NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY
DEPARTMENT OF PETROLEUM ENGINEERING
AND APPLIED GEOPHYSICS

Contact during exam:
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Exam results are due in week x, 2006.

**EXAM IN COURSE**
**TPG4145 RESERVOIR FLUIDS**

Saturday December 2, 2006

Time: 0900 – 1300

Permitted aids:
C:

- Any written and handwritten materials are permitted. Certain, specified calculator are permitted.

**General Description**

Problems 3 and 4 in the exam use some of the 2006 TPG4145 Project data but does not require that you have completed the Project (for students taking this exam a second time from an earlier year). These required data are included in the exam text and tables.

Problems 1 and 2 are totally unrelated to the 2006 Class Project.

**Problems:**

1. A gas condensate reservoir is discovered at initial pressure of $p_{Ri}$=800 bara and temperature $T_R$=150°C. Total wellstream (reservoir) gas specific gravity is $\gamma_w=\gamma_{gR}$=0.82 (air=1). Initial gas in place estimate is 0.1E12 $Sm^3$. Initial GOR is $R_p$=1000 $Sm^3/Sm^3$.

a. Calculate initial Z-factor.

b. Calculate HCPV (hydrocarbon pore volume).

A modeling study shows that after average reservoir pressure drops to 400 bara, which equals the dewpoint pressure, water encroachment from an outside aquifer results in a total water influx volume of $W_e$=0.2HCPV.

c. Calculate the cumulative surface gas produced at this time, expressed as a % recovery factor of initial surface gas in place ($G_p/G$), when average reservoir pressure equals 400 bara.

d. Calculate the cumulative surface condensate produced at this time, expressed as a % recovery factor of initial condensate in place ($N_p/N$), when average reservoir pressure equals 400 bara.

2. The table for Problem 2 below shows results from a separator test from an oil well.

a. Calculate the mass rates of separator gas and separator oil in kg/day.

b. Calculate the molar rates of separator gas and separator oil in kg-mol/day (kmol/day).

c. Calculate the mol-% methane in the produced wellstream.

d. Calculate the K-values of $C_1$, $C_3$, and $C_{7+}$ at separator conditions.

e. Estimated the K-value of $C_{7+}$ at 14.7 psia and separator temperature assuming "ideal" low-pressure K-value behavior. Note: you do not need to use the Wilson equation.

3. [Use Project PVT data.] An oil well flows at $q_o$=1000 $Sm^3/d$ with a producing GOR of 1000 $Sm^3/Sm^3$. Flowing bottomhole pressure (FBHP) $p_{wf}$=138 bara.

a. Calculate relevant black-oil PVT properties $B_o$, $R_s$, $B_{gd}$, and $r_s$ in SI units ($m^3/m^3$) at FBHP.

The total surface oil rate consists of surface oil from reservoir oil and surface oil (condensate) from reservoir gas – $q_o=q_{oo}+q_{og}$; and total surface gas rate consists of surface gas from reservoir gas and surface gas from reservoir oil – $q_g=q_{gg}+q_{go}$.

b. Calculate $q_{oo}$, $q_{og}$, $q_{gg}$, and $q_{go}$. Hint, rewrite the two equations in terms of $q_{gg}$ and $q_{oo}$ using the relations $q_{og}=q_{gg}r_s$ and $q_{go}=q_{oo}R_s$, then solve for $q_{gg}$ and $q_{oo}$.

c. Calculate reservoir gas and oil rates $q_{gR}$ and $q_{oR}$ at FBHP.

d. Calculate the $k_{rg}/k_{ro}$ ratio given that $q_{gR}/q_{oR}=(k_{rg}/\mu_g)/(k_{ro}/\mu_o)$, the ratio of phase mobilities.

4. [Use Project PVT data.] Given the total IOIP and IGIP (IOIP=N=126E6 STB, IGIP=G=237E9 scf) in Block A, Tilje formation in the Project. Assume these total surface initial in place volumes are fixed but that initial reservoir pressure is 4000 psia instead of the Skarv initial reservoir pressure (~5300 psia).

a. Does the block contain reservoir gas (RG) only, reservoir oil (RO) only, or both RG & RO?

b. Calculate the HCPV required to hold this amount of fluid at 4000 psia (i.e. if the initial reservoir pressure had been 4000 psia but contained the same fluids).

c. Calculate IGIP(RG), IOIP(RG), IGIP(RO), and IOIP(RO).

| Problem 2 - Separator Samples collected at 60 bara and 50°C with a separator gas rate of 0.2E6 $Sm^3/d$ and separator oil rate of 1000 $Sm^3/d$. | | |
|---|---|---|
| | Separator Gas mol-% | Separator Oil mol-% |
| $N_2$ | 1.28 | 0.13 |
| $CO_2$ | 1.60 | 0.78 |
| $C_1$ | 83.07 | 20.52 |
| $C_2$ | 7.27 | 6.63 |
| $C_3$ | 3.18 | 6.95 |
| $iC_4$ | 0.84 | 3.39 |
| $nC_4$ | 1.18 | 6.15 |
| $iC_5$ | 0.41 | 4.07 |
| $nC_5$ | 0.45 | 5.48 |
| $C_6$ | 0.48 | 12.73 |
| $C_{7+}$ | 0.24 | 33.12 |
| $M_{7+}$ | 115 | 210 |
| $\gamma_{7+}$ | 0.72 | 0.85 |
| Separator oil density is estimated by correlation to be 730 $kg/m^3$; separator oil molecular weight is 102. | | |

Problems 3&4 – Black-Oil PVT (Saturated) tables from class Project.

| PSAT | BO | RS | VISO | rs | BG | VISG |
|---|---|---|---|---|---|---|
| psia | rb/stb | scf/stb | cp | stb/mmcf | rb/scf | cp |
| 100 | 1.0841 | 8 | 1.103 | 72.28 | 0.03872 | 0.0131 |
| 500 | 1.1306 | 77 | 0.831 | 22.84 | 0.00722 | 0.0139 |
| 750 | 1.1560 | 121 | 0.745 | 17.72 | 0.00474 | 0.0143 |
| 1000 | 1.1809 | 166 | 0.677 | 15.67 | 0.00351 | 0.0147 |
| 1250 | 1.2056 | 212 | 0.620 | 14.98 | 0.00279 | 0.0151 |
| 1500 | 1.2302 | 260 | 0.571 | 15.06 | 0.00232 | 0.0156 |
| 1750 | 1.2549 | 309 | 0.528 | 15.63 | 0.00198 | 0.0162 |
| 2000 | 1.2797 | 359 | 0.490 | 16.58 | 0.00173 | 0.0168 |
| 2250 | 1.3049 | 411 | 0.456 | 17.84 | 0.00154 | 0.0175 |
| 2500 | 1.3304 | 464 | 0.425 | 19.37 | 0.00139 | 0.0182 |
| 3000 | 1.3829 | 576 | 0.372 | 23.20 | 0.00118 | 0.0199 |
| 3500 | 1.4379 | 695 | 0.329 | 27.99 | 0.00103 | 0.0219 |
| 4000 | 1.4960 | 823 | 0.292 | 33.76 | 0.00092 | 0.0241 |
| 4500 | 1.5580 | 962 | 0.261 | 40.60 | 0.00084 | 0.0265 |
| 4905 | 1.6117 | 1083 | 0.239 | 47.00 | 0.00080 | 0.0286 |
| 5500 | 1.6973 | 1279 | 0.211 | 57.92 | 0.00074 | 0.0319 |
| 6000 | 1.7755 | 1459 | 0.192 | 68.54 | 0.00071 | 0.0350 |
| 6500 | 1.8602 | 1657 | 0.175 | 80.58 | 0.00069 | 0.0384 |
| 7000 | 1.9523 | 1874 | 0.160 | 94.14 | 0.00067 | 0.0422 |
| 7500 | 2.0526 | 2112 | 0.148 | 109.26 | 0.00066 | 0.0466 |