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Effect of extended heavier hydrocarbon fraction (Cn+) composition on optimum surface separation pressure and temperature
Juvêncio Armando Massinguil, Luís Helder Lucas and Pål Skalle
Full Length Research Paper

Effect of extended heavier hydrocarbon fraction ($C_{n+}$) composition on optimum surface separation pressure and temperature

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Hydrocarbon fluids are made up of defined components which include $N_2$, $CO_2$, $H_2S$, $C_1$, $C_2$, $C_3$, $iC_4$, $iC_5$, and $C_6$ and undefined components known as heavier fractions ($C_{n+}$) which include paraffinic, naphthenic and aromatic compounds. The hydrocarbons are separated on the surface before they are sent to the market. There are several factors affecting the hydrocarbons surface separation condition which include; pressure, temperature, gas liquid flow rates, surging or slugging tendencies of the feed stream, presence of impurities such as paraffin and sands. This work is limited to the study of the effects of pressure and temperature. To obtain stabilized hydrocarbons phases optimum surface separation, pressure and temperature must be selected. Several empirical models have been developed to obtain optimum surface separation pressure and temperature. However, these models do not consider the full composition of the well stream, and the heavier fractions are most often treated as a single component. This paper presents the estimation of an optimum surface separation-pressure and temperature of crude oil while including the complete composition of the well stream and extended composition of the heavier fraction. The optimum pressure was estimated through the fluid properties such as oil formation volume factor, gas oil ratio and API gravity. Optimum pressure and temperature is the one that produces maximum liquid yield (by minimizing oil formation volume factor and gas oil ratio) of maximum quality (by maximizing API gravity). The fluid properties were predicted by phase equilibrium calculations using Peng Robinson thermodynamic Model. The optimum pressure was first estimated considering the heavier fraction as single component and second the heavier fraction was splitted in pseudo components, both including the full composition of the well stream. Ahmed splitting method was used to extend the heavier fraction composition, Kesler and Lee’s correlation was applied to assign critical properties of the pseudo components. The results indicate that it is possible to estimate more accurately the optimum separation pressure by extending a composition of heavier fraction and accurate values of fluid properties were obtained.

Key words: $C_{7+}$ fraction, splitting scheme, equation of state, Peng-Robinson thermodynamic model, optimum separator pressure.

INTRODUCTION

Hydrocarbon surface separation is an important operation in maximizing the oil and gas surface recovering.

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Studying factors that affect the surface separation of hydrocarbon fluids is an important contribution in petroleum industry. To obtain stabilized hydrocarbon phases, optimum surface separation pressure and temperature must be selected. Several empirical models have been developed to obtain optimum surface separation pressure and temperature. Al-Jawad and Hassan (2010a,b) developed a group of correlations for optimum separator pressure for volatile oils using the results of theoretical correlations.

According to Ling et al. (2013), these correlations were based on data from over 6000 test runs with various independent variables. They also stated that the correlations were empirical and did not consider the full composition of the well stream but heavier fraction was included. Whinery and Campbell (1958) developed a correlation for determining the optimum second-stage separator pressure in a three-stage separation system. Al-Jawad (2010a), stated that their new method was simple and it eliminated the need for the flash vaporization calculations.

On the other hand, Ling et al. (2013) pointed out that the disadvantage of this new correlation was that the accuracy and reliability of the calculations could not be guaranteed because the temperature of the separator, the stock tank, compositions of butane and heavier components were not included. In addition, Bahadori et al. (2008) presented a methodology for optimizing separator pressures in crude oil production units. Despite that in this method, the heavier fraction composition was extended, Ling et al. (2013) also pointed out that the drawback of this method is that it requires tremendous number of trial separator and still may not be able to obtain precise optimum pressures.

According to the above-mentioned literature, neither the effect of heavier fractions nor the full composition of the well stream have been taken into consideration and the heavier fractions most often are treated as a single component. That is the reason why the present study includes these parameters by splitting the heavier fraction in pseudo components using Ahmed’s splitting scheme. This study only compares to Al Jawad and Hassan (2010)’s correlations, since it is the one that includes the heavier fraction composition; consequently other studies are discarded from the comparison.

**Al-Jawad and Hassan correlation**

AL-Jawad and Hassan (2010) developed a correlation for estimating optimum separation pressure for heavy oils separation, one for high pressure separator in case for two stage and two for the first and second separators for three-stage separation system. In these correlations the optimum pressures have been correlated with mole percent of methane and hexane plus in the well stream, temperature of the separator and the optimum pressure of the previous separator. These equations represent unique correlations because they are using methane and hexanes plus mole percents. The correlation of the optimum first stage pressure is formulated in Equation 1 and second stage in Equation 2.

\[
(P_1)_{opt} = A(C_H \%) + B(C_n \%) + C(T) + D(T) + E(T) + F(T) + G(T) + H(T) + I(T) + J(T) + K(T) + L(T) + M(T) + N(T) + O(T) + P(T) + Q(T) + R(T) + S(T) + T(T) + U(T) + V(T) + W(T) + X(T) + Y(T) + Z(T)
\]

\[
(P_2)_{opt} = a(C_H \%) + b(C_n \%) + c(T) + d(T) + e(T) + f(T) + g(T) + h(T) + i(T) + j(T) + k(T) + l(T) + m(T) + n(T) + o(T) + p(T) + q(T) + r(T) + s(T) + t(T) + u(T) + v(T) + w(T) + x(T) + y(T) + z(T)
\]

The correlation coefficient A of these equations equal to 0.96. Table 1 presents the values of the constants ‘a’ of the correlations for this system.

**The heavier fraction (C_{n+})**

Barrufet (1998a) defined oil mixture as composed of defined and undefined components known as heavier fraction or C_{n+} fraction. Pedersen and Christensen (2015) stated that defined components of oil mixture are N_{2}, CO_{2}, H_{2}S, C_{1}, C_{2}, C_{3}, iC_{4}, iC_{5}, and C_{6} while Ahmed (2007) referred that undefined components will typically contain Paraffinic, Naphthenic, and Aromatic compounds. Barrufet (1998b) also mentioned that the defined components can be quantitatively identified using chromatographic analysis, while Ahmed referred that due to the limitation of laboratory separation techniques in analyzing and characterizing the undefined components of hydrocarbon fluids these components are traditionally lumped together and categorized as the plus fraction (C_{n+}).

Pedersen and Christensen (2015) also revealed that to perform a phase equilibrium analyses on hydrocarbon systems the physical properties for cubic equation of state (EOS) are critical pressure (P_c), critical temperature (T_c) and acentric factors (ω) of each component contained in the mixture. These properties have been measured and compiled for defined components. White (1982) and Sancet (2007) referred that undefined components are difficult components to be properly characterized in terms of their critical properties and acentric factors. Therefore, in this paper the phase equilibrium calculations are performed with splitted heavier fraction and assigned critical properties and acentric factor in each pseudo component.

**Splitting schemes**

Ahmed (2007) defined splitting schemes as the procedures of dividing the heavier fraction into hydrocarbons groups with single carbon number (C_{7}, C_{8}, C_{9} etc) described by the same physical properties used for pure components. Imo-Jack et al. (2012) stated that heavier fraction in reservoir fluids contains different components which are impossible to identify by chemical separation techniques.
Table 1. Table of the coefficient of the Equation 9.

<table>
<thead>
<tr>
<th>No. of carbon atoms</th>
<th>Condensate systems</th>
<th>Crude oil systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>n≤8</td>
<td>15.5</td>
<td>16.5</td>
</tr>
<tr>
<td>n&gt;8</td>
<td>17</td>
<td>20.1</td>
</tr>
</tbody>
</table>


Even if it was possible to identify them, it would not be possible to measure the critical properties and other EOS parameters for fluids heavier than C_{20+}. Stamaki (2001) mentioned that this problem is solved practically by making approximate characterization of the heavier compounds with experimental and mathematical methods.

According to Ahmed (2007), several authors have proposed different splitting methods for extending the molar distribution behavior of C_{7+}. Imo-Jack et al. also referred that these models are based on the assumption that there is a continuous relationship between composition and molecular weight of the pseudo components. Ahmed (2007a) and Riazi (1997) described the three main steps required for characterization of heavy end fractions:

(i). Splitting the heavier fraction into single carbon number, with known (molar and mass) amounts and molecular weights,
(ii). Assigning boiling point, molecular weight and specific gravity to each fraction,
(iii). Estimating critical properties of each fraction.

Ahmed described three important requirements to be satisfied when applying any of the proposed splitting models which are presented in Equations 3 to 5. The sum of the mole fraction of the individual pseudo components is equal to the mole fraction of C_{7+}, as expressed in Equation 3.

\[ \sum_{n=7}^{n} Z_n = Z_{7+} \]  

The sum of the products of the mole fractions and the molecular weight of the individual pseudo components is equal to the product of the mole fraction and molecular weight of C_{7+}, as expressed in Equation 4.

\[ \sum_{n=7}^{n} [Z_n M_n] = Z_{7+} M_{7+} \]  

The sum of the product of the mole fraction and molecular weight divided by the specific gravity of each individual component is equal to that of C_{7+}, as expressed in Equation 5.

\[ \frac{\sum_{n=7}^{n} Z_n M_n}{\gamma} = \frac{Z_{7+} M_{7+}}{\gamma_{7+}} \]  

Equations 4 and 5 can be solved for the molecular weight and specific gravity of the last fraction after splitting as:

\[ \gamma_{n+} = \frac{Z_{n+} M_{n+}}{Z_{7+} M_{7+} - \sum_{n=7}^{(n+1)} Z_n M_n} \]  

\[ M_{n+} = \frac{Z_{7+} M_{7+} - \sum_{n=7}^{n} [Z_n M_n]}{Z_{16+}} \]  

Several splitting schemes have been proposed, these schemes are used to predict the compositional distribution of the heavy plus fraction.

**Ahmed’s splitting method**

Ahmed devised a simplified method for splitting the C_{7+} fraction into pseudo components. The method originated from studying the molar behavior of 34 condensate and crude oil systems through detailed laboratory compositional analysis of the heavy fractions. The splitting scheme is based on calculating the mole fraction, \( Z_n \) at progressively higher number of carbon atoms. The extraction process continues until the sum of the mole fraction of the pseudo components are the same as the total mole fraction of the heptanes plus (Z_{7+}).

\[ Z_n = Z_{n+} \left[ \frac{M_{(n+1)} - M_{n+}}{M_{(n+1)} - M_n} \right] \]  

\( Z_n \): mole fraction of the pseudo component with a number of carbon atoms of \( n \) (\( Z_7, Z_8, Z_9 \)),

\( M_n \): Molecular weight of the hydrocarbon group with \( n \) carbon atoms.

\( M_{(n+1)} \): molecular weight of the n+ fraction as calculated by the following expression:
$M_{(n+1)c} = M_{n+} + S(n - 6)$

(9)

Where $n$ is the number of carbon atoms and $S$ is the coefficient of the equation with the values given in Table 1.

In this splitting method a set of physical properties proposed by Katz and Firoozabadi ($M_n$), specific gravity and critical properties for the petroleum fraction $C_6$ through $C_{45}$ are used. After extending the composition of heavier fractions in pseudo components, critical properties and acentric factors must be assigned for the last fraction $C_{n+}$. In this paper Kesler and Lee's correlation was used to estimate these properties.

**Surface separation conditions**

Separators are used to separate oil, water and to remove material such as entrained solid impurities from the crude oil production (Chilingar, 1969). Ling et al. (2013) explained that the separator working principle is based on the three hydrocarbon phases: vapor, liquid-oil and liquid-water with different densities, which allow them to separate when moving. Gas will be on top, water on the bottom, and oil in the middle. Each condition of pressure and temperature at which hydrocarbon phases are separated is called a stage of separation. There are different number of stage used in petroleum industry to separate oil and gas. Ling et al. (2013) also referred that the simplest system is two-stage separation consisting of one separator and one stock tank. It is most applicable for low-API-gravity oils, low gas/oil ratios (GORs), low flowing pressures. The three-stage separation illustrated in Figure 1 is used for intermediate gravity oils, intermediate to high GOR, and intermediate well-head flowing pressures.

The four-stage separation is designed for high-API gravity oils, high GOR, and high flowing pressures. Four-stage separation is also applicable when high flowing pressure gas is needed for market or for pressure maintenance. There are several factors affecting the separation of hydrocarbon fluids, such as: temperature, pressure, gas liquid flow rates, surging or slugging tendencies of the feed streams, presence of impurities (paraffin, sand). This paper will focus on pressure and temperature effect. Furthermore, Ahmed also referred that if the separator pressure is high, large amounts of light components will remain in the liquid phase at the separator and will be lost along with other valuable components to the gas phase at the stock tank. However, on the other hand, if the pressure is too low, large amounts of light components will be separated from liquids and they will attract substantial quantities of intermediates and heavier components. Therefore optimum surface separation pressure is required. Adewumi (2017) stated that optimum separator pressure is the one that produces the maximum liquid yield (at minimum gas/oil ratio and formation volume factor) of maximum quality (by maximizing stock tank API gravity) as shown in Figure 2. Table 2 shows the typical initial values of gas oil ratio, formation volume factor and API gravity for different reservoirs fluids.

**Equation of state (EOS)**

An equation of state (EOS) is used to predict the pressure, volume and temperature behavior of gas and
The specific gravity of C\textsubscript{7+} is 0.86.

crude oil fluid. Ramdharee and Muzenda (2013) mentioned that there are many families of EOS, suitable for different purposes and substances. In petroleum engineering the most commonly used EOS are cubic polynomials.

Barrufet (1998a) stated that cubic EOSs are the simplest polynomials that can provide an adequate description of both: liquid and gas properties. They can describe the state of pure fluids and mixtures (single or multiphase) and their properties. Funjinaga and Raijo (1999) stated that cubic equations are explicit in pressure and can be written as the sum of ‘b’ term indicating repulsion forces and ‘a’ term indicating attraction forces. One of the most used EOS in petroleum engineering is the Peng-Robinson EOS (1975). The Peng Robinson is three-parameter corresponding sates model which is expressed as:

\[
P = \frac{RT}{V-b} - \frac{aa}{V(V+b)+b(V-b)}
\]

Where ‘a’ is the attraction parameter and ‘b’ is the repulsion parameter defined by Equations 11 and 12 respectively:

\[
a = \frac{\Omega}{\mu} \frac{R^2T^2_{c}}{P_c}
\]
The cubic expression for a mixture is then evaluated using Equation 18 for A term:

\[ A = \frac{(a\alpha)_m P}{(RT)^2} \]  

(18)

And Equation 19 for B term

\[ B = \frac{b_m P}{RT} \]  

(19)

Where ‘m’ refers to mixture

MATERIALS AND METHODS

PVT data

This study was conducted based on the data presented by Bahadori (2008). According to Bahadori, this data were collected from Pazann-Asmari, black oil Reservoir-India and is presented in Table 2. The reservoir pressure is 3700 (psig), bottom hole temperature is 208 F and molecular weight of C\textsubscript{7+} is 236. The specific gravity of C\textsubscript{7+} is 0.86.

In this study the optimum pressure was estimated based on the fluid properties such as oil formation volume factor, gas oil ratio and API gravity. These properties were estimated through phase equilibrium calculations using Peng Robinson thermodynamic Model. The optimum pressure is the one that provide maximum API gravity, minimum oil formation volume factor and gas oil ratio. The optimum pressure was estimated considering the system as three stage, where second stage was optimization stage.

The heavier fraction was splitted in pseudocomponents using Ahmed splitting method. To perform phase equilibrium calculations critical properties and acentric factors must be assigned to the heavier fractions and pseudocomponents. Kesler and Lee’s correlation was used to assign these properties. The summary of this methodology is presented in Figure 3. The phase equilibrium calculations were conducted through VBA program, and the programing procedures are indicated in Figure 4.

RESULTS AND DISCUSSION

The heavier fraction was extended in 2, 3 and 4 pseudo components and the results of the new composition are presented in Tables 3 to 5. The maximum API gravity, minimum Bosb and Rssb was found at T = 70°F. Tables 3 to 5 present the results of extended heavier fraction, assigned critical properties, acentric factors in each new component. The last fraction is always a heavier fraction (C\textsubscript{m'}, which are C\textsubscript{9+}, C\textsubscript{10+}, C\textsubscript{11+}. All the splitting constraints presented in Equation 5 to 7 were satisfied. From Table 6 is observed that if the temperature increases, the fluid properties changes, where API gravity decrease, Bosb and Rssb increase. The optimum temperature used for pressure estimation for single and extended heavier fraction is 70°F. From Figures 5 to 7 is observed that with extended heavier fraction, the API gravity changes. The API gravity values are high for single heavier
Figure 4. Optimum pressure estimation procedure.

fraction, when compared to API for extended C\textsubscript{7+} fraction, these results were compared to initial stock tank liquid gravity API, presented in Table 7, where for crude oil the values are less than 45.

In the Table 7 is observed that API gravity values obtained using heavier fraction as single component are high compared to API gravity values for extended fraction in both methods, and keep decreasing as the number of pseudo components increases. The fluid properties predicted using the proposed methods are high when compared to properties obtained using empirical correlation. The optimum pressure predicted by the proposed method is greater compared to pressures obtained using empirical model. This shows the impact of using the full composition of the well stream and extended heavier fraction.
Table 3. Results of the extended C7 fraction in 2 pseudo-components.

<table>
<thead>
<tr>
<th></th>
<th>( \gamma_n )</th>
<th>M</th>
<th>Mn+</th>
<th>Zn</th>
<th>ZnMn</th>
<th>ZnMn/ ( \gamma_n )</th>
<th>Tc-R</th>
<th>Pc(psia)</th>
<th>( \omega_n )</th>
<th>Tb9+ (°R)</th>
<th>k</th>
<th>θ</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>0.727</td>
<td>96</td>
<td>236</td>
<td>0.029046</td>
<td>2.78845</td>
<td>3.22513</td>
<td>985</td>
<td>453</td>
<td>0.280</td>
<td>1304.56</td>
<td>12.6378</td>
<td>0.8424</td>
</tr>
<tr>
<td>8</td>
<td>0.749</td>
<td>107</td>
<td>252.5</td>
<td>0.025102</td>
<td>2.68589</td>
<td>3.10651</td>
<td>1036</td>
<td>419</td>
<td>0.312</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C_{9+}</td>
<td>0.865</td>
<td>269</td>
<td>269</td>
<td>0.221352</td>
<td>59.54366</td>
<td>68.8685</td>
<td>1548.62</td>
<td>121.239</td>
<td>2.483</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.2755</td>
<td>65.01800</td>
<td>75.2001</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Results of extended C7 fraction in 3 pseudo components.

<table>
<thead>
<tr>
<th></th>
<th>( \gamma_n )</th>
<th>M</th>
<th>Mn+</th>
<th>Zn</th>
<th>ZnMn</th>
<th>ZnMn/ ( \gamma_n )</th>
<th>Tc-R</th>
<th>Pc(psia)</th>
<th>( \omega_n )</th>
<th>Tb_{10+}(°R)</th>
<th>K</th>
<th>θ</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>0.727</td>
<td>96</td>
<td>236</td>
<td>0.0290</td>
<td>2.788</td>
<td>3.22</td>
<td>985</td>
<td>453</td>
<td>0.280</td>
<td>1327.14</td>
<td>12.5899</td>
<td>0.8456</td>
</tr>
<tr>
<td>8</td>
<td>0.749</td>
<td>107</td>
<td>252.5</td>
<td>0.0251</td>
<td>2.685</td>
<td>3.1</td>
<td>1036</td>
<td>419</td>
<td>0.312</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>0.768</td>
<td>121</td>
<td>269</td>
<td>0.0344</td>
<td>4.17</td>
<td>5.43</td>
<td>1085</td>
<td>383</td>
<td>0.348</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C_{10+}</td>
<td>0.87287</td>
<td>296.3</td>
<td>296.3</td>
<td>0.1868</td>
<td>55.37</td>
<td>63.43</td>
<td>1569.53</td>
<td>118.349</td>
<td>2.481</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.2755</td>
<td>65.018</td>
<td>75.20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5. Results of extended C7 fraction in 4 pseudo components.

<table>
<thead>
<tr>
<th></th>
<th>( \gamma_n )</th>
<th>M</th>
<th>Mn+</th>
<th>Zn</th>
<th>ZnMn</th>
<th>ZnMn/ ( \gamma_n )</th>
<th>Tc-R</th>
<th>Pc(psia)</th>
<th>( \omega_n )</th>
<th>Tb_{11+}(°R)</th>
<th>K</th>
<th>θ</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>0.727</td>
<td>96</td>
<td>236</td>
<td>0.0290</td>
<td>2.788</td>
<td>3.22</td>
<td>985</td>
<td>453</td>
<td>0.280</td>
<td>1353.66</td>
<td>12.5546</td>
<td>0.8497</td>
</tr>
<tr>
<td>8</td>
<td>0.749</td>
<td>107</td>
<td>252.5</td>
<td>0.0251</td>
<td>2.685</td>
<td>3.106</td>
<td>1036</td>
<td>419</td>
<td>0.312</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>0.768</td>
<td>121</td>
<td>269</td>
<td>0.0389</td>
<td>4.718</td>
<td>6.143</td>
<td>1085</td>
<td>383</td>
<td>0.348</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0.782</td>
<td>134</td>
<td>296.3</td>
<td>0.0260</td>
<td>51.332</td>
<td>58.258</td>
<td>1593.03</td>
<td>114.321</td>
<td>2.476</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C_{11+}</td>
<td>0.881</td>
<td>328.437</td>
<td>316.4</td>
<td>0.1562</td>
<td>51.332</td>
<td>58.258</td>
<td>1593.03</td>
<td>114.321</td>
<td>2.476</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.2755</td>
<td>65.018</td>
<td>75.20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Table 7 indicates that when the number of pseudo components increases API gravity decrease with tendency to theoretical API as presented in Table 8. This is also observed in oil formation volume factor where Figures 8 to 10 shows that increasing the number of pseudo components the oil formation volume factor increase, with tendency of predicting volatile oil when compared to theoretical expected properties as presented in Table 8, with values more than 2 bbl/STB. This observation is also valid to gas oil ratio where Figures 11 to 13 show an increase when the
Table 6. Comparison of fluid properties obtained with both methods with an increment in the second stage temperature.

<table>
<thead>
<tr>
<th>Second separator stage temperature (°F)</th>
<th>Proposed method</th>
<th>Al Jawad and Hassan method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>API</td>
<td>Bosb(bbl/STB)</td>
</tr>
<tr>
<td>70</td>
<td>64.95</td>
<td>1.461</td>
</tr>
<tr>
<td>85</td>
<td>64.91</td>
<td>1.463</td>
</tr>
<tr>
<td>100</td>
<td>64.86</td>
<td>1.466</td>
</tr>
<tr>
<td>115</td>
<td>64.82</td>
<td>1.469</td>
</tr>
<tr>
<td>130</td>
<td>64.78</td>
<td>1.472</td>
</tr>
</tbody>
</table>

Figure 5. Effect of splitted C7+ in API gravity for 2 pseudo components.

heavier fraction is splitted into more components, and value are less than 1750 scf/STB for crude oil as presented in Table 8. So this indicates the effect of extending the heavier fractions to more components than using as single component.

The optimum second stage for single heavier fraction is presented in the Figures 14 to 20, where for maximum in API gravity, minimum in Bosb and Rssb, the optimum pressure is found at 174 psia. Similar optimum pressures estimation were made for extended heavier fraction in 2, 3 and 4 pseudo components and the results are presented in Table 7. In Table 7 is observed that the optimum pressure obtained using the heavier fraction as single component as greater compared to pressures obtained with extended fraction and keeps decreasing as fraction is continuously extended.

Figure 6. Effect of splitted C7+ in API gravity for 3 pseudo components.

Conclusion

In this study, it is concluded that extended composition of C7+ fraction affects the optimum surface separator pressure of the fluid stream. Both method showed that splitting the composition of the C7+ fraction in pseudo components results in different estimated fluid properties when compared with properties estimated assuming the C7+ as single component. An increment in the number of pseudo components the optimum second stage pressure changes because of changes in the fluid properties. Where accurate results are obtained when the heavier fraction is splitted in several pseudo components. Both methods showed that with an increment in second stage
Figure 7. Effect of splitted C7+ in API gravity for 4 pseudo components.

Table 7. Comparison of the fluid properties and optimum second stage pressures obtained through the proposed method and Al jawad and Hassan method.

<table>
<thead>
<tr>
<th>Splitted C7+ fraction Composition</th>
<th>Proposed Method</th>
<th>Al-Jawad and Hassan Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single</td>
<td>64.95</td>
<td>1.461</td>
</tr>
<tr>
<td>2 Pseud.compts</td>
<td>60.92</td>
<td>1.472</td>
</tr>
<tr>
<td>3 Pseud.compts</td>
<td>58.14</td>
<td>1.475</td>
</tr>
<tr>
<td>4 Pseud.compts</td>
<td>56.77</td>
<td>1.474</td>
</tr>
</tbody>
</table>
temperature, the API gravity decrease, oil formation volume factor and solution gas oil ratio increase.

RECOMMENDATIONS

Present study was limited to one type of reservoir fluid exposed to only a single separator test therefore more
Table 8. Reservoir fluid properties.

<table>
<thead>
<tr>
<th></th>
<th>Black Oil</th>
<th>Volatile oil</th>
<th>Retrograde gas</th>
<th>Wet gas</th>
<th>Dry gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil formation volume factor</td>
<td>&lt; 2.0</td>
<td>&gt;2.0</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Initial producing gas liquid ratio (Sfc/STB)</td>
<td>&lt;1.750</td>
<td>1750 to 3200</td>
<td>&gt;3200</td>
<td>&gt;1500'</td>
<td>100 000'</td>
</tr>
<tr>
<td>Initial stock- tank liquid gravity API</td>
<td>&lt; 45</td>
<td>&gt; 45</td>
<td>&gt; 45</td>
<td>up to 70</td>
<td>No liquid</td>
</tr>
</tbody>
</table>

(McCain, 1994). *For engineering purposes.*
Table 9. Al-Jawad and Hassan correlation constants ‘a’ for equations 1 and 2.

<table>
<thead>
<tr>
<th>Constant</th>
<th>First stage</th>
<th>Second Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>30.82</td>
<td>0.23</td>
</tr>
<tr>
<td>$\alpha_1$</td>
<td>0.35</td>
<td>-2.00</td>
</tr>
<tr>
<td>$\alpha_2$</td>
<td>0.24</td>
<td>-0.003</td>
</tr>
<tr>
<td>$\alpha_3$</td>
<td>0.91</td>
<td>-4.024</td>
</tr>
<tr>
<td>$\alpha_4$</td>
<td>-0.21</td>
<td>3.27</td>
</tr>
<tr>
<td>$\alpha_5$</td>
<td>-0.59</td>
<td>-0.44</td>
</tr>
<tr>
<td>$\alpha_6$</td>
<td>-6.85</td>
<td>3.10</td>
</tr>
<tr>
<td>$\alpha_7$</td>
<td>1.72</td>
<td>-0.20</td>
</tr>
<tr>
<td>$\alpha_8$</td>
<td>-267.11</td>
<td>0.05</td>
</tr>
<tr>
<td>$\alpha_9$</td>
<td>----------</td>
<td>20.64</td>
</tr>
</tbody>
</table>

Figure 14. Optimum second stage pressure estimation from Rsrb and API for C7+ as single component.

Figure 15. Optimum second stage pressure estimation from Rsrb and API for C7+ as single component.

Figure 16. Optimum second stage pressure estimation from Rsrb and API for C7+ splitted in 2 pseudo components.

studies should be based in different reservoir fluids. More studies should be based on different splitting schemes techniques which can split the heavier fraction in different positions and allow more variation. In this study Ahmed's splitting scheme was the only method applied to extend the composition of the heavier fraction. We suggest performing more studies where fluid properties are obtained through laboratory PVT tests. In present
research, these properties were obtained from standard PVT experiments which are conducted through phase equilibrium simulations. It is recommended that simulation be performed by means of commercial simulator, which are also applied and recommended by the Petroleum Industry. It is recommended to split the
heavier fraction composition in more pseudo components. In this study the heavier fractions were extended into 4 pseudo components, due to the limitation of data. Other researchers should perform phase equilibrium calculations by estimating fluid properties through different tuned equations of state. In this study, the fluid properties were estimated through the Peng Robinson EOS.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Nomenclature

\( z \) \text{', Vapor compressibility; } z' \text{' Liquid compressibility; } T_b \text{' True boiling point; } T_c \text{' Critical Temperature; } P_c \text{' Critical Pressure; } (P_1)_{opt} \text{' Optimum first stage separator pressure; } (P_2)_{opt} \text{' Optimum second stage separator pressure; } GOR \text{' Gas Oil Ratio; API \text{' American Petroleum Institute; } PVT \text{' Pressure Volume and Temperature; } VLE, \text{Vapor Liquid Equilibrium; } STB, \text{Stock tank barrel; } EOS, \text{Equation of state; } VBA, \text{Visual Basic for Applications; } \gamma \text{' Specific gravity; } \omega \text{' Acentric factor.}

REFERENCES

Stamaki SK (2001). Characterization of heavy undefined fractions; Magoulas, National Technical University of Athens, Greece. SPE-64996.