Exam ta3440 Petroleum Engineering

22 August 2003

Instructions

- This exam consists of eight questions, some of which are divided in subquestions. The rating of each question is indicated behind the question in brackets.
- Duration: 3 hours.
- If you cannot answer a sub-question and can therefore not proceed to the next sub-question, guess the answer and proceed anyway.
- State your assumptions and explain your answers.

Questions

1. A gas-oil separator operates at a pressure of 83 psig and has an oil throughput of 20000 stb/d with a GOR of 700 scf/stb.
   - 1a) What are the pressure, oil throughput and GOR expressed in SI units? (½)
   - 1b) What is the gas throughput? Express your answer in field units at standard conditions and at operating conditions. Assume a Z factor equal to 1. (½)
   - 1c) What is separator carry over? (½)
2. A well has been drilled in a gas reservoir without an aquifer. After production of $G_p = 100*10^6$ scf (at 14.7 psia and 60°F) with the same composition the pressure has decreased from 4500 psia to 3000 psia. The Z-factors are respectively $Z = 0.95$ at 4500 psia and $Z = 0.85$ at 3000 psia. The reservoir temperature is 200 °F.
   - 2a) What is the value of the gas expansion factor E at 3000 psi and the initial expansion factor E_i at 4500 psi? Hint: remember to use absolute temperatures. (½)
   - 2b) What is the volume of gas initially in place (GIIP) G? (½)
   - 2c) What is the hydrocarbon pore volume (HCPV) V_{hp}? If you did not get the answer to question 2b) use the erroneous value $150 * 10^6$ scf? (½)
   - 2d) If the porosity is 20% and the connate water saturation 23%, compute the net reservoir volume. Use the erroneous value $0.75 * 10^5$ cuf in question 2c) if you did not find the result. (½)
   - 2e) If water influx would play a role do you expect that the GIIP would be less, equal to, or more than the result found under 2b)? Explain your answer. (½)
3. Consider an oil reservoir with the following properties:

   average thickness: $h = 90$ m
   area: $A = 5.7$ km^2
   net-to-gross ratio: $R_{n/g} = 0.35$
   porosity: $\phi = 0.20$
   water saturation: $S_{w,c} = 0.15$
   oil formation volume factor: $B_o = 1.15$ bbl/stb
   current recovery factor $E_R = 0.25$
   production rate: $q_{o,sc} = 30 * 10^3$ stb/d

   - 3a) What is the STOIIP expressed in stb? (½)
   - 3b) How long has the field been produced? (½)

4. Figure 1 below depicts an intake performance curve (IPC) for the tubing in combination with an inflow performance relationship (IPR) for the reservoir.
   4a) What are the closed-in and flowing bottomhole pressures for this well? (½)
   4b) What is the PI for this well? (½)
   4c) If we stimulate the well with acid to improve the inflow performance, how will the IPR change? Sketch the IPR (qualitatively) in the figure. (½)
   4d) If we do not stimulate the reservoir, and the the reservoir pressure drops to 24 MPa, what will be the production rate of the well? (½)

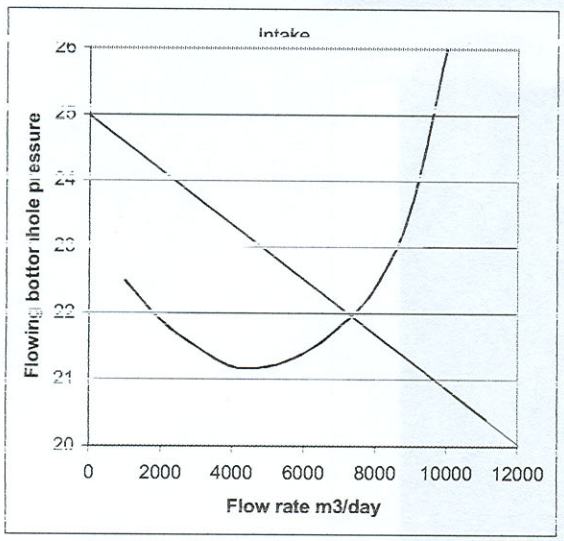

Figure 1: Intake pressure curve. Pressures in MPa.

5. Why are the pores in the oil zone of a reservoir never 100% filled with oil, but do always contain some "connate" water? (½)
6. Why does drilling mud need to have a certain viscosity?. What is a disadvantage of very viscous mud? (½)
7. Two wells have been drilled into an oil-water reservoir. One of them only penetrates the water layer, and pressure measurements at depths of 5300 and 5500 ft resulted in pressures of 2385 and 2475 psia. The other well only penetrates the oil layer, and pressure measurements at 4700 and 4950 ft resulted in pressures of 2158 and 2250 psia. What is the depth of the free water level? (1)
8. What is the NPV of the following cash flow at discount rates of 0 and 15%? (1)

Table 1: Undiscounted cash flow

Time (year)	1	2	3	4	5	6
Cash flow (10^6 $)	-4.2	-2.3	1.9	3.2	3.1	0.8

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Answers

1a 83 psig = 83 + 14.7 = 97.4 psia = 97.4 * 6895 = 672 * 10^3 Pa
20000 bpd = 20000 * 0.159 = 3180 m^3 d^{-1}
700 scf/stb = 700 * 0.178 = 125 m^3/m^3

1b $q_{g,sc} = R_{go} * q_{o,sc} = 700 * 20000 = 14 * 10^6$ scf/d.
$p_{sc} * V_{sc} = p * V$ or $p_{sc} * q_{g\cdot sc} = p * q_g$ and therefore
$q_g = q_{g,sc} * p_{sc} / p = 14 * 10^6 * 14.7 / 97.4 = 2.1 * 10^6$ cuf/d

1c Carry-over is the unwanted effect that liquid is leaving the separator with the gas stream.

2a $E = (Z_{sc}\, T_{sc}\, p) / (Z\, T\, p_{sc}) = [1 * (60 + 460) * 3000] / [0.85 * (200 + 460) * 14.7] = 189$
$E_i = (Z_{sc}\, T_{sc}\, p_i) / (Z_i\, T\, p_{sc}) = [1 * (60 + 460) * 4500] / [0.95 * (200 + 460) * 14.7] = 254$

2b $G = G_p / (E_i * (1/E - 1/E_i)) = 100 * 10^6 / (254 * (1/189 - 1/254)) = 291 * 10^6$ scf

2c $V_{hp} = G / E_i = 291 / 254 = 1.15 * 10^6$ cuf

2d $V_{R,net} = V_{hp} / (\varphi (1 - S_w)) = 1.15 / (0.20 * (1 - 0.23)) = 7.47 * 10^6$ cuf

2e Less. In the presence of an aquifer, water will enter the reservoir during gas production, and the pressure decrease will be lower than what it would have been without aquifer. To obtain the same pressure decrease, a smaller amount of gas should have been in place before production.

3a $N = h * A * R_{n/g} * \phi * (1 - S_w) / B_o = 90 * 5.7 * 10^6 * 0.35 * 0.20 * (1-0.15) / 1.15 = 26.5 * 10^6$ $m^3 = 26.5 * 10^6 / 0.159 = 167 * 10^6$ bbl.

3b $N_p = E_R * N = 0.25 * 167 * 10^6 = 41.7 * 10^6$ bbl.
$t_p = N_p / q_{o,sc} = 41.7 * 10^6 / 30 * 10^3 = 1390$ days

4a Closed-in bottom hole pressure: $p_{ws} = 25$ MPa (intersection of IPR with y-axis).
Flowing bottom hole pressure: $p_{wf} = 22$ MPa (intersection IPC and IPR)

4b PI: $J = q / (p_{ws} - p_{wf}) = 7500/(25 - 22) = 2500$ $m^3/(d*MPa)$.

4c See Figure 1 below.

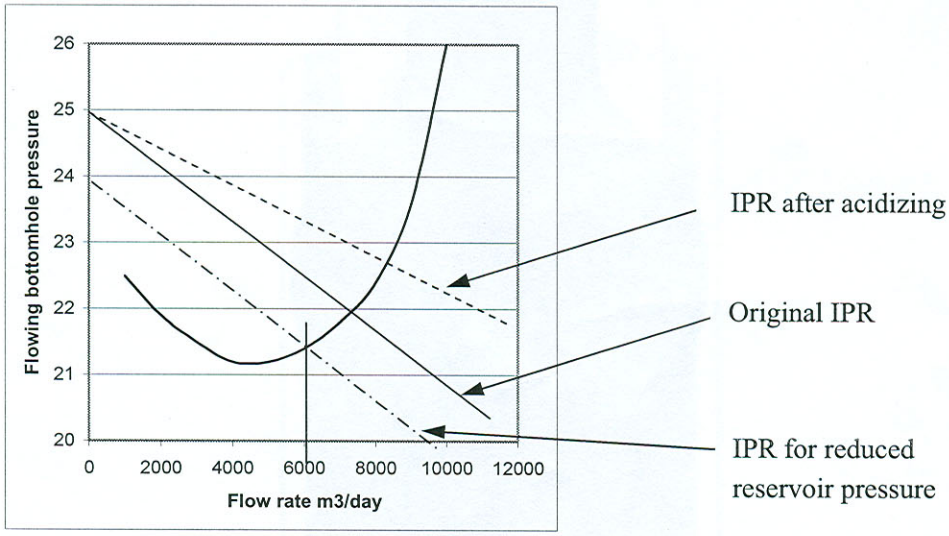

Figure 1: Changes in IPR. Pressures in MPa.

4d. For the reduced reservoir pressure the IPR is sketched in Figure 1 above. The production rate follows from the intersection of the IPC and the IPR as 6000 m^3/day.

5. The pores in the reservoir rock were initially filled with water. During migration of the oil from the source rock into the reservoir rock some of the water remained trapped in the pore space, in particular in the smaller pores.

6. Drilling mud needs viscosity in order to lift the cuttings out the hole. A disadvantage of the viscosity is that it increases the pressure drop over the fluid circulation system.

7. The water gradient is (2475 – 2385) / (5500 – 5300) = 0.450 psi/ft. The oil gradient is (2250 – 2158) / (4950 – 4700) = 0.368 psi/ft. The pressure-depth relationship of the water and the oil are therefore given by:

$$p_w = 2385 + 0.450 * (z - 5300)$$

$$p_o = 2158 + 0.368 * (z - 4700)$$

At the free water level, $p_o = p_w$, and therefore we find that z_{FWL} = 5224 ft.

8. $$S_{disc} = \frac{S}{(1 + R_{disc}/100)^n} = \frac{S}{(1.15)^n}$$

Table 1: Cash flow

Time (year)	1	2	3	4	5	6	**NPV**
Cash flow (10^6 \$)	-4.2	-2.3	1.9	3.2	3.1	0.8	**2.5**
Discounted cashflow (10^6 \$)	-3.65	-1.74	1.25	1.83	1.54	0.35	**-0.43**

The Net Present Value (NPV) is identical to the cumulative (discounted) cashflow, and is therefore obtained by adding up the yearly (discounted) cashflow figures.