilling

Skriv her. Bruk kulepenn. Ved feilskrift - bruk overstrykning. *Write here. Use a ballpoint pen. Cross out any mistakes.*

d) Probability and consequence in a risk assesment shows how big probability there is for something (a specific situation) to happen, and what consequences that might have.
This makes it possible to be prepared for the different situations, but also to try and prevent them from happening.
A risk factor ~~desse~~ represent a part of the operation that might cause risks.

e) There are differences between barriers in a drilling situation and in a production situation.

Drilling situation

Barriers are for instance: cement, casing and mud column.
The objective is to create a barrier for unwanted inflow of reservoir fluid.

Production situation

Barriers are for instance: Downhole Safety Valve, Packers and Annular Safety value. The objective here is to stop the production in case something happens at the surface, in order to produce as much as possible without losing any of it.