Exam ta3440 Petroleum Engineering

28 March 2003

Instructions

- This exam consists of eight questions, two 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 any way.
- State your assumptions and explain your answers.

Questions

1. A material balance may be used to estimate the hydrocarbons initially in place. In the case of an oil reservoir that is produced below the bubble point pressure three phases (oil, water and gas) and various processes play a role. Name the processes that have to be included in the material balance. (1)
2. A well has been drilled in an enclosed gas reservoir to be used for storage. After injection of 50 MMscf (at 14.7 psia and 60°F) with the same composition the pressure increases from 2500 psia to 3500 psia. The Z-factors are respectively $Z = 0.9$ at 3500 psia and $Z = 0.8$ at 2500 psia. The well bottom temperature is 220 °F.

   The gas constant $R_b = 8.31$ J/mole/K. MM means one million.

   2a) What are the temperatures expressed in K? (½)

   2b) How much gas is present in the reservoir after injection? (1)

   2c) What is the hydrocarbon pore volume (HCPV)? If you did not get the answer to question 2b) use the erroneous value 150 MMscf? (½)

   2d) If the porosity is 16% and the connate water saturation 24%, compute the net reservoir volume. Use the erroneous value 0.65 MMcuf in question 2c) if you did not find the result. (½)

   2e) If water influx plays a role do you expect that the amount of gas present after injection is less, equal to, or more than the result found under 2b)? Explain in detail. Hint: in the case of *production* the material balance reads (of course if you like all quantities to be positive there can be only a difference in signs for the injection case) (½):

$$\frac{G}{E} - \frac{G_p}{E} = \frac{G}{E_i} - W_e$$

3. Sketch carefully the pressure-temperature diagram for hydrocarbon mixture, indicating the main types of hydrocarbon reservoir. Explain the concept of retrograde condensation. Draw in the diagram a typical production path for a black oil reservoir. (1).
4. See Figure 1 below.

   4a) Initially the pressure in a reservoir is 22 MPa. When the well produces 5000 m^3/day, the flowing bottomhole pressure is 21.5 MPa. What is the Productivity Index? (½)

   4b) The intake pressure curve for the well is shown in the figure. What is the initial production rate? (1)

4c) If the PI stays constant, as the reservoir pressure drops, what is the lowest reservoir pressure at which the well will flow? (½)

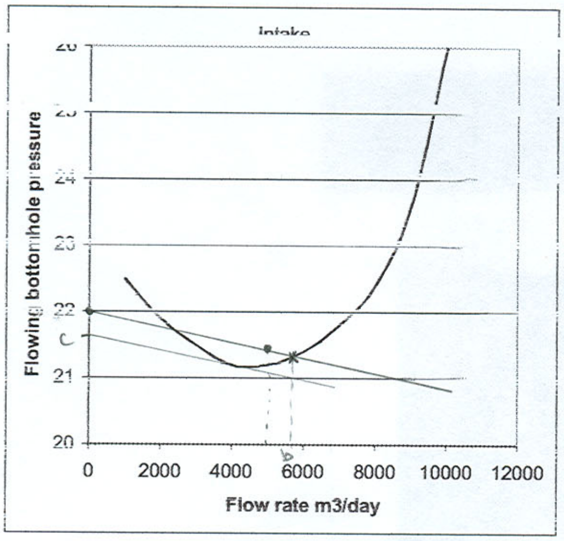

Figure 1: Intake pressure curve. Pressures in MPa.

5. What is formation damage ("skin")? What are two causes of formation damage? (½)
6. Give three main factors which determine the size of a separator. (½)
7. The pressure at the gas-oil contact in a reservoir is 4500 psi. The top of the reservoir is at a depth of 9500 ft, and the gas column has a height of 500 ft. The gas gradient is 0.08 psi/ft. What should be the minimum gradient of the drilling mud to avoid a "kick" when drilling into the gas cap? (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 $)	-5.3	-1.2	1.8	3.9	2.5	1.4

Answers exam ta3440 Petroleum Engineering

28 March 2003

Answers

1. – Production of oil, gas and water.
   – Expansion of the reservoir fluids.
   – Degassing of the oil.
   – Inflow of water from an aquifer.

2a 289 K, 377 K

2b $E = (Z_{sc}\, T_{sc}\, p) / (Z\, T\, p_{sc}) = (1 * 289 * 3500) / (0.9 * 377 * 14.7) = 203$

$E_i = (Z_{sc}\, T_{sc}\, p_i) / (Z_i\, T\, p_{sc}) = (1 * 289 * 2500) / (0.8 * 377 * 14.7) = 163$

$G = G_p / (E_i * (1/E - 1/E_i)) = -50 / (203 * (1/203 - 1/163)) = 204$ MMscf

$G_{tot} = G + G_p = 204 + 50 = 254$ MMscf

2c $V_{HC} = G / E_i = 204 / 163 = 1.25$ MMcuf

2d $V_{R,net} = V_{HC} / (\varphi\,(1 - S_w)) = 1.25 / (0.16 * (1 - 0.24)) = 10$ MMcuf

2e During gas injection, water will be forced into the aquifer, and the pressure increase will be lower than what it would have been without aquifer. The "corrected" higher pressure increase implies a smaller amount of gas in place before injection. The total amount after injection will therefore also be lower.

3. See Figure 5.21 of Jahn, Cook and Graham (1998). Retrograde condensation is condensation of liquid from gas when the pressure is decreased. Normal condensation occurs when the pressure is increased. Retrograde condensation occurs when high pressure gas is produced and the pressure drops below the dew point line. If this happens inside the reservoir, blockage of the pores occurs and the heavier, most valuable, hydrocarbons are left behind.

4a PI: $J = q / (p_R - p) = 5000/(22 - 21.5) = 10000$ m^3/(d*MPa) = 1000 m^3/(d*bar). The line for the PI passes through points A and B in Figure 1.

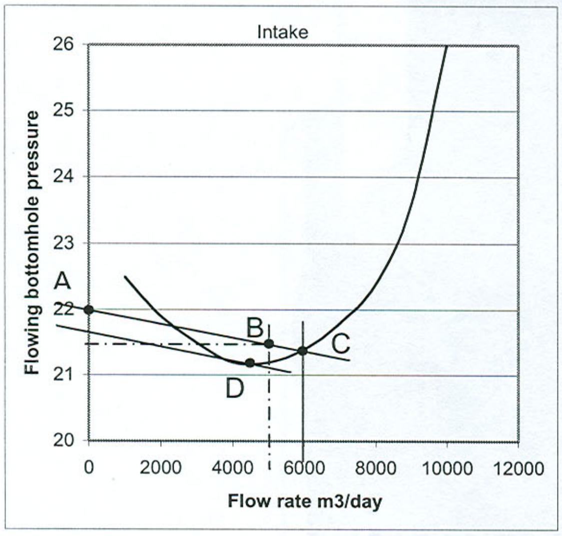

Figure 1: Intake pressure curve. Pressures in MPa.

4b Point C in Figure 1 represents the stable operating point at the intersection between the pressure intake curve and the PI. The corresponding flow rate is 6000 m^3/d.

4c The lowest pressure corresponds to the PI that intersects the intake curve in point D and has a magnitude of about 21.6 MPa.

5. See p. 216 and p. 355 of Jahn, Cook & Graham (1998).
6. See p. 245 of Jahn, Cook & Graham (1998).
7. $p_{top} = p_{GOC} - g_g * h_g = 4500 - 0.08 * 500 = 4460$ psi

   $g_{mud} = p_{top} / z_{top} = 4460 / 9500 = 0.47$ psi/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 \$)	-5.3	-1.2	1.8	3.9	2.5	1.4	**3.1**
Discounted cashflow (10^6 \$)	-4.61	-0.91	1.18	2.23	1.24	0.61	**-0.3**

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