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Examination paper for TPG 4145 Reservoir Fluids

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Problem 1. PVT & Material Balance

Consider the gas condensate reservoir with PVT properties given in Table 1.

1. Use Standing-Katz Z-factor chart to estimate the initial reservoir gas Z-factor.

2. Calculate initial solution oil-gas ratio (r_s) using approximate surface process given in Table 1.

3. Calculate initial <u>inverse</u> dry gas FVF ($b_{gd}=1/B_{gd}$) in scf/ft^3.

4. Calculate initial surface gas in place, IGIP.

5. Calculate initial surface oil (condensate) in place, IOIP.

6. Calculate the percentage of the initial total monetary value in place from surface oil using an oil price of USD 85/STB and gas price of USD 4/Mscf.

7. Assuming a gas material balance with zero water and pore compressibilities, calculate the recovery factor of surface gas and surface oil when average reservoir pressure reaches the dewpoint.

8. Assuming a gas material balance with total associated water volume ratio M=3.3, S_{wi}=0.35, c_f=6.5(10^{-6}) 1/psi, and c_w=3.5(10^{-6}) 1/psi, calculate the recovery factor of surface gas and surface oil when average reservoir pressure reaches the dewpoint.

9. Does the percentage of the total monetary value <u>produced</u> from surface oil (from initial- to dewpoint pressure) in (8) above differ from the value calculated in (6)?

10. Of the components in Table 1, which component's equilibrium K-value ($K_i=y_i/x_i$) has the greatest impact on dewpoint pressure calculation, and why?

Problem 2. Fluid flow Calculations

A gas well (Well "C" in the Fetkovich paper "Multipoint Testing of Gas Wells" is tested with results of A=1 psi^2/(Mscf/D) and B=27(10^{-6}) psi^2/(Mscf/D)^2, based on the low-pressure reservoir rate equation $Aq_g+Bq_g^2=(p_R^2-p_{wf}^2)$, determined by a plot of $(p_R^2-p_{wf}^2)/q_g$ versus q_g.

$$A = \frac{1424\ (\overline{\mu z})\ T}{Kh} \left[\ln\left(\frac{.472\ r_e}{r_w}\right) + S \right] \quad ..(6)$$

or for the transient period

$$A(t) = \frac{1424\ (\overline{\mu z})\ T}{Kh} \left[\frac{1}{2}\ (\ln t_D + 0.809) + S \right] \quad ..(7)$$

$$B = \frac{1424\ (\overline{\mu z})\ T}{Kh}\ D \quad ..(4)$$

The test A value represents an infinite-acting "transient" 1-hour test corresponding to $p_{D(t=1hr)}$ $=½[(\ln t_{D1\text{-}hr}+0.809)=7.5$. The pseudosteady state value for A would be higher because the term $\ln(0.472r_e/r_w)$ (which replaces p_D) is closer to a value of 10 for the assumed wide well spacing. Therefore, a pseudosteady state $A_{pss}=1(10/7.5)=1.33$ should be used in all engineering calculations (if the well had no skin during test). Because the well had a positive skin during the test, the corrected $A_{pss}=A_{test}[\ln(0.472r_e/r_w)+s_{development}]/[p_D(t_{test})+s_{test}]$.

A geometric (partial penetration) skin factor during the test is assessed to be +22. Initial reservoir pressure is 1370 psia.

The test flowing surface tubing pressure p_t=744 psia during the 52 500 Mscf/D flow period. The static gas gradient term $\exp(S/2)=1.08$ is used to convert bottomhole to surface pressures: e.g. $p_c=p_R/\exp(S/2)$ and $p_w=p_{wf}/\exp(S/2)$. Test tubing size was 4-inch inner diameter.

Development plans rely on the following assumptions:

a. Geometric skin is removed by completing the well throughout the pay zone, so $s_{development}=0$ (instead of $s_{test}=+22$).
b. Tubing inner diameter size is 6.5 inches (instead of 4 inches).
c. Reservoir B does not change with well recompletion.

1. Calculate the flowing bottomhole pressure p_{wf} for the test rate of 52 500 Mscf/D.

2. Calculate the tubing performance equation constant B_t for the test well: $B_t q_g^2=(p_w^2-p_t^2)$. This constant (B_{t4}) is for 4-inch inner diameter tubing.

3. Calculate the B_t constant for 6.5-inch inner diameter tubing using the relation $B_{t6.5}=B_{t4}[(4/6.5)^{2.612}]^2$. Explain this relationship based on Fetkovich's paper.

4. Calculate the wellhead backpressure constants A_{wh} and B_{wh} that can be used through the entire life of the well: $A_{wh}q_g+B_{wh}q_g^2=(p_c^2-p_t^2)$. Note, B_{wh} is based of the "non-Darcy" reservoir flow term (B) and the tubing pressure drop term B_t.

5. Abandonment is defined as a well rate of 10 000 Mscf/D with flowing tubing pressure of 10 psia (minimum compressor intake pressure). Determine the average reservoir pressure at abandonment, and approximate gas recovery factor.

TABLE 1—MEASURED CONSTANT-VOLUME DEPLETION DATA FOR THE NS-1 FLUID AT 280°F (psia)

	Compositions								
	Equilibrium Vapor							Equilibrium Liquid	
								Experi-mental	Calcu-lated
Component	6764.7	5514.7	4314.7	3114.7	2114.7	1214.7	714.7	714.7	714.7
Carbon dioxide	2.37	2.40	2.45	2.50	2.53	2.57	2.60	0.59	0.535
Nitrogen	0.31	0.32	0.33	0.34	0.34	0.34	0.33	0.02	0.017
Methane	73.19	75.56	77.89	79.33	79.62	78.90	77.80	12.42	10.704
Ethane	7.80	7.83	7.87	7.92	8.04	8.40	8.70	3.36	3.220
Propane	3.55	3.47	3.40	3.41	3.53	3.74	3.91	2.92	2.896
isobutane	0.71	0.67	0.65	0.64	0.66	0.72	0.78	0.91	0.916
n-butane	1.45	1.37	1.31	1.30	1.33	1.44	1.56	2.09	2.103
isopentane	0.64	0.59	0.55	0.53	0.54	0.59	0.64	1.40	1.417
n-pentane	0.68	0.62	0.58	0.56	0.57	0.61	0.66	1.60	1.624
Hexanes	1.09	0.97	0.88	0.83	0.82	0.85	0.90	3.68	3.755
Heptanes-plus	8.21	6.20	4.09	2.64	2.02	1.84	2.12	71.01	72.815
Totals	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
$M_{C_{7+}}$	184.0	160.0	142.0	127.0	119.0	115.0	114.0	213.0	207.8
$\gamma_{C_{7+}}$	0.816	0.799	0.783	0.770	0.762	0.758	0.757	0.833	0.843
Z	1.238	1.089	0.972	0.913	0.914	0.937	0.960		
n_p, %	0.000	9.024	21.744	38.674	55.686	72.146	81.301		
S_L, %	0.0	14.1	19.7	21.6	21.3	20.2	19.3		

Initial reservoir pressure: 12,000 psia.
HCPV: 10^{11} ft^3.
Surface process approximation: C_{5-} = surface gas | C_{6+} = surface oil.