University of Stavanger

FACULTY OF SCIENCE AND TECHNOLOGY

SUBJECT: MPE 450: MODERN WELL DESIGN

DATE: 16 FEBRUARY, 2006

TIME: 0900 - 1300

AID: CALCULATOR

THE EXAM CONSISTS OF 6 PAGES

REMARKS: PLEASE STATE ALL ASSUMPTIONS

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a) $LOT = 2\sigma - P_o \rightarrow \sigma = \frac{1}{2}(LOT + P_o)$
Let: $M_w = \sigma$
Midline principle

Problem 1: Geomechanics

a) Show an expression for the horizontal in-situ stress. How would you select the mudweight relative to this? What do we call this concept?

b) Three LOT data sets are given in a well as follows:

Depth(m):	LOT(s.g.):	Pore(s.g.):	Overburden(s.g.):	Inclination(°):	
890	1,51	1,03	1,62	0	1,51
1124	1.35	1.21	1.76	30	1,61
1540	1,27	1,30	1,80	39	1,65

Estimate the LOT values for vertical hole sections.

c) Compute the horizontal stress levels from the data above.
State all assumptions.

Depth	σ_h/σ_v:	σ_h:
890	0.78	1,26
1124	0.8	1,41
1540	0.82	1,48

Problem 2: Casing Design

A directional exploration well is under planning. It is vertical to 1000 m, kick off to a sail angle of 45 degrees. The total depth is 2200 mMD or 1925 mTVD. Your job is to design the production casing for the well.

The water depth is 110 m, and the well is drilled from a jack-up rig.

a) Prepare a figure of the entire well. The reservoir section covers 90 m of the bottom of the well. Propose additional rathole length. Why is this required? 135m, to land perf. tools

b) After drilling, coring, logging and possibly pressure testing the well will be permanently plugged and abandoned. The time frame is two months. Propose:

- Design criteria and fluids in/outside the casing for burst design   gas filled csg. mud in/out / leaking tbg.
- Design criteria and fluids in/outside the casing for collapse design   mud in/out / thief zone.
- Design criteria and fluids in/outside for tensional strength design.   mud in/out / wt + press test

c) Perform casing design for burst collapse and tension. Well Data:

9-5/8 in. 47 lbs/ft P110	Gas density negligible.
Weight: 68.73 kg/m	Cemented : 300 mMD from bottom reservoir.
Burst strength: 651 bar	Mud weight: 1,60 s.g.
Collapse: 366 bar	Produktion packer 100MD m from bottom reservoir
Tension: 6590 kN	
Inner diam. 220,5 mm	

Problem 3: Pore pressure

In the planning of a new well the geologist identifies a significant uncertainty in the estimation of the pore pressure profile. The following data were used:

Depth:	1800 m
Estimated pore pressure:	1.23 s.g.
Reservoir interval:	1800 - 2000 m

a) Determine the density of the oil in the reservoir. What is the expected pore pressure gradient at the bottom of the reservoir? $S_{oil} = 0.77$ 1,03 sg @ 2000 m

b) After many discussions they decided that the reservoir section more probable covers the interval 1800 - 2100 m. Assume the same oil density and compute the pressure gradients at the top and bottom of the reservoir now.   1,33   1,03

c) Assuming that it is a water driven reservoir, where would you perforate your production casing? When water breakthrough occurs after some time production, a workover is called for. Where would you perforate now?

Perforate low
Plug back, perforate higher

Problem 4:

The figure below shows a gradient plot for a North Sea well.

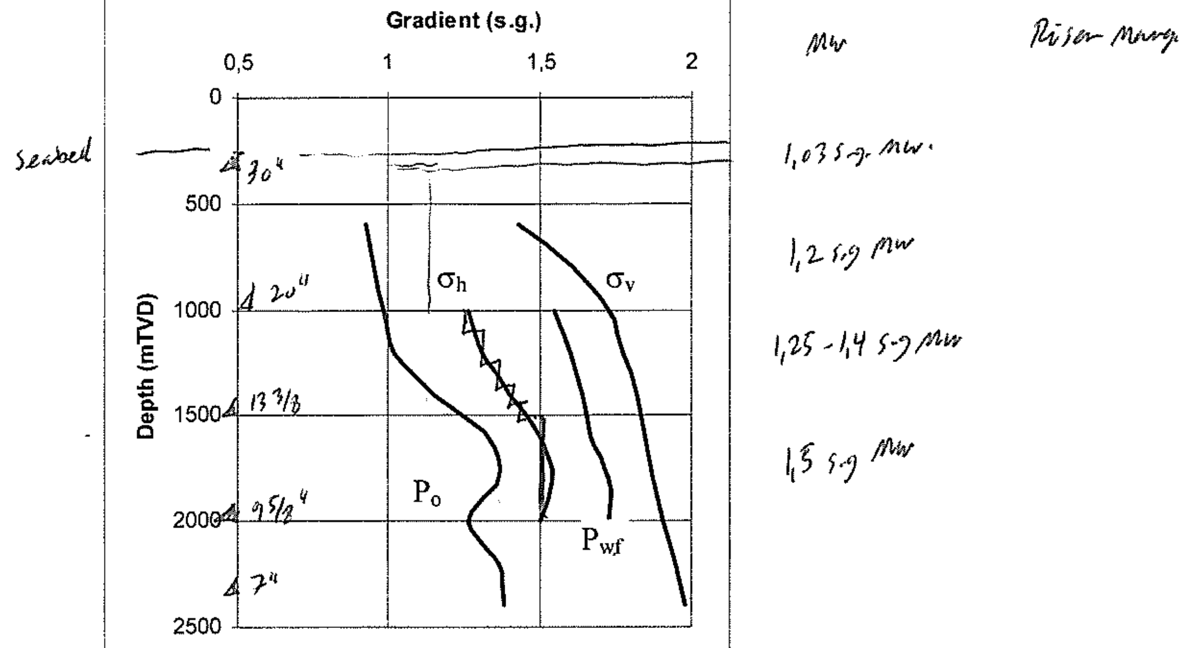

Figure 4: Gradient plot for Field case B.

The 9-5/8 in. production casing will be set at 2000 m, just above the reservoir. A 7 in. liner will be set through the reservoir down to 2300 m.

The 30 in conductor is set at 350 m, it has a length of 50 m.

a) Propose setting depths of the 13-3/8 in intermediate casing and the 20 in. surface casing. Explain your choices.

b) Propose mud weights for the entire well.

c) Propose mud weights if a riser margin is included. Do we need to adjust the casing setting depths? Which rig types uses riser margin, and why?

d) The production packer is set at 1950 m. Determine the minimum test pressure of the production tubing and packer. Also propose a maximum test pressure, and explain why.

e) One suspect temperature induced pressures in the B-annulus during production. Suggest reasons to avoid or reduce this problem. Also explain at which wells this might be a problem.

subsea wells,
do not cement above shoe,
leave open hole.

Problem 5: Pressure testing of casing

You are designing HPHT production casing test. The following data applies:

Well depth:	5000 m
Casing:	P 110, 58.4 lbs/ft
	Burst: 820 bar
	Collapse: 673 bar
	Tension: 8260 kN
Water depth:	500 m
Reservoir pressure:	2.18 s.g.
Reservoir fluid density:	0.5 s.g.
Mud density :	2.20 s.g.
Packer fluid:	1.2 s.g.
Packer depth:	4900 m
Cemented interval:	4600 - 5000 m with 1.9 s.g. cement

Semi-submersible drilling rig with 25 m drillfloor elevation

Because it is a critical well you are required to pressure test it throughout the well. Assume that the well will be produced for many years.

a) Prepare a figure. Define burst scenario for the casing test. Compute test pressure.

b) If the entire well cannot be tested simultaneously, propose other testing procedures that resolves the problem. Perform this design.

c) If the well during these operations are exposed to a high collapse loading, define these criteria and perform the design.

a) Long term
Seawater outside csg.
Leaking tubing
Test pressure
top: 800 bar (gas filled csg.)
btm: 871 bar (leaking tubing)

b) Displace upper part to seawater to 4281 m
Apply 800 bar surface pressure
OK - throughout well.

c) Worst case after installation, with seawater inside.
@ 4281 m, Pcollapse = 431 bar << 673 bar OK.

Some Formulas

P(bar) = 0.098 x d(s.g.) x D(m)

$P_3 = Cq^m$

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

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)	$5P_1/C(m+5)$

$A = q\{\rho/2gP_2\}^{1/2}/0.95$

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.

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

$LOT = 2\sigma_a - P_o$

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

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

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

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

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

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

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

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

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

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

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

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