King Saud University

Petroleum and Natural Gas Engineering

PGE 362: **Properies of Reservior Fluids**

Tutorial 9

The table below shows the laboratory analysis of a reservoir sample from an oil well producing 14.5° API stock-tank oil at 941 scf/STB. The sample was obtained from the reservoir at 184° F and 3463 psig.

1. Plot oil formation volume factor and solution gas-oil ratio vs. pressure and compare the shape of Bo graph and Rs graph then state your comments.
2. Determine the values of total formation volume factor of black oil at 4000, 3200, 2100, and 1800 psig.
3. Determine the values of the coefficient of isothermal compressibility of black oil at 4000, 3200, 2100, and 1800 psig.

Pressure psig	Oil formation volume gas-oil factor B_o res bbl/STB	Solution gas-oil ratio R_s scf/STB	Gas formation volume factor B_g bbl/scf
5000	1.498	941	
4500	1.507	941	
4000	1.517	941	
3500	1.527	941	
3400	1.530	941	
3300	1.532	941	
3200	1.534	941	
3100	1.537	941	
3054 = p_b	1.538	941	0.000866
2700	1.484	819	0.000974
2400	1.441	732	0.001090
2100	1.401	646	0.001252
1800	1.361	562	0.001475
1500	1.323	481	0.001795
1200	1.287	400	0.002285
900	1.252	321	0.003108
600	1.215	240	0.004760
300	1.168	137	0.009683

See solution next page

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1. Figure 1 represents the plot of oil formation volume factor and solution gas-oil ratio vs. pressure. It is clear from the plot that both the oil formation volume factor (B_o) and solution gas-oil ratio (R_s) are increasing for pressure values less than the bubble point pressure P_b. On the other hand, B_o is decreasing with pressure values greater than the bubble point pressure while R_s is constant.

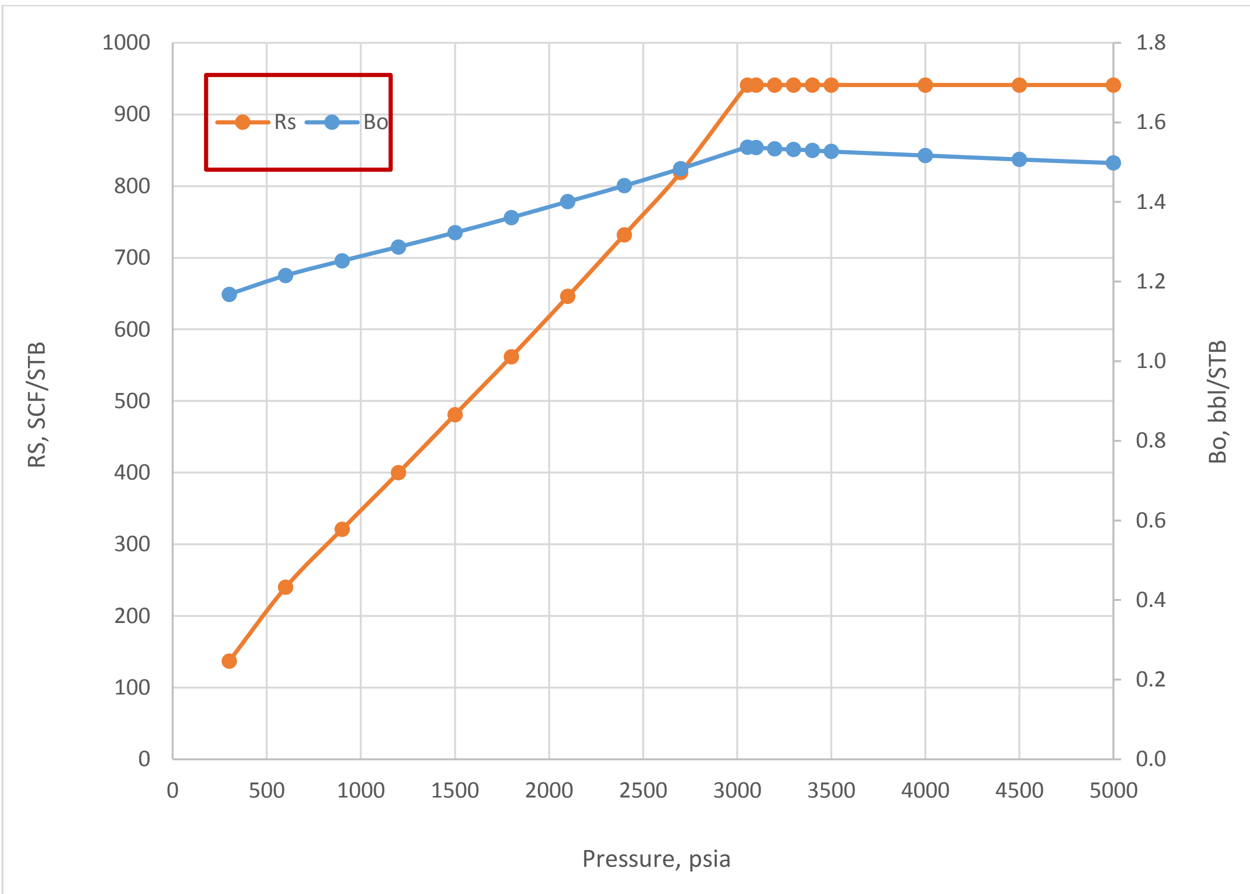

Figure 1: Oil formation volume factor and Gas-oil-ration vs. pressure

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2. In order to calculate the total formation volume factor it is required to use equation (1);

$$B_t = B_o + B_g \left(R_{sb} - R_s\right) \qquad (1)$$

<u>Case-1: Pressure blow bubble point pressure ($P < P_b$)</u>

For this case the values of gas-oil ratio R_s is increases with pressure and hence ($R_{sb} - R_s$) will decreses therefore B_t decrease with pressure. Below is a sample calculation for P = 1800 psig

B_t@(1800) = 1.361 + 0.001475 (941 – 562) = 1.92 bbl/STB

<u>Case-2: Pressure above bubble point pressure (P > Pb)</u>

For this case the values of gas-oil ratio R_s is not changing with pressure and hence ($R_{sb} - R_s$) = 0 therefore B_t is equivalent to B_o. Below is a sample calculation for P = 4000 psig

B_t@(4000) = 1.517 + B_g (941 – 941) = 1.517 bbl/STB

Figure 2 symbolizes the plot of both oil formation volume factor and total formation volume factor vs. pressure.

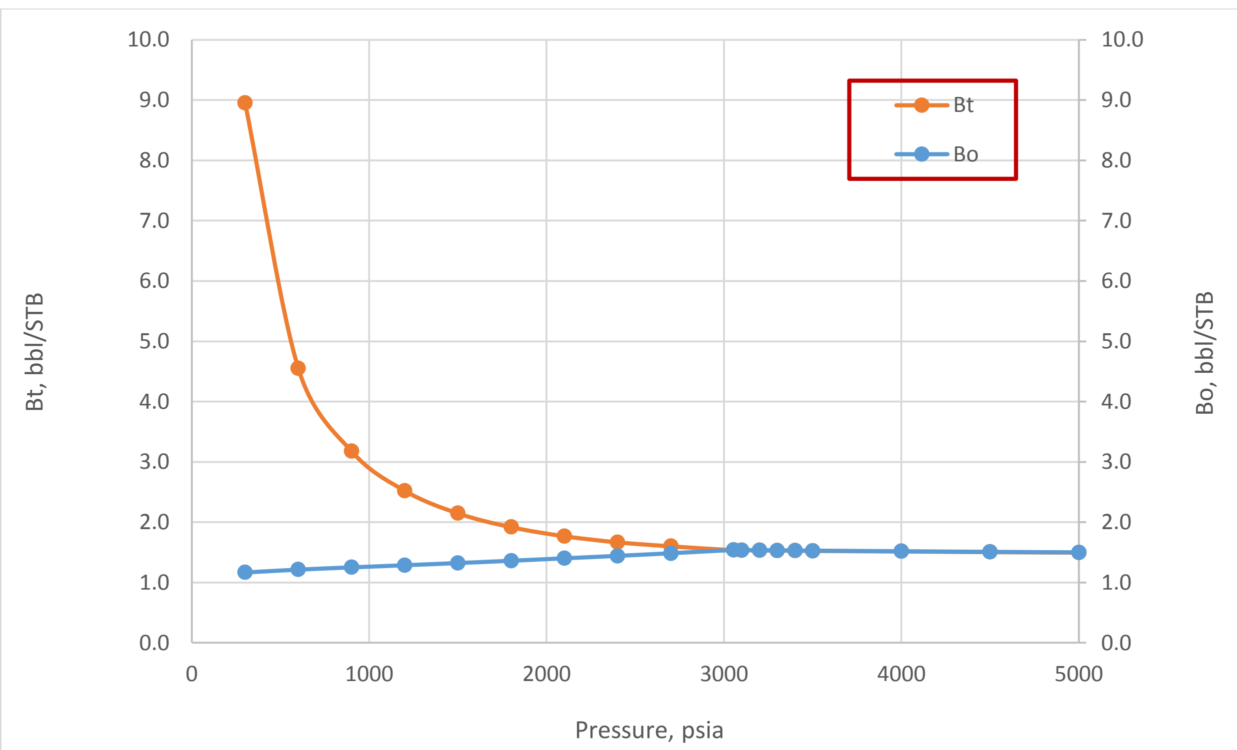

Figure 2: Oil formation volume and total formation volume factor vs. pressure

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3. In order to determine the coefficient of isothermal compressibility of black oil equation (2) should be used;

$$C_o = -\frac{1}{B_o}\left(\frac{\partial B_o}{\partial P}\right)_T + \frac{B_g}{B_o}\left(\frac{\partial R_s}{\partial P}\right)_T \qquad (2)$$

Case-1: Pressure blow bubble point pressure ($P < P_b$)

According to equation (2) both the derivative of oil formation volume factor and gas-oil ratio with pressure should be obtained. Simply the derivatives can be calculated numerically using two pressure points as shown in the example below for P = 1800 psig;

For this pressure the oil formation volume factor derivative $\left(\frac{\partial B_o}{\partial P}\right)_T$ can be calculated using two pressure values (1800 & 1500) and also for the gas-oil ratio derivative $\left(\frac{\partial R_s}{\partial P}\right)_T$.

$$C_o\ @(1800) = -\frac{1}{1.361}\left[\frac{1.323-1.361}{1500-1800}\right] + \frac{0.001475}{1.361}\left[\frac{481-562}{1500-1800}\right] = 1.995 \times 10^{-4}\ \text{psi}^{-1}$$

Case-2: Pressure above bubble point pressure ($P > P_b$)

For pressure above the bubble point pressure Rs in constant therefore its derivative is zero hence equation (2) will be reduced to;

$$C_o = -\frac{1}{B_o}\left(\frac{\partial B_o}{\partial P}\right)_T$$

Sample calculation for pressure P = 4000 psig

$$C_o\ @(4000) = -\frac{1}{1.517}\left[\frac{1.527-1.517}{3500-4000}\right] = 1.318 \times 10^{-5}\ \text{psi}^{-1}$$

Table 1 shown next page summarizes the calculations for all the pressure values.

Table 1: Example detailed calculations

Pressure	Bo	Rs	Bg	Co	dRs/dp	dBo/dp	Bt
5000	1.498	941		1.202E-05		-1.80E-05	1.498
4500	1.507	941		1.327E-05		-2.00E-05	1.507
4000	1.517	941		1.318E-05		-2.00E-05	1.517
3500	1.527	941		1.965E-05		-3.00E-05	1.527
3400	1.530	941		1.307E-05		-2.00E-05	1.530
3300	1.532	941		1.305E-05		-2.00E-05	1.532
3200	1.534	941		1.956E-05		-3.00E-05	1.534
3100	1.537	941		1.414E-05		-2.17E-05	1.537
3054	**1.538**	**941**	**0.000866**	**9.487E-05**	**0.3446**	**1.53E-04**	**1.538**
2700	1.484	819	0.000974	9.375E-05	0.2900	1.43E-04	1.603
2400	1.441	732	0.001090	1.243E-04	0.2867	1.33E-04	1.669
2100	1.401	646	0.001252	1.551E-04	0.2800	1.33E-04	1.770
1800	1.361	562	0.001475	1.995E-04	0.2700	1.27E-04	1.920
1500	1.323	481	0.001795	2.756E-04	0.2700	1.20E-04	2.149
1200	1.287	400	0.002285	3.769E-04	0.2633	1.17E-04	2.523
900	1.252	321	0.003108	5.717E-04	0.2700	1.23E-04	3.179
600	1.215	240	0.004760	1.216E-03	0.3433	1.57E-04	4.552
300	1.168	137	0.009683	4.525E-04	0.4567	3.89E-03	8.953