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Evaluation of Different Correlation Performance for the Calculation of the Critical Properties and Acentric Factor of Petroleum Heavy Fractions

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Abstract

The characterization of petroleum fluids is fundamental for the calculation of their thermodynamic properties. Laboratory experiments are able to identify a limited number of pure components present in a sample. All remaining species, the so called “cut”, are characterized by its molecular weight and density. The thermodynamic calculations performed using cubic equations of state require the critical properties and the acentric factor, which are unknown for the petroleum “cut.” In this chapter, different correlations are used to calculate the critical properties and the acentric factor of the “cut” fraction. The performance of the correlations is evaluated through the comparison of a simulated pressure-volume-temperature (PVT) experiment using an equation of state and experimental data of two reservoir fluids.

Keywords: correlations of critical properties, petroleum heavy fractions, PVT experiments, thermodynamics, phase equilibrium

1. Introduction

Petroleum is a complex mixture of several chemical components, mainly hydrocarbons. In addition to the hydrocarbons, it may also contain some inorganic contaminants such as carbon dioxide (CO₂), nitrogen (N₂) and hydrogen sulfide (H₂S).

The physical properties of reservoir fluids are related to the concentration of their components. Some properties such as bubble point pressure, oil formation volume factor, solubility ratio, oil

density, gas formation volume factor and gas specific gravity are of particular interest in black oil reservoir engineering studies. These properties are generally obtained in laboratory using reservoir fluids samples. These experiments seek to replicate the isothermal recovery path of an oil field.

Pressure-volume-temperature (PVT) experiments are carried out in liquid mixtures of hydrocarbons and during the pressure reduction steps, dissolved gas is released. There are two types of experiments that simulate the constant temperature depletion of a reservoir fluid, “flash” and “differential”. In a “flash” experiment, the overall composition of the system is kept constant, whereas in a “differential” experiment the gas phase is removed from the system at each pressure step.

These experiments can be simulated using equations of state in order to evaluate different recovery schemes without carrying out one experiment for each possible scenario, especially in the cases of enhanced oil recovery techniques. The correct identification of the species and their concentrations is fundamental for the success of the simulation. However, in any laboratory test, the heavy fraction of the oil, the so-called “cut,” is characterized by its molecular weight and density. In order to simulate the experiment, correlations are necessary to calculate the critical properties and the acentric factor of the “cut” from its molecular weight and density. In this chapter, different correlations are used to determine the critical properties and acentric factor of the heavy fraction of two reservoir fluids, the PVT experiments of these fluids are simulated using an equation of state and the results are compared with laboratory data.

2. Methodology

Cubic equations of state are widely used to describe the volumetric properties of pure substances and mixtures in the petroleum industry. Furthermore, these models can be used for equilibrium calculations and to estimate PVT properties, such as bubble point pressure, oil formation volume factor, solubility ratio, oil specific weight, gas formation volume factor and gas density.

The input parameters of the most used equations of state are the acentric factor, ω , critical temperature, T_c , and critical pressure, P_c , of the mixture components. These parameters are tabulated for a large number of chemical compounds, but for the heavy fractions of petroleum fluids, they are determined from correlations. Most correlations are functions of density, γ , molecular mass, M , and/or normal boiling temperature, T_b , of the fractions [1].

Edmister [2] proposed a correlation to estimate the acentric factor of pure liquids and petroleum fractions. This correlation is given by:

$$\omega = \frac{3 \left[\log \left(\frac{P_c}{14.7} \right) \right]}{7 \left[\frac{T_c}{T_b} - 1 \right]} - 1 \quad (1)$$

Cavett [3] presented equations to estimate the critical temperature and pressure of hydrocarbon fractions. These correlations are a function of the normal boiling point and the API gravity:

$$T_c = a_0 + a_1(T_b) + a_2(T_b)^2 + a_3(API)(T_b) + a_4(T_b)^3 + a_5(API)(T_b)^2 + a_6(API)^2(T_b)^2 \quad (2)$$

$$\log(P_c) = b_0 + b_1(T_b) + b_2(T_b)^2 + b_3(API)(T_b) + b_4(T_b)^3 + b_5(API)(T_b)^2 + b_6(API)^2(T_b) + b_7(API)^2(T_b)^2 \quad (3)$$

T_b : normal boiling temperature [°F].

The coefficients of Eqs. (2) and (3) are shown in **Table 1**.

Kesler and Lee [4] developed correlations for critical temperature and pressure, molecular weight and acentric factor of oil fractions. These expressions are given by:

$$\ln(P_c) = 8.3634 - \frac{0.0566}{\gamma} - \left(0.24244 + \frac{2.2898}{\gamma} + \frac{0.11857}{\gamma^2}\right)10^{-3}T_b + \left(1.4685 + \frac{3.648}{\gamma} + \frac{0.47227}{\gamma^2}\right)10^{-7}T_b^2 - \left(0.42019 + \frac{1.6977}{\gamma^2}\right)10^{-10}T_b^{-3} \quad (4)$$

$$T_c = 341.7 + 811.1\gamma + (0.4244 + 0.1174\gamma)T_b + (0.4669 - 3.26238\gamma)\frac{10^5}{T_b} \quad (5)$$

$$\omega = -7.904 + 0.1352K_w - 0.007465K_w^2 + 8.359T_{br} + (1.408 - 0.01063K_w)\frac{1}{T_{br}}, \quad (6)$$

for $T_{br} > 0.8$, and

$$\omega = \frac{-\ln\left(\frac{P_c}{14.7}\right) - 5.92714 + \frac{6.09648}{T_{br}} + 1.28862 \ln(T_{br}) - 0.169347T_{br}^6}{15.2518 - \frac{15.6875}{T_{br}} - 13.4721 \ln(T_{br}) + 0.43577T_{br}^6}, \quad (7)$$

for $T_{br} \leq 0.8$.

i	a_i	b_i
0	768.0712100000	2.82904060
1	1.7133693000	$0.94120109 \times 10^{-3}$
2	-0.0010834003	$-0.30474749 \times 10^{-5}$
3	-0.0089212579	$-0.20876110 \times 10^{-4}$
4	$0.3889058400 \times 10^{-6}$	$0.15184103 \times 10^{-8}$
5	$0.5309492000 \times 10^{-5}$	$0.11047899 \times 10^{-7}$
6	$0.3271160000 \times 10^{-7}$	$-0.48271599 \times 10^{-7}$
7		$0.13949619 \times 10^{-9}$

Table 1. Coefficients of Cavett [3] correlation.

θ	a	b	c	Average deviation (%)	Max deviation (%)
M	-4.56730×10^{-5}	2.19620	-1.0164	2.6	11.8
T_c	24.27870	0.58848	0.3596	1.3	10.6
P_c	-3.12281×10^9	-2.31250	2.3201	3.1	-9.3
V_c	-7.52140×10^{-3}	0.28960	-0.7666	2.3	-9.1

Table 2. Coefficients of Riazi and Daubert [6] correlation.

In Eq. (6), K_w is the Watson characterization factor, given by:

$$K_w = \frac{(T_b)^{\frac{1}{3}}}{\gamma} \quad (8)$$

Standing [5] developed the following correlations based on experimental data:

$$T_c = 608 + 364 \log (M - 71.2) + [2450 \log (M) - 3800] \log (\gamma) \quad (9)$$

$$P_c = 1188 - 431 \log (M - 61.1) + [2319 - 852 \log (M - 53.7)](\gamma - 0.8) \quad (10)$$

Riazi and Daubert [6] proposed a simple two-parameter equation to calculate the physical properties of pure components and mixtures of hydrocarbons:

$$\theta = a T_b^b \gamma^c \quad (11)$$

where θ is the property (T_c , P_c , v_c or M), v_c is the critical volume (ft^3/lb) and a to c are constants for the correlation of each property.

Table 2 shows the coefficients of Eq. (11) and the errors in the estimative of each property.

Sim and Daubert [13] determined expressions to calculate the critical pressure and critical temperature of petroleum “cuts,” given by:

$$P_c = 3.48242 \times 10^9 T_b^{-2.3177} \gamma^{2.4853} \quad (12)$$

$$T_c = \exp (3.99347 T_b^{0.08615} \gamma^{0.04614}) \quad (13)$$

Twu [7] proposed a set of correlations, based on the perturbation-expansion theory with normal paraffins as the reference state, to determine the critical properties of heavy fractions of hydrocarbons. The method is based on the selection of a normal paraffin with normal boiling temperature, T_{bPi} , identical to the normal boiling temperature of the C_{n+} fraction. Once the normal paraffin is chosen, the heavy fraction critical properties are calculated through the following steps:

1. Calculate the critical properties of the normal paraffin

$$T_{cPi} = T_{bC+} + \left[A_1 + A_2 T_{bC+} + A_3 T_{bC+}^2 + A_4 T_{bC+}^3 + \frac{A_5}{(A_6 T_{bC+})^{13}} \right] \quad (14)$$

$$P_{cPi} = \left[A_1 + A_2 \left(1 - \frac{T_{bC+}}{T_{cPi}} \right)^{0.5} + A_3 \left(1 - \frac{T_{bC+}}{T_{cPi}} \right) + A_4 \left(1 - \frac{T_{bC+}}{T_{cPi}} \right)^2 + A_5 \left(1 - \frac{T_{bC+}}{T_{cPi}} \right)^4 \right] \quad (15)$$

$$\gamma_{Pi} = \left[A_1 + A_2 \left(1 - \frac{T_{bC+}}{T_{cPi}} \right) + A_3 \left(1 - \frac{T_{bC+}}{T_{cPi}} \right)^3 + A_4 \left(1 - \frac{T_{bC+}}{T_{cPi}} \right)^{12} \right] \quad (16)$$

$$v_{cPi} = \left[1 - A_1 + A_2 \left(1 - \frac{T_{bC+}}{T_{cPi}} \right) + A_3 \left(1 - \frac{T_{bC+}}{T_{cPi}} \right)^3 + A_4 \left(1 - \frac{T_{bC+}}{T_{cPi}} \right)^{14} \right]^{-8} \quad (17)$$

The constants of the Eqs. (14)–(17) are shown in **Table 3**.

Property	A ₁	A ₂	A ₃	A ₄	A ₅	A ₆
T _{cPi}	0.5332272	0.191017 × 10 ⁻³	0.779681 × 10 ⁻⁷	-0.284376 × 10 ⁻¹⁰	0.959468 × 10 ⁻²	0.01
P _{cPi}	3.83854	1.19629	34.8888	36.1952	104.193	—
γ _{Pi}	0.843593	-0.128624	-3.36159	-13749.5	—	—
v _{cPi}	-0.419869	0.505839	1.56436	9481.7	—	—

Table 3. Constants used in the calculation of the critical properties of the normal paraffin [7].

2. Calculate the heavy petroleum fraction properties from the equations

$$T_{cCn+} = T_{cPi} \left[\frac{1 + 2f_{Ti}}{1 - 2f_{Ti}} \right] \quad (18)$$

$$f_{Ti} = \left\{ \exp \left[5 \left(\gamma_{pi} - \gamma_{Cn+} \right) \right] - 1 \right\} \left[\frac{A_1}{T_{bCn+}^{0.5}} + \left(A_2 + \frac{A_3}{T_{bCn+}^{0.5}} \right) \left\{ \exp \left[5 \left(\gamma_{pi} - \gamma_{Cn+} \right) \right] - 1 \right\} \right] \quad (19)$$

$$v_{cCn+} = v_{cPi} = \left[\frac{1 + 2f_{vi}}{1 - 2f_{vi}} \right]^2 \quad (20)$$

$$f_{vi} = \left\{ \exp \left[4 \left(\gamma_{pi}^2 - \gamma_{Cn+}^2 \right) \right] - 1 \right\} \left[\frac{A_1}{T_{bCn+}^{0.5}} + \left(A_2 + \frac{A_3}{T_{bCn+}^{0.5}} \right) \left\{ \exp \left[4 \left(\gamma_{pi}^2 - \gamma_{Cn+}^2 \right) \right] - 1 \right\} \right] \quad (21)$$

$$P_{cCn+} = P_{cPi} \left(\frac{v_{cPi}}{v_{cCn+}} \right) \left[\frac{1 + 2f_{Pi}}{1 - 2f_{Pi}} \right]^2 \quad (22)$$

$$f_{Pi} = \left\{ \exp \left[0.5 \left(\gamma_{Pi} - \gamma_{Cn+} \right) \right] - 1 \right\} \left[\left(A_1 + \frac{A_2}{T_{bCn+}^{0.5}} + A_3 T_{bCn+} \right) + \left(A_4 + \frac{A_5}{T_{bCn+}^{0.5}} + A_6 T_{bCn+} \right) \left\{ \exp \left[0.5 \left(\gamma_{Pi} - \gamma_{Cn+} \right) \right] - 1 \right\} \right] \quad (23)$$

where T_{cPi} is the critical temperature of the normal paraffin ($^{\circ}\text{R}$), T_{cC+} is the critical temperature of the heavy petroleum fraction ($^{\circ}\text{R}$), P_{cPi} is the critical pressure of the normal paraffin (psia), P_{cC+} is the critical pressure of the heavy oil fraction (psia), γ_{Pi} is the density of the normal paraffin, γ_{C+} is the density of the heavy petroleum fraction, v_{cPi} is the critical volume of the normal paraffin (ft^3/lbmol) and v_{cC+} is the critical volume of the heavy oil fraction (ft^3/lbmol).

Constants utilized in Eqs. (18)–(23) are presented in **Table 4**.

Riazi and Daubert [8] developed a general correlation given by the following expression:

$$\theta = a\theta_1^b\theta_2^c \exp(d\theta_1 + e\theta_2 + f\theta_1\theta_2) \quad (24)$$

In Eq. (24), θ_1 and θ_2 are two parameters accounting for the molecular forces and molecular size of a component. It was found that (T_b, γ) and (M, γ) are appropriate sets of input parameters for the correlation. Based on these results, two expressions were proposed:

$$\theta = aT_b^b\gamma^c \exp(dT_b + e\gamma + fT_b\gamma) \quad (25)$$

$$\theta = aM^b\gamma^c \exp(dM + e\gamma + fM\gamma) \quad (26)$$

Tables 5 and 6 present the coefficients for Eqs. (25) and (26).

Property	A ₁	A ₂	A ₃	A ₄	A ₅	A ₆
f_{Ti}	−0.362456	0.0398285	−0.948125	—	—	—
f_{vi}	0.466590	−0.182421	3.01721	—	—	—
f_{Pi}	2.53262	−46.19553	−0.00127885	−11.4277	252.14	0.00230535

Table 4. Constants used in the calculation of the critical properties of the heavy oil fraction C_{n+} [7].

θ	a	b	c	d	e	f
M	581.96	−0.97476	6.51274	0.000543076	9.53384	0.00111056
T_c	10.6443	0.81067	0.53691	−0.000517470	−0.54444	0.00035995
P_c	6162000	−0.4844	4.0846	−0.00472500	−4.8014	0.0031939
V_c	0.0006233	0.7506	−1.2028	−0.00146790	−0.26404	0.001095

Table 5. Coefficients of Riazi and Daubert [8] correlation as a function of T_b and γ .

θ	a	b	c	d	e	f
T_c	544.4	0.2998	1.0555	-0.000134780	-0.61641	
P_c	45203	-0.8063	1.6015	-0.000180780	-0.3084	
V_c	0.01206	0.20378	-1.3036	-0.00265700	0.5287	0.0026012
T_b	6.77857	0.401673	-1.58262	0.00377409	2.984036	-0.00425288

Table 6. Coefficients of Riazi and Daubert [8] correlation as a function of M and γ .

The coefficients were adjusted to experimental data of 38 pure hydrocarbons with carbon number in the range of 1–20, including paraffins, olefins, naphthenes and aromatics with molecular weight between 70 and 300, and boiling point in the range of 80–650°F.

Magoulas and Tassios [9] correlated the critical properties of heavy fractions through the following expressions:

$$T_c = -1247.4 + 0.792M + 1971\gamma - \frac{27000}{M} + 707.4 \quad (27)$$

$$\ln(P_c) = 0.01901 - 0.0048442M + 0.13239\gamma + \frac{227}{M} - \frac{1.1663}{\gamma} + 1.2702\ln(M) \quad (28)$$

$$\omega = -0.64235 + 0.00014667M + 0.021876\gamma - \frac{4.559}{M} + 0.21669\ln(M) \quad (29)$$

Riazi and Alsahhaf [10] developed a correlation for the acentric factor:

$$\omega = -[0.3 - \exp(-6.252 + 3.64457M^{0.1})] \quad (30)$$

Sancet [11] proposed correlations for P_c and T_c as a function of the molecular weight of the heavy oil fractions:

$$P_c = 82.82 + 653 \exp(-0.007427M) \quad (31)$$

$$T_c = -778.5 + 383.5 \ln(M - 4.075) \quad (32)$$

From the aforementioned correlations, 22 sets were created and used to calculate the critical properties and acentric factor of the heavy fraction of two reservoir fluids (**Table 7**). These sets were evaluated by comparing the experimental data and simulated PVT analysis of these fluids. The PVT experiment was simulated using the Peng-Robinson equation of state [12]:

$$P = \frac{RT}{v - b} - \frac{a}{v(v + b) + b(v - b)} \quad (33)$$

where R is the universal gas constant, T is the temperature and v is the molar volume.

Set	P _c and T _c	ω	Set	P _c and T _c	ω
1	Cavett [3]	Riazi and Alsahhaf [10]	12	Twu [7]	Riazi and Alsahhaf [10]
2	Cavett [3]	Edmister [2]	13	Twu [7]	Edmister [2]
3	Standing [5]	Riazi and Alsahhaf [10]	14	Riazi and Daubert [8]	Riazi and Alsahhaf [10]
4	Standing [5]	Edmister [2]	15	Riazi and Daubert [8]	Edmister [2]
5	Kesler and Lee [4]	Kesler and Lee [4]	16	Riazi and Daubert [8]	Riazi and Alsahhaf [10]
6	Kesler and Lee [4]	Riazi and Alsahhaf [10]	17	Riazi and Daubert [8]	Edmister [2]
7	Kesler and Lee [4]	Edmister [2]	18	Magoulas and Tassious [9]	Magoulas and Tassious [9]
8	Riazi and Daubert [6]	Riazi and Alsahhaf [10]	19	Magoulas and Tassious [9]	Riazi and Alsahhaf [10]
9	Riazi and Daubert [6]	Edmister [2]	20	Magoulas and Tassious [9]	Edmister [2]
10	Sim and Daubert [13]	Riazi and Alsahhaf [10]	21	Sancet [12]	Riazi and Alsahhaf [10]
11	Sim and Daubert [13]	Edmister [2]	22	Sancet [12]	Edmister [2]

Table 7. Sets used to characterize the properties of heavy oil fractions.

3. Results

In order to choose the most appropriate correlation for the calculation of the critical properties of heavy fractions of a reservoir fluid, 22 sets of correlations were used in the estimative of properties of the “cut” of fluids A and B [14]. The compositions of the fluids A and B are presented in **Tables 8** and **9**, respectively.

Fluid A contains approximately 40% of methane and 6% of hydrocarbons with 20 or more carbons, while fluid B contains 13% of heavy fractions and 27% of methane.

The PVT experiments were simulated using the Peng-Robinson equation of state. The results were compared with the experimental data, and the total relative deviations are shown in **Tables 10** and **11**.

The best correlation for fluids A and B is chosen based on the sum of the average deviation for each property (**Tables 10** and **11**). For fluid A, the correlation of Twu [7] led to the best results in terms of the critical properties while for the fluid B it was the correlation of Kesler and Lee [4]. For both fluids, the correlation of Riazi and Alsahhaf [10] was chosen to calculate the acentric factor (**Table 12**).

Figures 1–6 compare the experimental and calculated PVT data of fluid A using the Peng-Robinson equation of state with the critical pressure and temperature calculated from the correlation of Twu [7] and the acentric factor calculated from the Riazi and Alsahhaf [10] correlation. It is possible to note the excellent agreement between the experimental and simulated data. **Figures 7–10** show the same results for fluid B, with similar performance.

Component	Mole fraction (%)	Component	Mole fraction (%)	Component	Mole fraction (%)
N ₂	0.390	nC ₅	2.150	C ₁₃	1.590
CO ₂	0.300	C ₆	2.790	C ₁₄	1.220
C ₁	40.200	C ₇	4.280	C ₁₅	1.250
C ₂	7.610	C ₈	4.310	C ₁₆	1.000
C ₃	7.950	C ₉	3.080	C ₁₇	0.990
iC ₄	1.190	C ₁₀	2.470	C ₁₈	0.920
nC ₄	4.080	C ₁₁	1.910	C ₁₉	0.600
iC ₅	1.390	C ₁₂	1.690	C ₂₀₊	6.640

Table 8. Fluid A composition [14].

Component	Mole fraction (%)	Component	Mole fraction (%)	Component	Mole fraction (%)
H ₂ S	0.383	iC ₅	1.937	C ₁₂	0.02285
N ₂	0.450	nC ₅	2.505	C ₁₃	2.364
CO ₂	2.070	C ₆	3.351	C ₁₅	1.752
C ₁	26.576	C ₇	4.311	C ₁₆	1.589
C ₂	7.894	C ₈	4.133	C ₁₇	1.492
C ₃	6.730	C ₉	0.03051	C ₁₈	1.263
iC ₄	1.485	C ₁₀	0.02033	C ₁₉	0.812
nC ₄	3.899	C ₁₁	0.02635	C ₂₀₊	12.962

Table 9. Fluid B composition [14].

Set	Average B _o (%)	Average R _s (%)	Average ρ _o (%)	Average B _g (%)	Average Z _g (%)	Average γ _g (%)	Average P _b (%)	Total deviation (%)
1	1.98	5.64	6.00	2.33	2.55	1.74	11.07	31.31
2	2.75	9.69	7.87	2.04	2.08	1.04	22.43	47.91
3	5.21	15.60	23.08	1.72	1.14	1.40	38.58	86.74
4	7.36	15.89	18.63	2.53	2.79	1.71	8.83	57.73
5	2.06	6.88	6.48	2.25	2.42	1.54	14.90	36.51
6	2.01	6.08	6.13	2.29	2.48	1.53	12.61	33.13
7	2.42	8.42	7.20	2.13	2.22	1.23	19.27	42.88
8	5.97	11.28	15.58	2.08	2.09	0.40	16.98	54.38
9	5.12	9.58	15.81	2.18	2.22	0.74	18.37	54.04

Set	Average B_o (%)	Average R_s (%)	Average ρ_o (%)	Average B_g (%)	Average Z_g (%)	Average γ_g (%)	Average P_b (%)	Total deviation (%)
10	1.15	7.33	2.48	2.67	2.98	2.36	6.90	25.88
11	1.73	9.08	3.53	2.31	2.48	1.69	13.84	34.67
12	1.96	3.95	3.64	2.52	2.79	1.45	7.32	23.61
13	2.25	9.06	5.48	2.19	2.31	1.31	18.88	41.48
14	2.67	4.24	4.69	2.42	2.63	0.83	8.54	26.01
15	2.84	9.83	7.23	1.89	1.77	0.59	23.75	47.91
16	5.75	14.71	23.21	1.84	1.65	0.86	29.23	77.24
17	6.96	21.15	27.12	1.18	1.32	1.36	25.00	84.08
18	3.20	11.82	8.44	1.88	1.78	1.10	27.97	56.20
19	1.75	6.04	5.57	2.40	2.64	2.24	11.90	32.54
20	2.55	8.99	6.99	2.04	2.10	1.09	20.77	44.52
21	4.53	13.00	20.59	1.91	1.73	0.79	30.85	73.39
22	4.63	13.49	20.85	1.83	1.64	0.73	32.29	75.46

Table 10. Deviations between measured and calculated properties for fluid A.

Set	Average B_o (%)	Average R_s (%)	Average ρ_o (%)	Average Z_g (%)	Average P_b (%)	Total deviation (%)
1	0.56	10.87	5.17	2.65	0.56	19.80
2	1.73	8.50	7.18	3.14	17.86	38.41
3	3.52	26.85	28.74	3.60	38.09	100.80
4	3.41	29.22	27.19	3.29	28.32	91.42
5	1.30	8.00	3.60	2.74	5.44	21.07
6	0.59	9.16	2.82	2.60	3.54	18.70
7	1.80	7.39	4.28	2.92	11.61	27.99
8	4.42	28.11	19.98	3.23	11.99	67.73
9	3.64	26.31	20.31	3.18	15.25	68.69
10	0.53	10.68	4.32	2.58	6.35	24.47
11	2.21	5.79	1.54	2.83	7.63	20.00
12	0.97	7.90	2.04	2.50	21.16	34.57
13	2.95	4.92	0.81	2.76	7.61	19.04
14	0.81	8.78	1.61	2.71	16.27	30.18
15	3.51	6.76	2.18	3.27	17.56	33.28

Set	Average B_o (%)	Average R_s (%)	Average ρ_o (%)	Average Z_g (%)	Average P_b (%)	Total deviation (%)
16	4.24	31.31	28.49	3.31	27.69	95.04
17	4.69	25.44	32.52	3.40	49.36	115.40
18	2.17	9.25	10.62	3.09	24.93	50.05
19	0.82	12.16	7.85	2.60	2.57	25.99
20	1.95	9.84	10.62	3.19	25.10	50.71
21	3.02	26.67	26.45	3.43	32.53	92.10
22	3.16	26.63	26.78	3.48	34.50	94.55

Table 11. Deviations between measured and calculated properties for fluid B.

Fluid	Set	P_c and T_c	ω
Fluid A	12	Twu [7]	Riazi and Alsahhaf [10]
Fluid B	6	Kesler and Lee [4]	Riazi and Alsahhaf [10]

Table 12. Best correlations for the critical properties and the acentric factor.

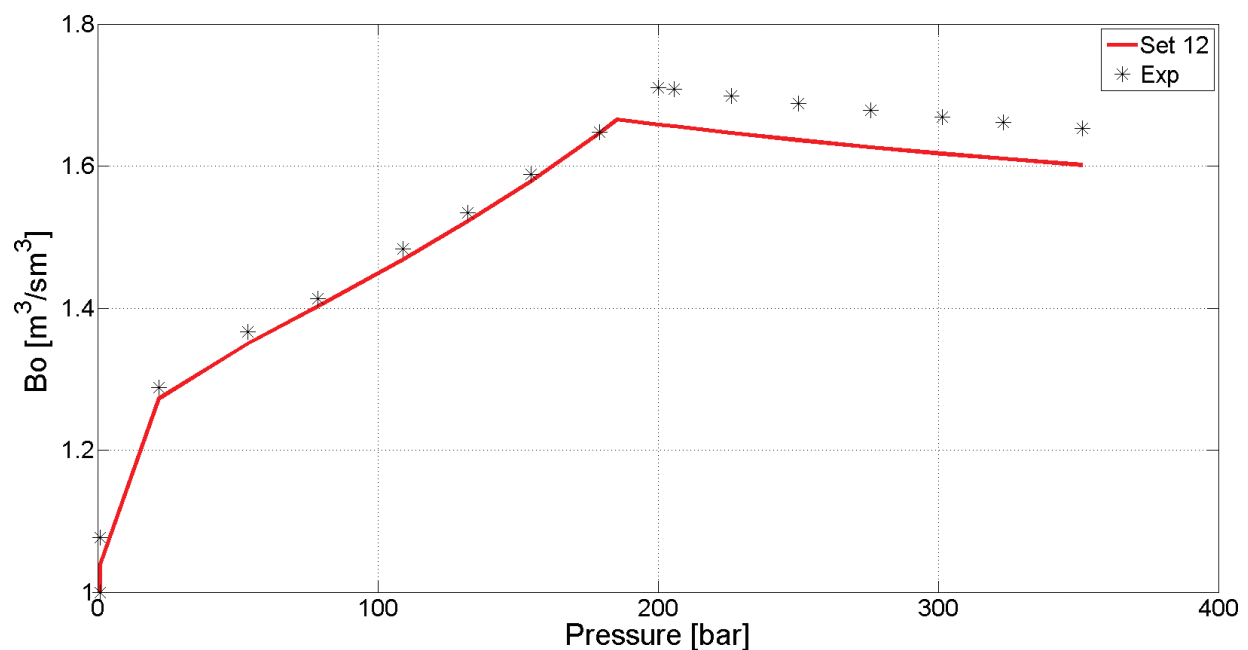


Figure 1. Fluid A—oil formation-volume-factor.

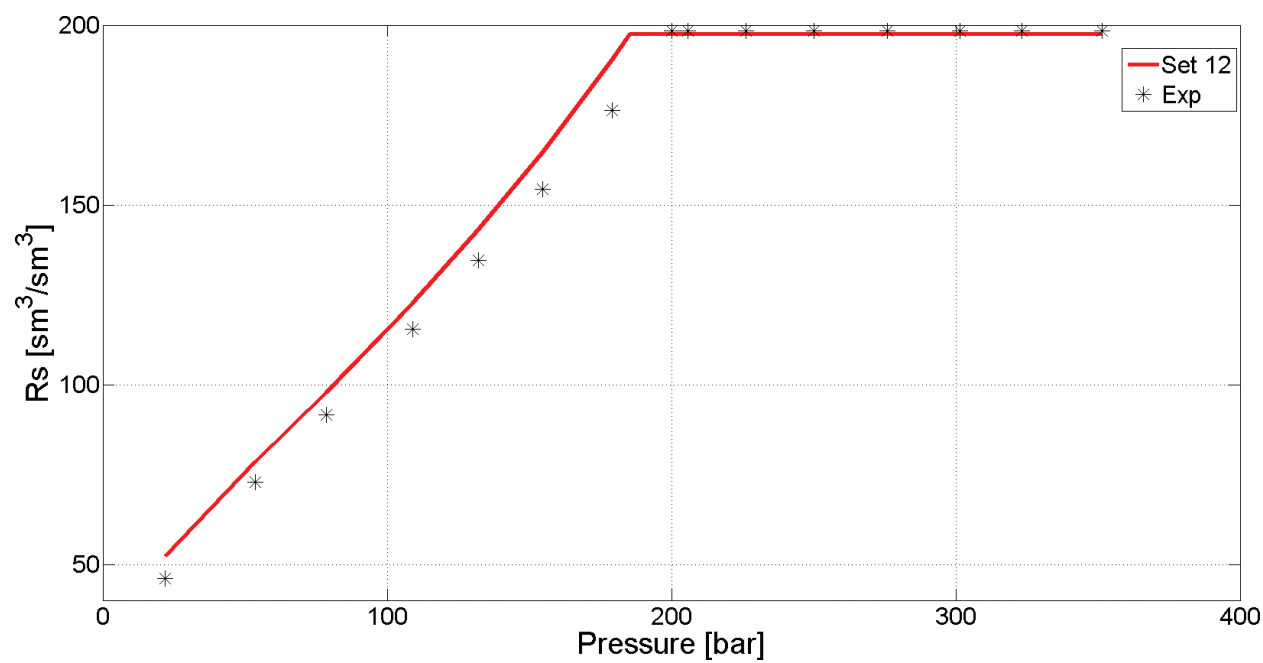


Figure 2. Fluid A—solubility ratio.

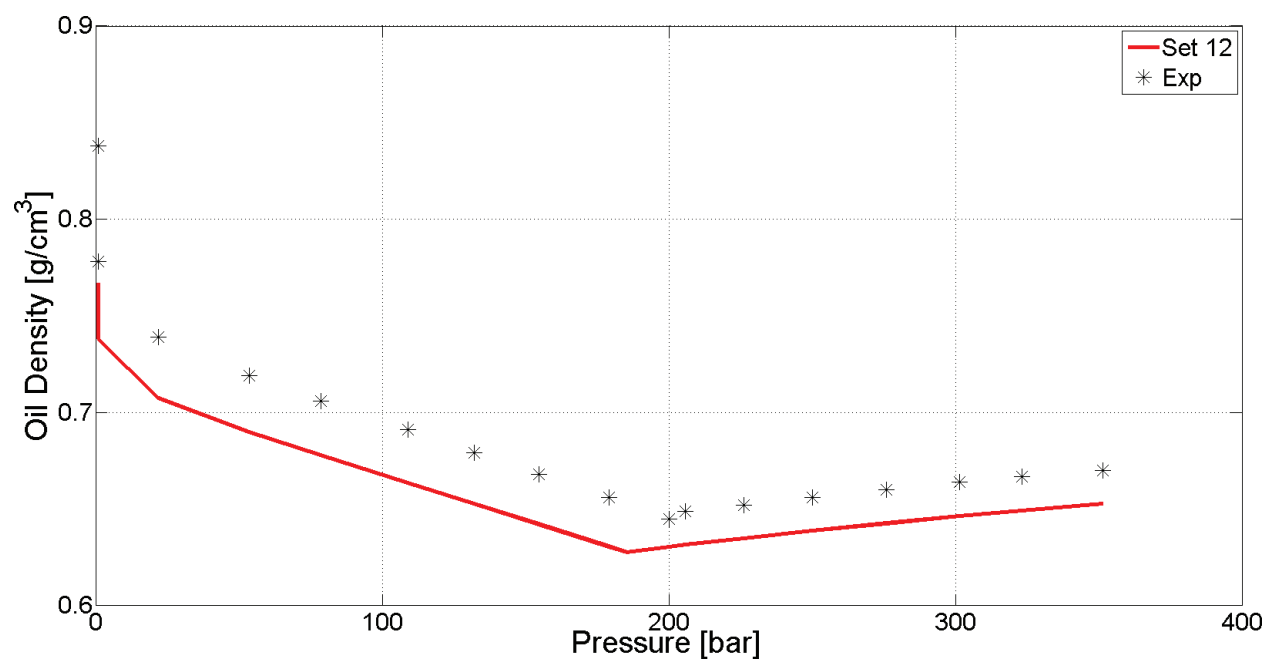


Figure 3. Fluid A—oil density.

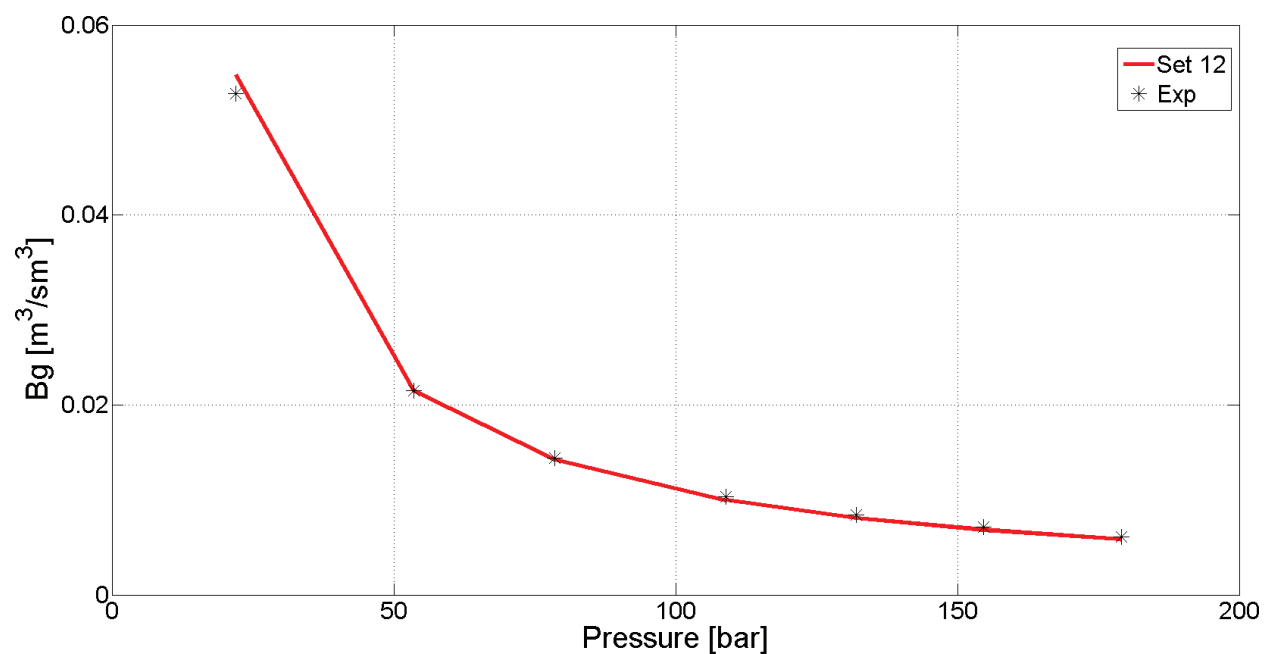


Figure 4. Fluid A—gas formation-volume-factor.

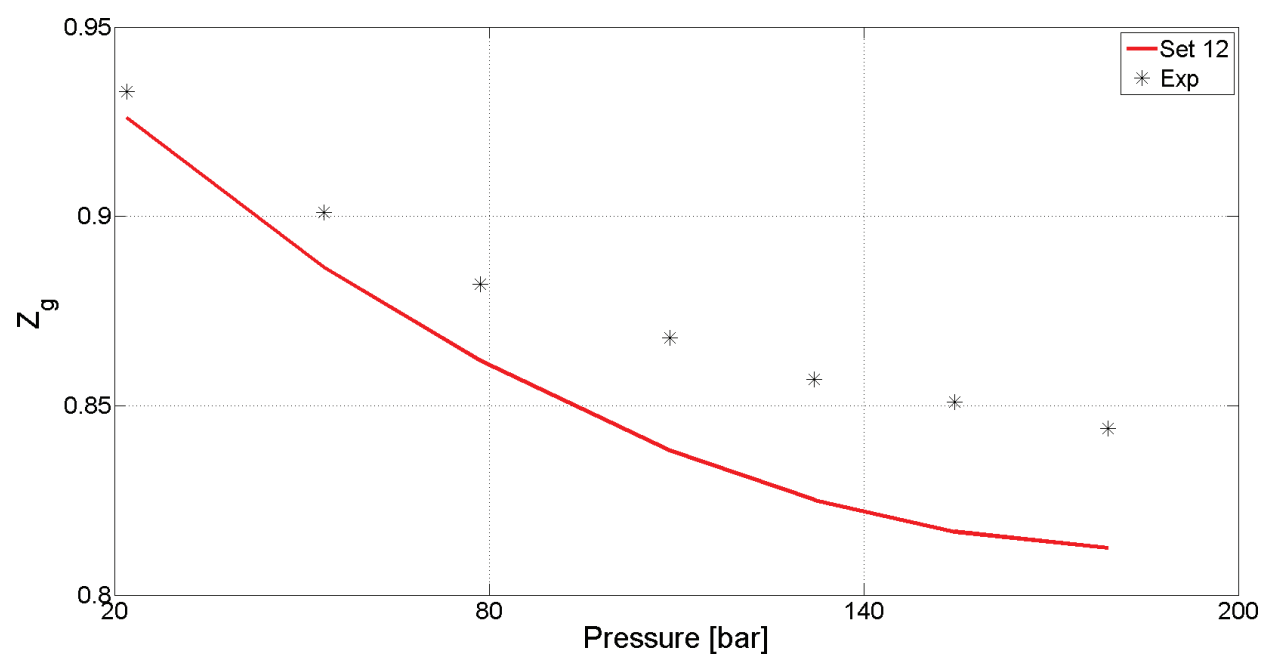


Figure 5. Fluid A—gas compressibility factor.

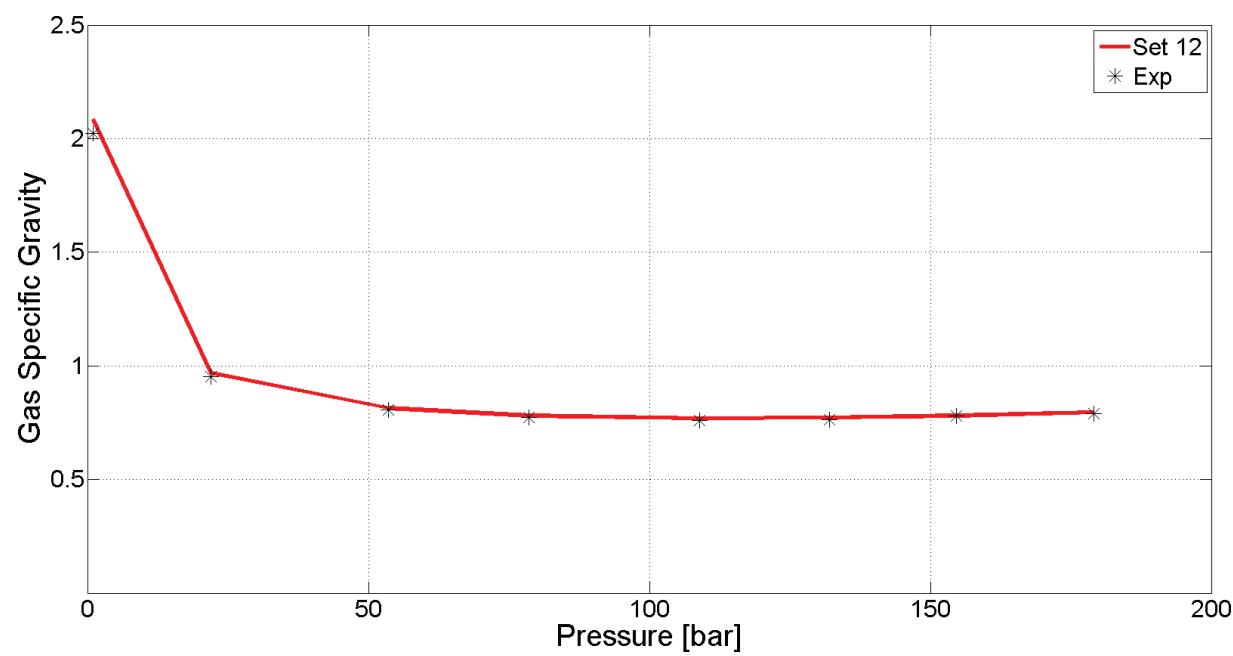


Figure 6. Fluid A—gas specific gravity.

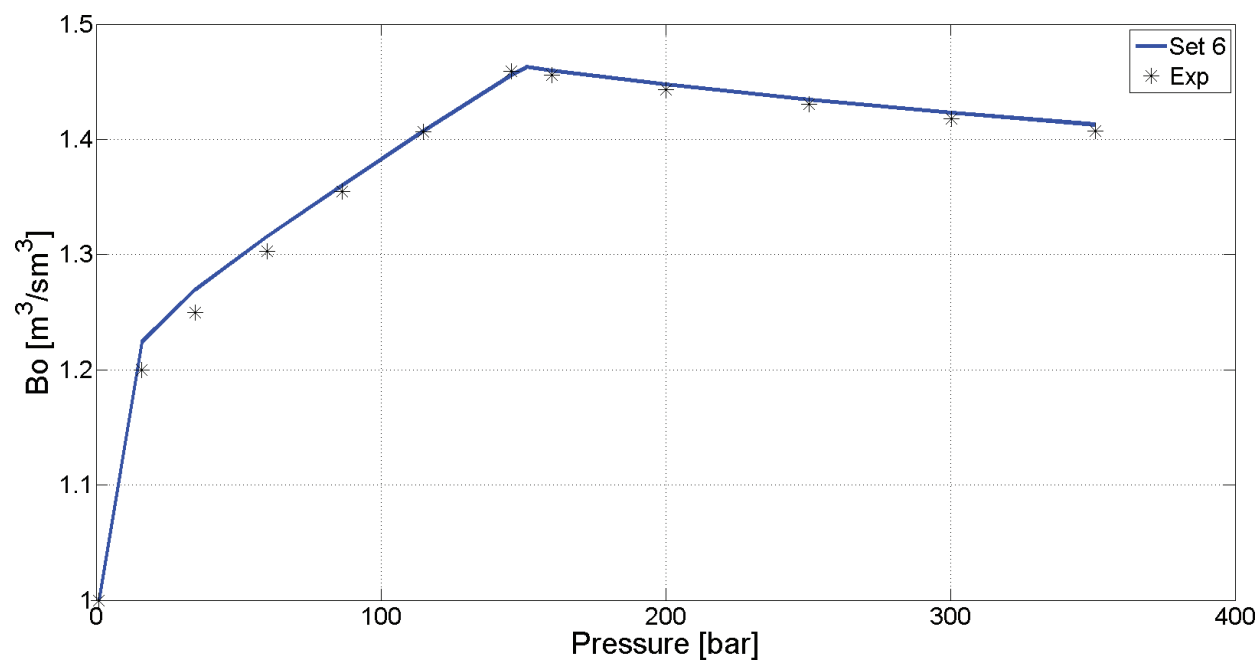


Figure 7. Fluid B—oil formation-volume-factor.

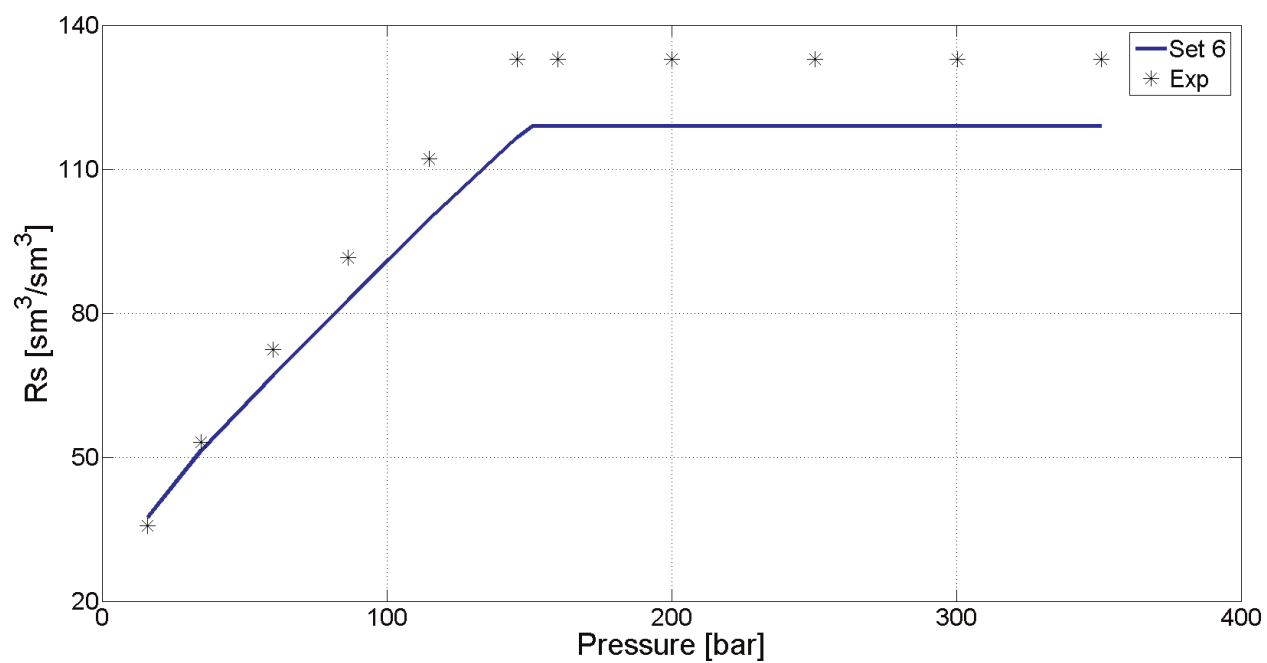


Figure 8. Fluid B—solubility ratio.

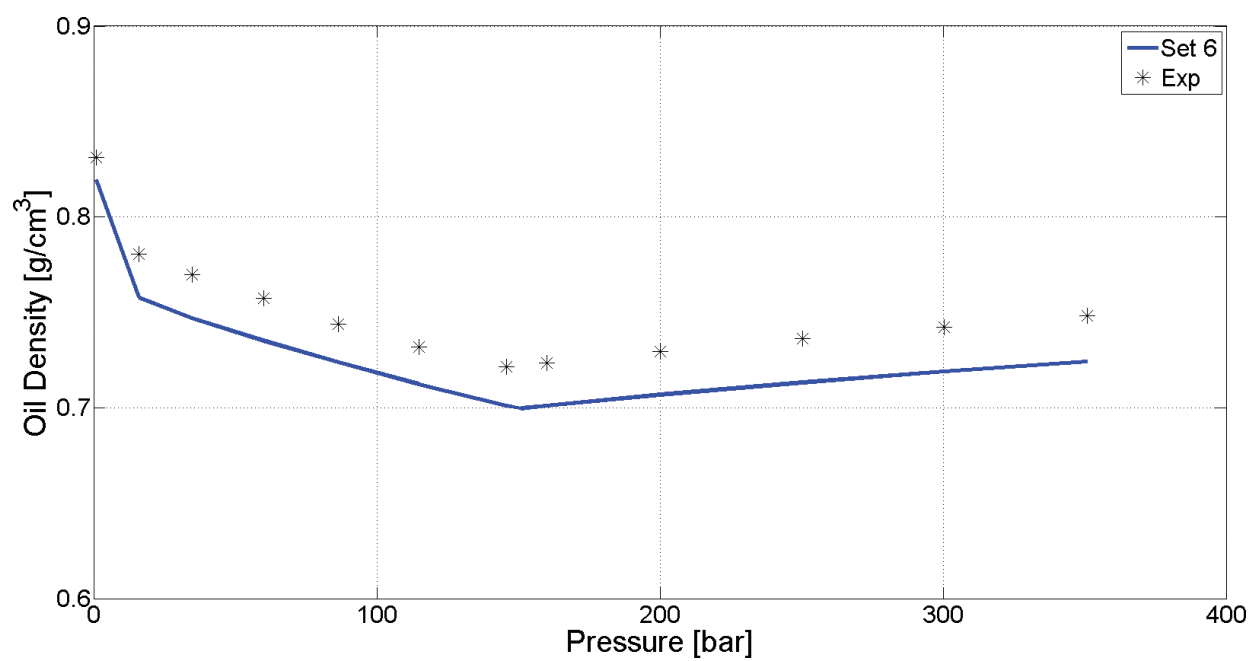


Figure 9. Fluid B—oil density.

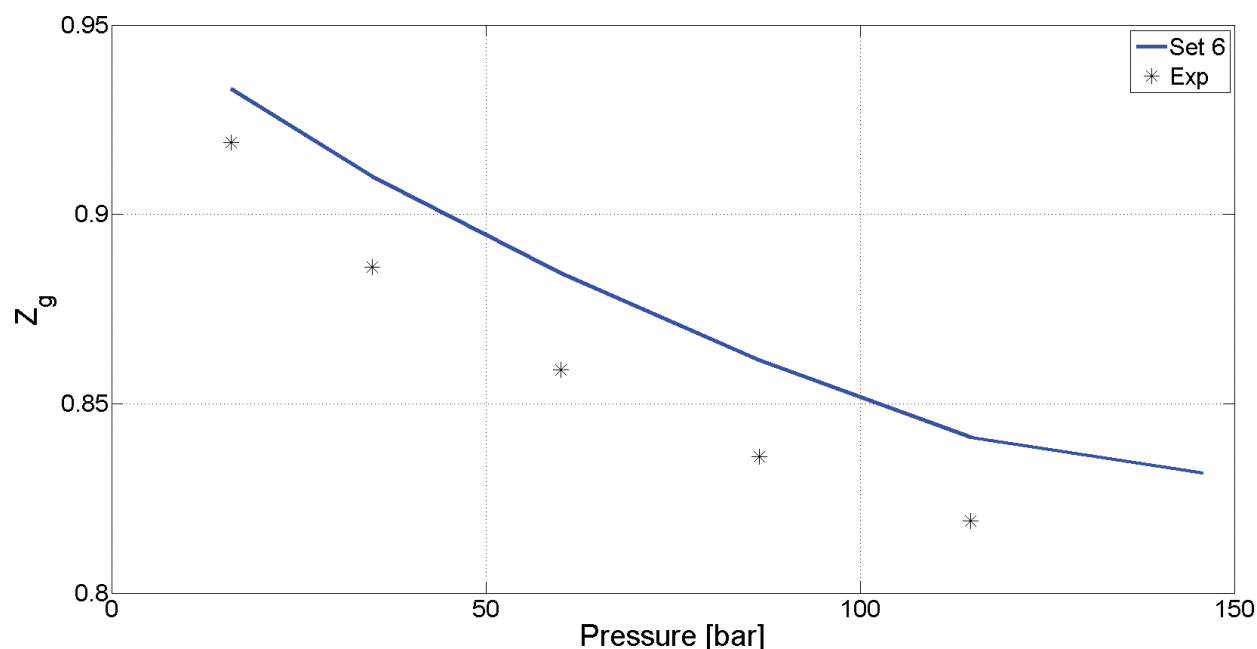


Figure 10. Fluid B—gas compressibility factor.

4. Conclusions

Overall, 22 sets of correlations to calculate the critical properties and acentric factors of heavy oil fractions were tested in order to simulate a PVT experiment of two reservoir fluids. The results obtained from the simulation were compared with experimental laboratory PVT data. The Twu [7] correlation showed the best performance for one case, while the Kesler and Lee [4] correlation led to better results for the other fluid. In both cases, the Riazi and Alsahhaf [10] correlation was used to calculate the acentric factor. These results show the importance of evaluating the correlations for each reservoir fluid since no model for the critical properties and acentric factor calculations can be applied in any case.

Nomenclature

B_g : gas formation volume factor [m^3/sm^3]

B_o : oil formation volume factor [m^3/sm^3]

K_w : Watson's characterization factor

M : molecular weight

P_b : bubble point pressure [psia]

P_c : critical pressure [psia]

T_b : normal boiling temperature [$^{\circ}\text{R}$]

T_c : critical temperature [$^{\circ}\text{R}$]

R_s : solubility ratio [m^3/sm^3]

Z_g : gas compressibility factor

v_c : critical volume [ft^3/lbmol]

ω : acentric factor

ρ_o : oil density [g/cm^3]

γ_g : gas specific gravity

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