Estimation of Natural Gas Compressibility Factors Using Mathematical Correlations For Sirte Oil Fields

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Abstract:

Knowledge of the pressure-volume-temperature (PVT) behavior of natural gases is necessary to solve many petroleum engineering problems. Gas reserves, gas metering, gas pressure gradients, pipeline flow and compression of gases are some of the problems requiring the gas compressibility factor, or Z factor. Typically, the Z factor is determined by laboratory measurement. However, laboratory data is only applicable for the conditions and condition investigated. When conditions
of interest are different from those of the laboratory studies or data is not available, correlations must be used.

This study has been conducted on four gas fields of Sirte Oil Company, namely Zeltinfield, Al Ragouba field, Al Hotayba field and Al Braiga field. The Z factor has been calculated for the different fields using mathematical correlations and charts through the calculations of pseudocritical and pseudoreducedtemperature $T_{pr}$ and pressure $P_{pr}$. The values obtained are corrected because the natural gases contain impurities (H$_2$S, CO$_2$, N$_2$) that caused factor deviation. The results exhibit some variation due the different constituents of gas mixture.

Key words: Natural gas, compressibility factor, pseudocritical temperature, pseudocritical pressure, pseudoreduced temperature, pseudoreduced pressure, correlations, equation of state.

1. Introduction

Basically the magnitude of deviation of real gases from the conditions of the ideal gas law increases with increasing pressure and temperature and varied widely with the composition of the gas. Real gases behave differently than ideal gases. The reason for this is the perfect gas law was derived under the assumption that the volume of molecules is insignificant and no molecular attraction or repulsion exist between them. This is not the case of real gases.$^{[1]}$

Numerous equationsofstate have been developed in the attempt to correlate the pressure-volume-temperature variables for real gases with
experimental data. More recent equations-of-state are suggested. In order to express a more exact relationship between the variables P, V and T, a correction factor called the gas compressibility factor, gas deviation factor, or simply the Z-factor, must be introduced into the general equation of gases to account for departure gases from ideality. The compressibility factor Z is a dimensionless quantity and is defined as the ratio of actual volume of n-moles of gas at T and P to the ideal volume of the same number of moles at the same T and P.

For a perfect gas, the compressibility factor Z is equal to one. For a real gas, the Z-factor is greater or less than one depending on the pressure, temperature and the composition of the gas.

The value of Z at any given pressure and temperature can be determined experimentally by measuring the actual volume of some quantity of gas at the specified P and T.

It is commonly known that natural gas owns compressibility. When subjected to the reservoir pressure and temperature, the natural gas is in compression. However, various parameters of it undergo gradual changes at any stage of its flowing course which involves the underground percolation in formation and the wellbore flowing, resulting from the pressure drop and volume expansion. State equations are commonly used for gas to indicate its change in state (pressure P, volume V, and temperature T), and some high-pressure physical parameters which are quite practical in engineering are also introduced, for example, volume factor, isothermal compressibility, and viscosity ratio\(^1\).
The basic methods for estimating the gas compressibility factor are well known. The principle of corresponding states, kay's pseudocritical point, and the standing and kay's chart are commonly used. If the composition of the gas is known, the pseudocritical temperature $T_{pc}$ and pressure $P_{pc}$ may be calculated using Kay's rules-molar averages of the critical properties of the mixture's components. Otherwise, the pseudocritical temperature and pressure may be calculated using correlation based on gas specific gravity. The pseudo reduced temperature $T_{pr}$ and pressure $P_{pr}$ may be calculated and the equation of state may be used to determine the $Z$ factor.

2. Composition of Natural Gas

Generally, natural gas is flammable or inflammable gaseous mixtures of hydrocarbons and non-hydrocarbons, extracted from the underground, at normal temperature and pressure.

3. Classification of Natural Gas

Narrowly speaking, natural gas can be classified into different types:

(1) According to the essential features of the deposits: The natural gas can be ranged into two types: oil reservoir associated gas and gas from gas reservoir. The former one is dissolved in crude oil at the reservoir condition and released from oil as pressure drops. The later one, gas from gas reservoir, is in a gaseous state in the underground formations and includes two types named pure gas and condense gas, respectively. The principal constituent of the gas in pure gas reservoirs is
methane, with some others such as ethane, propane, and butane. The gas from gas-condensate reservoir, on analysis of the effluent at the oil wellhead, contains not only methane, ethane, propane and butane, but also some liquid $C_{5+}$ hydrocarbons between $C_7$ and $C_{11}$.

(2) According to the composition, natural gas can be described in two ways: dry gas and wet gas, or poor gas and rich gas.$^{[1]}$

**Dry gas**: The content of liquid $C_{5+}$ heavy hydrocarbons in wellhead effluent is less than $13.5$ cm$^3$/m$^3$ at standard temperature and pressure.

**Wet gas**: On analysis of the wellhead effluents, which are subjected to standard temperature and pressure, the content of liquid $C_{5+}$ heavy hydrocarbons is more than $13.5$ cm$^3$/m$^3$.

**Poor gas**: On analysis of the wellhead effluents, which are subjected to standard temperature and pressure, the content of liquid $C_{3+}$ heavy hydrocarbons is less than $94$ cm$^3$/m$^3$.

**Rich gas**: On analysis of the wellhead effluents, which are subjected to standard temperature and pressure, the content of liquid $C_{3+}$ heavy hydrocarbons is more than $94$ cm$^3$/m$^3$.

(3) According to the content of the acidic gases such as $H_2S$ and $CO_2$:

**Sour natural gas** contains significant amount of acidic gases such as $H_2S$ and $CO_2$. This kind of natural gases is required to be processed and clarified to reach the standards for pipeline transportation.

**Clean natural gas** is also named as sweet gas. This kind of natural gas contains very minor amount of acidic gases, and the cleaning (purification) treatment is not required for it.
3. Properties of Natural Gas

Properties of natural gas include gas-specific gravity, pseudocritical pressure and temperature, viscosity, compressibility factor, gas density, and gas compressibility. Knowledge of these property values is essential for designing and analyzing natural gas production and processing systems. Because natural gas is a complex mixture of light hydrocarbons with a minor amount of inorganic compounds, it is always desirable to find the composition of the gas through measurements. Once the gas composition is known, gas properties can usually be estimated using established correlations with confidence.

3.1. Specific Gravity

Gas-specific gravity ($\gamma_g$) is defined as the ratio of the apparent molecular weight of a natural gas to that of air, itself a mixture of gases. The molecular weight of air is usually taken as equal to 28.97 (approximately 79% nitrogen and 21% oxygen). Therefore the gas gravity is \cite{2}:

$$\gamma_g = \frac{M_{W_g}}{28.97}$$ (1)

where

$\gamma_g =$ Specific gravity of gas.

$M_{W_g} =$ molecular weight of gas mixture

$M_{W_{air}} =$ molecular weight of air (air=28.97)
Where the apparent molecular weight of gas can be calculated based on gas composition. Gas composition is usually determined in a laboratory and reported in mole fractions of components in the gas. Let $y_i$ be the mole fraction of component $i$, the apparent molecular weight of the gas can be formulated using mixing rule as $^{[2]}$:

$$MW_a = \sum_{i=1}^{N_c} y_i MW_i$$  \hspace{1cm} (2)

where $MW_i$ is the molecular weight of component $i$, and $N_c$ is the number of components. The molecular weights of compounds ($MW_i$) can be found in textbooks on organic chemistry or petroleum fluids such as that by McCain$^{[2]}$. A light gas reservoir is one that contains primarily methane with some ethane. Pure methane would have a gravity equal to $(16.04/28.97) = 0.55$. A rich or heavy gas reservoir may have a gravity equal to 0.75 or, in some rare cases, higher than 0.9$^{[2]}$.

Similar to gas apparent molecular weight, the critical properties of a gas can be determined on the basis of the critical properties of compounds in the gas using the mixing rule. The gas critical properties determined in such a way are called pseudocritical properties. Gas pseudocritical pressure ($p_{pc}$) and pseudocritical temperature ($T_{pc}$) are, respectively, expressed as $^{[3]}$:

$$p_{pc} = \sum_{i=1}^{N_c} y_i P_{ci}$$ \hspace{1cm} (3)
and

\[ T_{pc} = \sum_{i=1}^{N_c} y_i T_{ci} \quad (4) \]

Where: \( P_{ci} \) and \( T_{ci} \) are critical pressure and critical temperature of component \( i \), respectively.

If the gas composition is not known but gas-specific gravity is given, the pseudocritical pressure and temperature can be determined from various charts or correlations developed based on the charts. One set of simple correlations is \(^3\):

\[ p_{pc} = 709.604 - 58.718 \quad (5) \]

\[ T_{pc} = 170.491 - 307.344 y_g \quad (6) \]

which are valid for \( \text{H}_2\text{S} < 3\%, \text{N}_2 < 5\%, \) and total content of inorganic compounds less than 7%.

### 3.2. Compressibility Factor (Z)

Gas compressibility factor is also called deviation factor, or Z-factor. Its value reflects how much the real gas deviates from the ideal gas at given pressure and temperature. Definition of the compressibility factor is expressed as \(^4\):

\[ z = \frac{V_{actual}}{V_{ideal \ gas}} \quad (7) \]

Introducing the Z-factor to the gas law for ideal gas results in the gas law for real gas as:
\[ pV = nzRT \quad (8) \]

Where \( n \) is the number of moles of gas. When pressure \( p \) is entered in psia, volume \( V \) in ft\(^3\), and temperature in \(^0\)R, the gas constant \( R \) is equal to \( R = 10.73 \) psia-ft\(^3\)/Mole-\(^0\)R\(^4\):

The gas compressibility factor can be determined on the basis of measurements in PVT laboratories. For a given amount of gas, if temperature is kept constant and volume is measured at 14.7 psia and an elevated pressure \( P_1 \), z-factor can then be determined with the following formula\(^4\):

\[ z = \frac{P_1 V_1}{14.7 V_0} \quad (9) \]

Where \( V_0 \) and \( V_1 \) are gas volumes measured at 14.7 psia and \( P_1 \) respectively.

Very often the Z-factor is estimated with the chart developed by Standing and Katz\(^5\). This chart has been set up for computer solution by a number of individuals, yield Z-factor values accurate enough for many engineering calculations. Brill and Beggs' Z-factor correlation is expressed as follows\(^4\):

\[
A = 1.39(T_{pr} - 0.92)^{0.5} - 0.36T_{pr} - 0.10 \\
B = (0.62 - 0.23T_{pr})P_{pr} + \left( \frac{0.066}{T_{pr} - 0.86} - 0.037 \right) P_{pr}^2 \\
+ \frac{0.32P_{pr}^6}{10^6} \\
C = 0.132 - 0.032 \log(T_{pr})
\]

\[ (10) \]

\[ (11) \]
\[ D = 10^C \] \hspace{1cm} (13)

\[ E = 9(T_{pr} - 1) \] \hspace{1cm} (14)

\[ F = 0.3106 - 0.49T_{pr} + 0.1824T_{pr}^2 \] \hspace{1cm} (15)

and

\[ z = A + \frac{1 - A}{e^B} + Cp_{pr} \] \hspace{1cm} (16)

3.3. Formation Volume Factor

Formation volume factor is defined as the ratio of gas volume at reservoir condition to the gas volume at standard condition, that is:

\[ B_g = \frac{V}{V_{sc}} = \frac{P_{sc}}{P} \frac{T}{T_{sc}} \frac{z}{z_{sc}} = 0.0283 \frac{z}{p} \] \hspace{1cm} (17)

Where the unit of formation volume factor is ft\(^3\)/scf. If expressed in rb/scf, it takes the form of:

\[ B_g = 0.00504 \frac{zT}{p} \] \hspace{1cm} (18)

4. Effect of Non-hydrocarbon Components

Natural gases commonly contain hydrocarbon sulfide, carbon dioxide, and nitrogen. The presence of these gases does affect the Z-factor obtained by the previously described methods. Hence, limits have to be put up for the usage of those methods: The content of the non-
hydrocarbons in the studied natural gas must be less than 5% by volume (the volume content of N\textsubscript{2} is less than 2% and the volume content of CO\textsubscript{2} is less than 1%), and what’s more, the volume content of methane should not be less than 50%. Exceeding these limits means great error (more than 3%). For this reason, when the non-hydrocarbon or C\textsubscript{5+} components of a natural gas (e.g., condensate gas) make a comparatively high contribution, the methods should undergo a correction by referring to some other charts and equations. To remedy this problem, methods have been developed to eliminate the error caused by non-hydrocarbons, and two of them will be introduced below.

4.1. Wichert-Aziz Correction Method

In order to get a corrected Z-factor, this method adjusts the pseudo-critical parameters and the pseudo-reduced parameters, through an adjustment of the curve on the reference chart, to account for the unusual behavior of these gases containing impurities: Firstly, bring in an adjustment factor \( \varepsilon \), a function of the concentrations of H\textsubscript{2}S and CO\textsubscript{2}, to the pseudo-critical temperature \( T_{pr} \); Secondly, correct the pseudo-critical pressure \( P_{pc} \); thirdly, with the corrected \( T_{pr} \) and \( P_{pc} \), calculate the \( T'_{pc} \) and \( P'_{pc} \); and finally get the value of Z-factor on basis of \( T_{pr} \) and \( P_{pr} \), referring to their original Z-chart. Then, we can get the compressibility factor for the acid natural gases that contain H\textsubscript{2}S and CO\textsubscript{2}.

Corrections for impurities in sour gases are always necessary. The corrections can be made using either charts or correlations such as the Wichert and Aziz correction by calculation acentric factor \( \varepsilon \) expressed as follows\cite{3}:

\[
\varepsilon = \left\{ \begin{array}{ll}
0.04 & \text{if } \beta \leq 1.0 \\
0.02 & \text{if } \beta > 1.0
\end{array} \right.
\]
\[ A = y_{H_2S} + y_{CO_2} \] (19)

\[ B = y_{H_2S} \] (20)

\[ \varepsilon = 120(A^{0.9} - A^{1.6}) + 15(B^{0.5} - B^{4.0}) \] (21)

\[ T'_{pc} = T_{pc} - \varepsilon_3 \text{(corrected } T_{pc}) \] (22)

\[ P'_{pc} = \frac{p_{pc}T_{pc}}{T_{pc} + B(1 - B)\varepsilon_3} \text{ (corrected } T_{pc}) \] (23)

Correlations with impurity corrections for mixture pseudocritical are also available\[^6\].

\[ p_{pc} = 678 - 50(y_g - 0.5) - 206.7y_{N_2} + 440y_{CO_2} + 606.7 \] (24)

\[ T_{pc} = 326 + 315.7(y_g - 0.5) - 204y_{N_2} - 83.3y_{CO_2} + 133.3y_{H_2S} \] (25)

Applications of the pseudocritical pressure and temperature are normally found in natural gas engineering through pseudo reduced pressure and temperature defined as:

\[ P'_{pr} = \frac{p}{p'_{pc}} \] (26)

\[ T'_{pr} = \frac{T}{T'_{pc}} \] (27)

Where

\[ T_{pc}, P_{pc} \] respectively the pseudocritical temperature (°R) and the pseudocritical pressure (psi) of the mixture of hydrocarbons.
The pseudocritical temperature (°R) and the pseudocritical pressure (psia) after correction; \( n \) the mole fraction of the H\(_2\)S in natural gas; \( \varepsilon \) the adjustment factor for the pseudocritical temperature (°R) as a function of the concentrations of H\(_2\)S and CO\(_2\).

\( T'_{pc}, P'_{pc} \) are pseudo-reduced temperature and pressure respectively.

### 4.2. Carr-Kobayashi-Burrows Correction Method

Carr, Kobayashi, and Burrows\(^7\) proposed a simplified procedure to adjust the pseudocritical properties of natural gases when nonhydrocarbon components are present. The method can be used when the composition of the natural gas is not available.

\[
P'_{pc} = p_{pc} - 440y_{CO_2} + 600y_{H_2S} - 170y_{N_2} \tag{28}
\]

\[
T'_{pc} = T_{pc} - 80y_{CO_2} + 130y_{H_2S} - 250y_{N_2} \tag{29}
\]

Where

- \( T'_{pc} \) = the adjusted pseudocritical temperature, °R
- \( T_{pc} \) = the unadjusted pseudocritical temperature, °R
- \( P'_{pc} \) = the adjusted pseudocritical pressure, psia
- \( P_{pc} \) = the unadjusted pseudocritical pressure, psia
- \( y_{CO_2} \) = mole fraction of CO\(_2\)
\[ y_{N_2} = \text{mole fraction of nitrogen} \]

\[ y_{H_2S} = \text{mole fraction of H}_2\text{S in gas mixture} \]

5. Material and Methods

5.1. Location of Study

This study has been carried out on four gas fields are Zeltin field, Al Ragouba field, Al Hotayba field and Al Braigaterminal of Sirte Oil Company. The data of chemical analysis of the investigated gas fields are obtained from central laboratory of Oil Company.

The distribution of different oil and gas fields of Sirte Oil Company are illustrated in Figure 1.
Fig. 1 Distribution of different oil and gas fields of Sirte Oil Company
6. Results and Discussion

Tables 1 through 4 show the chemical composition of natural gas for the different gas fields. The pseudocritical properties, molecular weight, specific gravity, acentric factor $\epsilon$ and Z factor are calculated by applying the above Equations and presented in these tables.

On the other hand, from Standing-Katz chart, Fig. 2 the relationship between $T_r$ & $P_r$ can be used to determine the compressibility factor $Z$ of a gases$^{[5,8-10]}$.

The adjusted (corrected)pseudocritical temperature, $T'_{pc}$ and the adjusted pseudocritical pressure $P'_{pc}$ are calculated from Equations 26 and 27 using Wichert-Aziz correction method, as well as Equations 28 and 29 of Carr-Kobayashi-Burrows correction method.
Fig. 2: Compressibility factor chart\textsuperscript{[4]}
6.1. Zeltin Gas Field

Table 1. Chemical composition and critical properties of Zeltin gas field.

<table>
<thead>
<tr>
<th>Components</th>
<th>$y_i$</th>
<th>$p_{ci}$ (psi)</th>
<th>$T_{ci}$ (˚R)</th>
<th>$M_i$</th>
<th>$y_i p_{ci}$</th>
<th>$y_i T_{ci}$</th>
<th>$y_i M_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₄</td>
<td>0.690</td>
<td>673.1</td>
<td>343.0</td>
<td>16.043</td>
<td>464.44</td>
<td>236.67</td>
<td>11.07</td>
</tr>
<tr>
<td>C₂H₆</td>
<td>0.111</td>
<td>708.3</td>
<td>549.6</td>
<td>30.070</td>
<td>78.62</td>
<td>61.01</td>
<td>3.43</td>
</tr>
<tr>
<td>C₃H₈</td>
<td>0.074</td>
<td>617.4</td>
<td>665.6</td>
<td>44.097</td>
<td>45.69</td>
<td>49.25</td>
<td>3.26</td>
</tr>
<tr>
<td>C₄H₁₀</td>
<td>0.012</td>
<td>550.7</td>
<td>765.3</td>
<td>58.123</td>
<td>6.61</td>
<td>9.18</td>
<td>0.70</td>
</tr>
<tr>
<td>C₅H₁₂</td>
<td>0.024</td>
<td>489.0</td>
<td>845.6</td>
<td>72.150</td>
<td>11.74</td>
<td>20.29</td>
<td>1.73</td>
</tr>
<tr>
<td>C₆H₁₄</td>
<td>0.001</td>
<td>439.7</td>
<td>914.2</td>
<td>86.177</td>
<td>0.44</td>
<td>0.914</td>
<td>0.086</td>
</tr>
<tr>
<td>C₇H₁₆⁺</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CO₂</td>
<td>0.061</td>
<td>1071.1</td>
<td>547.6</td>
<td>44.010</td>
<td>65.34</td>
<td>33.40</td>
<td>2.68</td>
</tr>
<tr>
<td>N₂</td>
<td>0.013</td>
<td>187.5</td>
<td>227.2</td>
<td>28.013</td>
<td>2.44</td>
<td>2.95</td>
<td>0.36</td>
</tr>
<tr>
<td>H₂S</td>
<td>0.011</td>
<td>493.1</td>
<td>672.4</td>
<td>34.08</td>
<td>5.43</td>
<td>7.40</td>
<td>0.37</td>
</tr>
<tr>
<td>Σ</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td>$p_{pc}$=</td>
<td>$T_{pc}$=</td>
<td>$M_w$=</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>680.74</td>
<td>421.06</td>
<td>23.69</td>
</tr>
</tbody>
</table>

Specific gravity $SG = M_w / 29 = 23.69 / 29 = 0.82$

Z factor 0.92

Corrected Z 0.90
### 6.2. Al Ragouba Gas Field

Table 2. Chemical composition and critical properties of Al Ragouba gas field

<table>
<thead>
<tr>
<th>Components</th>
<th>$y_i$</th>
<th>$p_{ci}$ (psi)</th>
<th>$T_{ci}$ (°R)</th>
<th>$M_i$</th>
<th>$y_i p_{ci}$</th>
<th>$y_i T_{ci}$</th>
<th>$y_i M_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH$_4$</td>
<td>0.679</td>
<td>673.1</td>
<td>343.0</td>
<td>16.043</td>
<td>469.15</td>
<td>232.90</td>
<td>10.89</td>
</tr>
<tr>
<td>C$_2$H$_6$</td>
<td>0.116</td>
<td>708.3</td>
<td>549.6</td>
<td>30.070</td>
<td>82.16</td>
<td>63.75</td>
<td>3.49</td>
</tr>
<tr>
<td>C$_3$H$_8$</td>
<td>0.085</td>
<td>617.4</td>
<td>665.6</td>
<td>44.097</td>
<td>52.50</td>
<td>56.58</td>
<td>3.75</td>
</tr>
<tr>
<td>C$<em>4$H$</em>{10}$</td>
<td>0.015</td>
<td>550.7</td>
<td>765.3</td>
<td>58.123</td>
<td>8.26</td>
<td>11.48</td>
<td>0.87</td>
</tr>
<tr>
<td>C$<em>5$H$</em>{12}$</td>
<td>0.005</td>
<td>489.0</td>
<td>845.6</td>
<td>72.150</td>
<td>2.45</td>
<td>4.23</td>
<td>0.36</td>
</tr>
<tr>
<td>C$<em>6$H$</em>{14}$</td>
<td>0.0004</td>
<td>439.7</td>
<td>914.2</td>
<td>86.177</td>
<td>0.18</td>
<td>0.37</td>
<td>0.034</td>
</tr>
<tr>
<td>C$<em>7$H$</em>{16}$</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CO$_2$</td>
<td>0.047</td>
<td>1071.1</td>
<td>547.6</td>
<td>44.010</td>
<td>50.34</td>
<td>25.74</td>
<td>2.09</td>
</tr>
<tr>
<td>N$_2$</td>
<td>0.019</td>
<td>187.5</td>
<td>227.2</td>
<td>28.013</td>
<td>3.56</td>
<td>4.32</td>
<td>0.53</td>
</tr>
<tr>
<td>H$_2$S</td>
<td>0.013</td>
<td>493.1</td>
<td>672.4</td>
<td>34.08</td>
<td>6.41</td>
<td>8.74</td>
<td>0.44</td>
</tr>
<tr>
<td>Σ</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td>$p_{pc}$ = 675.01</td>
<td>$T_{pc}$ = 408.11</td>
<td>$M_w$ = 22.45</td>
</tr>
</tbody>
</table>

Specific gravity $SG = M_w/29 = 22.45/29 = 0.77$

Z factor 0.92

Corrected Z 0.89
6.3. Al Hotayba Gas Field

Table 3. Chemical composition and critical properties of Al Hotayba gas field

<table>
<thead>
<tr>
<th>Components</th>
<th>$y_i$</th>
<th>$p_{ci}$ (psi)</th>
<th>$T_{ci}$ (°R)</th>
<th>$M_i$</th>
<th>$\gamma_i$</th>
<th>$\gamma_i^T$</th>
<th>$\gamma_i^M$</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH$_4$</td>
<td>0.785</td>
<td>673.1</td>
<td>343.0</td>
<td>16.043</td>
<td>528.38</td>
<td>269.26</td>
<td>12.59</td>
</tr>
<tr>
<td>C$_2$H$_6$</td>
<td>0.044</td>
<td>708.3</td>
<td>549.6</td>
<td>30.070</td>
<td>31.16</td>
<td>24.18</td>
<td>1.32</td>
</tr>
<tr>
<td>C$_3$H$_8$</td>
<td>0.014</td>
<td>617.4</td>
<td>665.6</td>
<td>44.097</td>
<td>8.64</td>
<td>9.32</td>
<td>0.62</td>
</tr>
<tr>
<td>C$<em>4$H$</em>{10}$</td>
<td>0.009</td>
<td>550.7</td>
<td>765.3</td>
<td>58.123</td>
<td>4.96</td>
<td>6.89</td>
<td>0.52</td>
</tr>
<tr>
<td>C$<em>5$H$</em>{12}$</td>
<td>0.005</td>
<td>489.0</td>
<td>845.6</td>
<td>72.150</td>
<td>2.45</td>
<td>4.23</td>
<td>0.36</td>
</tr>
<tr>
<td>C$<em>6$H$</em>{14}$</td>
<td>0.003</td>
<td>439.7</td>
<td>914.2</td>
<td>86.177</td>
<td>1.32</td>
<td>2.74</td>
<td>0.26</td>
</tr>
<tr>
<td>C$<em>7$H$</em>{16}^+$</td>
<td>0.002</td>
<td>392.8</td>
<td>972.3</td>
<td>100.204</td>
<td>0.79</td>
<td>1.94</td>
<td>0.20</td>
</tr>
<tr>
<td>CO$_2$</td>
<td>0.104</td>
<td>1071.1</td>
<td>547.6</td>
<td>44.010</td>
<td>111.39</td>
<td>56.95</td>
<td>4.57</td>
</tr>
<tr>
<td>N$_2$</td>
<td>0.015</td>
<td>187.5</td>
<td>227.2</td>
<td>28.013</td>
<td>2.81</td>
<td>0.34</td>
<td>0.42</td>
</tr>
<tr>
<td>H$_2$S</td>
<td>0.016</td>
<td>493.1</td>
<td>672.4</td>
<td>34.08</td>
<td>7.89</td>
<td>10.76</td>
<td>0.55</td>
</tr>
<tr>
<td>$\Sigma$</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td>$p_{pc}$= 699.79</td>
<td>$T_{pc}$= 386.61</td>
<td>$M_w$= 21.41</td>
</tr>
</tbody>
</table>

Specific gravity $SG = M_w/29 = 21.41/29 = 0.74$

Z factor 0.90

Corrected Z 0.87

Figure 3 depicts the variation of pseudocritical properties and molecular weights of natural gases in studied fields. This variance reveal the different concentrations of mixture components.
6.4. Al Braiga Gas Field

Table 4. Chemical composition and critical properties of Al Braiga terminal gas field

<table>
<thead>
<tr>
<th>Components</th>
<th>$y_i$</th>
<th>$p_{ci}$ (psi)</th>
<th>$T_{ci}$ (˚R)</th>
<th>$M_{ci}$</th>
<th>$y_iT_{ci}$</th>
<th>$y_iM_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH$_4$</td>
<td>0.7316</td>
<td>673.1</td>
<td>343.0</td>
<td>16.043</td>
<td>492.44</td>
<td>250.94</td>
</tr>
<tr>
<td>C$_2$H$_6$</td>
<td>0.1004</td>
<td>708.3</td>
<td>549.6</td>
<td>30.070</td>
<td>71.11</td>
<td>55.18</td>
</tr>
<tr>
<td>C$_3$H$_8$</td>
<td>0.0255</td>
<td>617.4</td>
<td>665.6</td>
<td>44.097</td>
<td>15.74</td>
<td>16.97</td>
</tr>
<tr>
<td>C$_4$H$_10$</td>
<td>0.1310</td>
<td>550.7</td>
<td>765.3</td>
<td>58.123</td>
<td>72.14</td>
<td>100.25</td>
</tr>
<tr>
<td>C$_5$H$_12$</td>
<td>0.0161</td>
<td>489.0</td>
<td>845.6</td>
<td>72.150</td>
<td>7.89</td>
<td>13.65</td>
</tr>
<tr>
<td>C$_6$H$_14$</td>
<td>0.0025</td>
<td>439.7</td>
<td>914.2</td>
<td>86.177</td>
<td>1.10</td>
<td>2.29</td>
</tr>
<tr>
<td>C$_7$H$_16$</td>
<td>0.0008</td>
<td>392.8</td>
<td>972.3</td>
<td>100.204</td>
<td>0.332</td>
<td>0.78</td>
</tr>
<tr>
<td>CO$_2$</td>
<td>0.0507</td>
<td>1071.1</td>
<td>547.6</td>
<td>44.010</td>
<td>54.30</td>
<td>27.76</td>
</tr>
<tr>
<td>N$_2$</td>
<td>0.020</td>
<td>187.5</td>
<td>227.2</td>
<td>28.013</td>
<td>3.75</td>
<td>4.54</td>
</tr>
<tr>
<td>H$_2$S</td>
<td>0.012</td>
<td>493.1</td>
<td>672.4</td>
<td>34.08</td>
<td>5.92</td>
<td>0.069</td>
</tr>
<tr>
<td>Σ</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td>$p_{pc} = 724.72$</td>
<td>$T_{pc} = 472.43$</td>
</tr>
</tbody>
</table>

Specific gravity $SG = M_w/29 = 27.87/29 = 0.96$

Z factor 0.89
Corrected Z 0.88

On the other hand, the specific gravity, Z factor and the corrected values of Z show variation from field to another, this also attributed to the mixture composition of natural gases (Fig. 4).

Also, from the results we can conclude that the presence of non hydrocarbon impurities in a gas caused some deviation of compressibility factor. Hence, this gases must be treated before delivered to the consumers.
The presence of non-hydrocarbon impurities in a gas must be accounted for when using a gas specific gravity correlation. Errors in Z factors as high as 27 percent occurred when high concentrations of acid gas were ignored.

The pseudocritical properties and molecular weights of natural gases show a variation in studied fields. This variance reveal the different concentrations of mixture components.

Fig. 3 Pseudocritical properties and molecular weights of natural gases

Fig. 4 Specific gravity and Z factors of natural gases

7. Conclusion

The presence of non-hydrocarbon impurities in a gas must be accounted for when using a gas specific gravity correlation. Errors in Z factors as high as 27 percent occurred when high concentrations of acid gas were ignored.

The pseudocritical properties and molecular weights of natural gases show a variation in studied fields. This variance reveal the different concentrations of mixture components.
The Z factors exhibit a variation from field to another, this also attributed to the mixture composition and the impurities content of natural gases. Consequently, these gases must treated to eliminate from nonhydrocarbons components.

**Nomenclature**

- $B_g = \text{gas formation volume factor}$
- $MW_g = \text{molecular weight of gas mixture}$
- $MW_{air} = \text{molecular weight of air}$
- $PVT = \text{pressure-volume-temperature}$
- $p = \text{pressure, psia}$
- $p_c = \text{critical pressure, psia}$
- $p_{pc} = \text{pseudocritical pressure}$
- $p_{pr} = \text{pseudoreduced pressure}$
- $R = \text{universal gas constant}$
- $T = \text{temperature, } °R$
- $T_c = \text{critical temperature, } °R$
- $T_{pc} = \text{pseudocritical temperature}$
- $T_{pr} = \text{pseudoreduced temperature}$
- $y_i = \text{mole fraction of the i-th component}$
- $Z = \text{gas compressibility factor}$
- $\gamma_g = \text{Specific gravity of gas mixture.}$
- $\varepsilon = \text{Wichert and Aziz pseudocritical temperature adjustment parameter, } °R$
References


