DIFFERENT PROPERTIES OF REAL GAS AND SOLUTION - GAS RESERVOIR IN RESERVOIR ENGINEERING

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ABSTRACT

Although the reserve serves as the basis for the evaluation of assets and the making of exploitation policy decisions for all petroleum reservoirs, an error in the determination of a gas reserve is often more critical than a similar error in the determination of an oil reserve. This stems from the fact that the sale and distribution of natural gas is such as to require producers and distributors to enter into long-term contractual agreements. However, the reserve can be determined with certainty only when the accumulation has been depleted, which in such knowledge is of historical interest only. Throughout the producing life of an accumulation, the reserve can be estimated with an accuracy which usually varies directly as the degree of depletion. Thus when an accumulation is first discovered and an accurate reserve estimate is most desired, it is least possible to obtain it. Consequently, the estimation of gas reserves has long been considered a problem of major significance.

In recent years the demand for natural gas has increased to the point where a more sophisticated engineering approach to natural gas reservoirs is desirable. Therefore, it seems appropriate at this time to review the various reserve estimation techniques available and to examine them critically with a view towards improvement wherever possible. Since the major portion of existing reserves is of the dry-gas type this paper will be restricted to reservoirs of that type.

INTRODUCTION

Gas Reservoirs

Gases have unique properties that set them apart from any other known substance. Under certain ideal pressure and temperature conditions, gases can be considered ideal gases, which can distinguish them from what we consider real gases.

Treating a gas as an ideal gas often greatly simplifies the mathematical formulations behind the calculations of gas properties

Ideal Gas Law

The ideal gas law is the equation of state of a hypothetical ideal gas. It is a good approximation to the behavior of many gases under many conditions, although it has several limitations. The relationship
\[ \frac{PV}{T} = \text{constant} \]

may be obtained. The constant in the above equation is called the ideal gas constant and is designated by \( R \); thus the ideal gas equation becomes

\[ PV = RT \]

where the pressure and temperature are absolute values. The values of the ideal gas constant (\( R \)). The individual gas constant (\( R \)) may be obtained by dividing the universal gas constant (\( R_0 \)) by the molecular weight (\( MW \)) of the gas,

\[ R = \frac{R_0}{MW} \]

The units of \( R \) must always be consistent with the units of pressure, temperature, and volume used in the gas equation. No real gases follow the ideal gas law or equation completely.

At temperatures near a gas's boiling point, increases in pressure will cause condensation to take place and drastic decreases in volume. At very high pressures, the intermolecular forces of a gas are significant. However, most gases are in approximate agreement at pressures and temperatures above their boiling point. The compression process using ideal gas considerations results in work performed on the system and is essentially the area under a P-V curve.

**Specific gravity (relative density)**

The specific gravity of a gas, \( \gamma \), is the ratio of the density of the gas at standard pressure and temperature to the density of air at the same standard pressure and temperature. The standard temperature is usually 60°F, and the standard pressure is usually 14.696 psia. However, slightly different standards are sometimes used in different locations and in different units.

The ideal gas laws can be used to show that the specific gravity (ratio of densities) is also equal to the ratio of the molecular weights. By convention, specific gravities of all gases at all pressures are usually set equal to the ratio of the molecular weight of the gas to that of air (28.967). Although specific gravity is still frequently used, this traditional term is not used under the SI system; it has been replaced by "relative density."

**Specific gravity of gas mixtures**

The specific gravity (\( \gamma_g \)) of a gas mixture is the ratio of the density of the gas mixture to that of air. It is measured easily at the wellhead in the field and therefore is used as an indication of the composition of the gas. The specific gravity of gas is proportional to its molecular weight (\( M_g \)) if it is measured at low pressures where gas behavior approaches ideality. Specific gravity also has been used to correlate other physical properties of natural gases. To do this, it is necessary to assume that the analyses of gases vary regularly with their gravities.

**Gas specific gravity**

The ratio of density of any gas at standard conditions (14.7 psia and 60 °F) to the density of air at standard conditions; based on the ideal gas law \( (pV = nRT) \), gas gravity is also equal to the gas molecular weight divided by air molecular weight \( (M_{\text{air}} = 28.97) \). Denoted mathematically as \( \gamma_g \) (where air = 1).
Calculating the relative density (specific gravity)

Calculate the relative density (specific gravity) of natural gas with the following composition (all compositions are in mol%):

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<table>
<thead>
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<tbody>
<tr>
<td>C₁</td>
<td>83.19%</td>
</tr>
<tr>
<td>C₂</td>
<td>8.48%</td>
</tr>
<tr>
<td>C₃</td>
<td>4.37%</td>
</tr>
<tr>
<td>i-C₄</td>
<td>0.76%</td>
</tr>
<tr>
<td>n-C₄</td>
<td>1.68%</td>
</tr>
<tr>
<td>i-C₅</td>
<td>0.57%</td>
</tr>
<tr>
<td>n-C₅</td>
<td>0.32%</td>
</tr>
<tr>
<td>C₆</td>
<td>0.63%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
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</tbody>
</table>

Solution gas Oil ratio

Solution gas-oil ratio is an important parameter to be determined for estimation of solution gas reserves of an oil reservoir. The gas in solution normally refers to the total amount for gas that has been liberated bringing the oil under reservoir pressure and temperature conditions to stock-tank conditions and is reported in cubic meters of gas produced per tonne of stock-tank oil. This parameter can, therefore, be determined from the surface measurements through separators, of the volume of gas produced from a measured quantity of stock-tank oil. This can also be determined in the laboratory from the bottom hole fluid samples (PVT samples) either by flash or differential liberation process.

Real gases

At low pressures and relatively high temperatures, the volume of most gases is so large that the volume of the molecules themselves may be neglected. Also, the distance between molecules is so great that the presence of even fairly strong attractive or repulsive forces is not sufficient to affect the behavior in the gas state. However, as the pressure is increased, the total volume occupied by the gas becomes small enough that the volume of the molecules themselves is appreciable and must be considered. Also, under these conditions, the distance between the molecules is decreased to the point at which the attractive or repulsive forces between the molecules become important. This behavior negates the assumptions required for ideal gas behavior, and serious errors are observed when comparing experimental volumes to those calculated with the ideal gas law. Consequently, a real gas law was formulated (in terms of a correction to the ideal gas law) by use of a proportionality term.

Real gas law

The volume of a real gas is usually less than what the volume of an ideal gas would be at the same temperature and pressure; hence, a real gas is said to be super compressible. The ratio of the real volume to the ideal volume, which is a measure of the amount that the gas deviates from perfect behavior, is called the super compressibility factor, sometimes shortened to the compressibility factor. It is also called the gas deviation factor and given the symbol \( z \).

The gas deviation factor is by definition the ratio of the volume actually occupied by a gas at a given pressure and temperature to the volume it would occupy if it behaved ideally, or:

\[
z = \frac{\text{Actual volume of gas at specified } T \text{ and } p}{\text{Ideal volume of gas at same } T \text{ and } p}
\]

Note that the numerator and denominator of above Equation refer to the same mass. (This equation for the \( z \) factor is also used for liquids.) Thus, the real gas equation of state is written:
The gas deviation factor, $z$, is close to 1 at low pressures and high temperatures, which means that the gas behaves as an ideal gas at these conditions. At standard or atmospheric conditions, the gas $z$ factor is always approximately 1. As the pressure increases, the $z$ factor first decreases to a minimum, which is approximately 0.27 for the critical temperature and critical pressure. For temperatures of 1.5 times the critical temperature, the minimum $z$ factor is approximately 0.77, and for temperatures of twice the critical temperature, the minimum $z$ factor is 0.937. At high pressures, the $z$ factor increases above 1, where the gas is no longer supercompressible. At these conditions, the specific volume of the gas is becoming so small, and the distance between molecules is much smaller, so that the density is more strongly affected by the volume occupied by the individual molecules. Hence, the $z$ factor continues to increase above unity as the pressure increases.

Compressibility factors for mixtures (or unknown pure compounds) are measured easily in a Burnett\[1\] apparatus or a variable-volume PVT equilibrium cell. The gas deviation factor, $z$, is determined by measuring the volume of a sample of the natural gas at a specific pressure and temperature, then measuring the volume of the same quantity of gas at atmospheric pressure and at a temperature sufficiently high so that the hydrocarbon mixture is in the vapor phase.

**Real gas pseudo potential**

In the analysis of gas reservoirs, well-test analysis, gas flow in pipes, and other calculations can be made more accurate by the use of the real gas pseudopotential. This is because the $z$ factor and viscosity that appear in such equations along with pressure terms are dependent on pressure. Consequently, the integral of pressure divided by the $z$ factor and viscosity is defined as a separate parameter called the real gas pseudopotential.

**Gas Formation Volume Factor**

Gas formation volume factor, which is known as $B_g$, is equal to:

$\frac{1}{B_g} = \frac{r_{gw}f}{r_{asc}}$

Gas volume at reservoir conditions divided by gas volume at standard conditions. This factor is used to convert surface measured volumes to reservoir conditions, just as oil formation volume factors are used to convert surface measured oil volumes to reservoir volumes.

The volume occupied by a given amount of hydrocarbon varies depending on the pressure and temperature. A volume factor is a ratio of the volume at one set of conditions to a set of standard conditions. Typical volume factors include the formation volume factor, two-phase formation volume factor and gas volume factor. We’ll review the single-phase and two-phase volume factors for a specific reservoir fluid.
declines further. For the purposes of this illustration we are going to assume it stays at the same temperature. At some pressure between B(2500 psia) and C (1200 psia) the fluid passes the bubble point, and gas begins to break out of solution. This results in a much larger increase in the overall volume occupied and a decrease in the liquid volume. As the fluid reaches atmospheric pressure (D), it expands to its maximum extent and the last traces of gas break out of solution. Finally, at point E, the fluid cools to ambient temperature. The volume of both the liquid and the gas decrease slightly.

Gas Density
To calculate the natural gas density one should start with the real gas law. The gas law as applied to the behavior of natural gas is most commonly stated as:

\[ PV = znRT \]

where: \( P \) = pressure, \( V \) = volume, \( n \) = number of mols, \( R \) = gas constant, \( T \) = absolute temperature and \( z \) = deviation factor (compressibility factor).

The value of gas constant, \( R \), is dependent on the system of units used as follows.

<table>
<thead>
<tr>
<th>Table Values of Gas Constants</th>
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<table>
<thead>
<tr>
<th>VALUE OF GAS CONSTANT</th>
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<tbody>
<tr>
<td>( P ), ( V ), ( T ), ( n ), ( R )</td>
</tr>
<tr>
<td>Atm.</td>
</tr>
<tr>
<td>Psia</td>
</tr>
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</table>

The values of \( z \) (compressibility factor) for natural gas mixtures have been experimentally correlated as a function of pressure, temperature and composition. In preparing a correlation for hydrocarbon mixtures, the ratios of actual pressure and temperature to the molar average of critical or pseudo-critical pressure and temperature have been used.

CONCLUSION

Increasing demand of fuel globally formulates gas as one of the most valuable natural resources. There is lot of uncertainties in estimating hydrocarbon volume correctly from exploration to development stage of a gas field. The accuracy and reliability of data (reservoir geological model, fluid and rock properties) make the implement very hard-hitting. So estimating and updating the gas reserve has become vital issue, as it helps the planners for drawing mid-term and long-term development plan from field development level to national level.

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