University of Stavanger

FACULTY OF SCIENCE AND TECHNOLOGY

SUBJECT: PET 535 Modern Well Design and Well Mechanics

DATE: May 16, 2014

TIME: 0900-1300

AID: Approved calculator

THE EXAM CONSISTS OF 5 PROBLEMS PLUS FORMULA SHEETS ON 7 PAGES

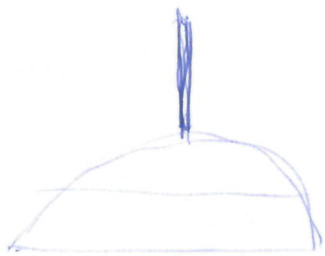
PLEASE STATE ALL ASSUMPTIONS

Problem 1: Pore pressure

Figure 1 shows a reservoir that contains oil and gas, and you may assume that the oil-water-contact (OWC) has a normal pressure.

a) Calculate the pore pressure at the top of the reservoir. Also calculate the minimum mud density (s.g.) required to drill into the reservoir with a 6 bar overpressure.

b) The geologists inform you that the reservoir section probably extends down to 1300m (OWC at 1300m with normal pressure). What is the critical oil-gas-contact depth if you should balance the pore pressure when entering the reservoir and you are using the mud density calculated in a).



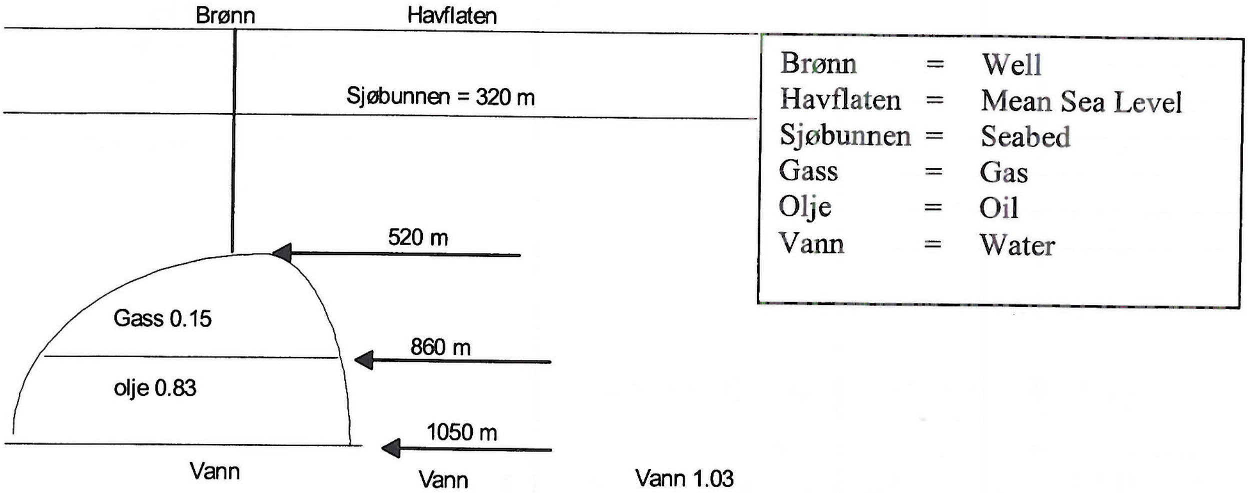


Figure 1 – Shallow reservoir containing oil and gas

c) Figure 2 shows two reservoirs that are separated by a fault. Initially both reservoirs were at the same depth and filled with oil of density 0.77 s.g. The reservoir pore pressure in well B2 is 165 bar. What is the reservoir pore pressure in well B1 if

  i. The fault is open and connecting the two reservoirs.

  ii. The fault is closed and sealing and overpressure is preserved.

d) Calculate the mud densities (s.g.) required to drill wells B1 and B1 having 5 bar overpressure.

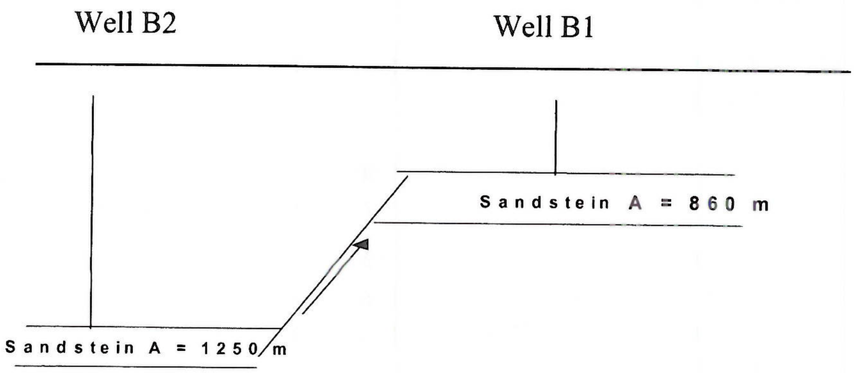


Figure 2 – Reservoirs separated by fault.

Problem 2: Casing strength

The following casing types are available:

Size(in):	Grade, weight(lb/ft):	Outer diam.(mm):	Inner diam.(mm)
20	P110, 133	508	475,7
13-3/8	K55,88.2	346.1	314.3
10-3/4	N80, 60.7	273	245.4
7	L80, 20	177.8	164

a) Compute the burst strength of each casing. List the casings from strongest to weakest in burst.

b) Are these casings suitable for use in the same well? Explain which of the casings could be replaced, and indicate if it should be stronger or weaker.

c) A closed pipe is pressurized from the inside. Define two failure modes, and show which failure mode is dominating.

$\tau = \tau_0 + \sigma \tan(\gamma)$

$(\sqrt{J_2}, \sigma_m - P_0)$.

Problem 3: Design of the Production Casing

We will design the production casing of a well. The following data applies:

From Aadnøy: Assume pore pressure of 1.4 s.g otherwise state assumption.

9-5/8 in. 47 lbs/ft P110	
Weight:	68.73 kg/m
Burst strength:	651 bar
Collapse:	366 bar
Tension:	6590 kN
Mud weight:	1,60 s.g. on in/outside of csg.
Inner diam.	220,5 mm
Setting depth:	2909 mMD, 2350 mTVD
Depth next hole:	3341 mMD, 2655 mTVD
Cemented interval:	2131 – 2909 mMD, 1800 - 2350 mTVD
Produktion packer at	2414 mMD, 2000 mTVD
Gas density negligible.	
bar x cm² = daN	

$P_0 = 1.4$ s.g

The well is vertical down to 1000 m, followed by a sharp build up. From 1000 m to the bottom assume a constant inclination of 45 degrees.

Assume that the well is drilled from a jack-up rig with 25 m airgap. Use the enclosed prognosis, Fig. 1. Please write all assumptions.

a) Prepare a figure of the well and define two criteria for burst of the production casing, and determine the safety factor.

Remember plotting the pressures!!

964

b) Decide a criterion for collapse and determine the factor of safety.

c) Determine the total weight in air of the casing string, and the buoyed weight in the well.

Determine the factor of safety. Bending may be neglected.

Problem 4: Hydraulics

a) In the hydraulic system of the drilling rig, is the flow mostly laminar or mostly turbulent? Provide you answer with an example.

b) Which parameter contributes mostly to the pressure drop, viscosity or density of the drilling fluid? Explain.

c) Comparing ordinary rotary drilling with drilling with a motor, are there any differences? If yes, identify one important difference.

d) The drill string is changed from 3.5 in to 5 in in a well. Identify three improvements in the hydraulic system.

e) Define an equation for mechanical power and one for hydraulic power. Define the variables.

Problem 5: Mud weight optimalization

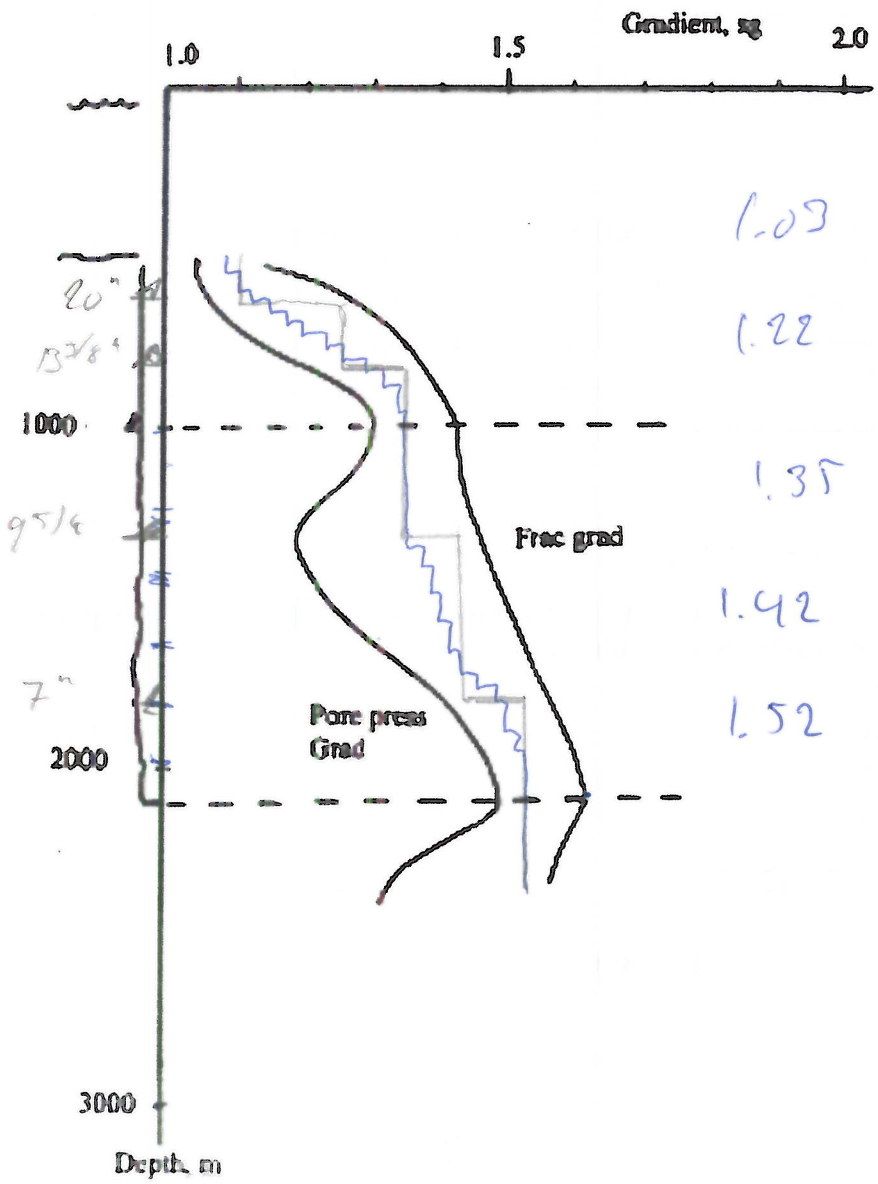
a) Define the two classical limits for the mud weight. What are the failure mechanisms?

$P_{wf} = 3\sigma_h - \sigma_H - P_o$

b) Using a simple fracturing equation, define the new optimization criterion presented in this course. What is this criterion called? Median line.

c) Define two advantages of using this criterion. Also define two concerns.

d) In the figure on the following page propose a mud weight schedule.


Gradient, sg
1.0
1.5
2.0
1000
2000
3000
Depth, m
Frac grad
Pore press
Grad
20"
7"
1.09
1.22
1.35
1.42
1.52

Some Formulas

$P(bar) = 0.098 \times d(s.g.) \times D(m)$

$P_3 = Cq^m$

$P_2 = \rho q^2/2A^2 0.95^2$

Index:	Equation:	Criterion:	Fraction parasitic pressure loss:	Flow rate:
1	qP_2	Max. HP	$1/(m+1)$	$P_1/C(m+1)$
2	$q\sqrt{P_2}$	Max. jet impact	$2/(m+2)$	$2P_1/C(m+2)$
3	$q3/2\sqrt{P_2}$	New A	$3/(m+3)$	$3P_1/C(m+3)$
4	$q^2\sqrt{P_2}$	New B	$4/(m+4)$	$4P_1/C(m+4)$
5	$q^{5/2}\sqrt{P_2}$	New C	$5/(m+5)$	$5P_1/C(m+5)$

$A = q\{\rho/2P_2\}^{1/2}/0.95$

Using the units of: density(kg/l), flowrate (l/min) and pressure (bar), the nozzle area in in^2 can be obtained by dividing the equation above with 122.4.

$d_{RKB1} = d_{RKB2}D/(D-\delta h)$

$LOT = 2\sigma_a - P_o$

$P_{wf}(\gamma) = P_{wf}(0) + {}^1/_3\,(P_o - P_o^*)\sin^2\gamma$

$P_{wf}(0) = \{P_{wf}(\gamma) + (\sigma_o - 1/2P_o)\sin^2\gamma\}/\{1 + 1/2\sin^2\gamma\}$

$\Delta\sigma_a = \Delta P_o(1-2\nu)/(1-\nu)$

$\Delta P_{wf} = \Delta P_o(1-3\nu)/(1-\nu)$

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

$P_{collapse} = \{2CE/1 - \nu^2\}\{1/(D_o/t - 1)^2 D_o/t\}$

$(\sigma_t/\sigma_{yield}) = 1/2(\sigma_a/\sigma_{yield}) +/- \{1 - 3/4(\sigma_a/\sigma_{yield})^2\}^{1/2}$

$\rho = (d_p D - 1.03h_w)/(D - h_f - h_w)$

$$d_{wf2} = d_{wf1}\frac{D_1}{D_2} + d_{sw}\frac{D_{w2} - D_{w1}}{D_2}$$

§.(3.6.1)
s.94->...

Penetration depth, Sbuke og hf = lik. Uforandret

$$D_2 = D_1 + (D_{w2} - D_{w1}) + (D_{f2} - D_{f1})$$

$$D_2 = D_1 + (D_{w2} - D_{w1}) + (D_{f2} - D_{f1}) + \left(\frac{d_{ob1}}{d_{ob2}} - 1\right)(D_1 - D_{w1} - D_{f1})$$

$$\frac{\Delta V}{V} = \frac{1}{2}\alpha\Delta T$$

$$\Delta P = \left(\frac{-1}{c}\right)\frac{\Delta V}{V}$$

Units

1 bar = 14.5 psi = 10^5 Pa
1 ft = 0.3048 m = 12 in
1 lb_f = 0.454 kp = 4.45 N