# Determination of Original Gas Condensate Composition in The Case of Gas Coning

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**ABSTRACT:** *Obtaining samples that represent original fluid of reservoirs optimizes reservoirs management. The optimized management increases recovery. Also, selecting and performing proper Improved Oil Recovery (IOR) or Enhance Oil Recovery (EOR) programs depend on collecting representative samples. Achieving accurate compositions of original in-situ fluid prevents overdesigning surface facilities. Representative samples cannot be collected from wells which are perforated at the gas / oil contact and are producing non-equilibrium gas. In some cases, samples must be or are collected, when gas coning occurs. There is no standard method for determining accurate original compositions in this situation. We want to discover a method that can estimate original in-situ compositions when gas coning is happened for the first time. Real fluid properties of Iranian oil reservoirs are imported to a synthetic reservoir model that is constructed by a compositional simulator for this purpose. Sampling is performed in the model and methods of determining original in-situ fluid compositions are modeled by detailed Equation Of State (EOS) characterization in the new scheme. In the result an accurate method is found. In this new approach gas coning is not a limitation in sampling even it is a benefit.*

**KEY WORDS:** *Original in-situ compositions, Sampling, Gas coning, Non-representative samples, EOS characterization.*

## INTRODUCTION

It is obvious obtaining representative samples makes proper reservoir management. However, when the bottom-hole flowing pressure is less than the saturation pressure of the original reservoir oil, gas escapes from the oil around the wellbore and is produced. As the result properties of the oil left behind in the formation are alert. The greater drop in pressure around the wellbore extends alerted oil region. Thus, the composition of the mixture of oil and gas flowing into the wellbore is considerably different from the unaltered reservoir oil. The distance

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that altered oil extends out from the wellbore increases with the duration of production and with the amount of bottom-hole pressure drawdown below the current reservoir pressure. In this situation preparing representative sample is impossible [1].

Some studies focus on obtaining original in-situ compositions from collected samples. *Strong et al.* [2] have indicated significant of using an Equation Of State (EOS) in recombination separator samples of oil reservoirs. *Thomas et al.* [3] have introduced three methods for correcting results of recombination separator samples of oil reservoirs, basis on material balance calculation. They tried to eliminate the deficits of their methods in third one, which takes a material balance view of the gas cap and solution gas contributions to separator gas can always be used since it does at least as much as simple depletion. When the initial oil bubble point is known with confidence, it is advisable to adjust the recombination ratio to achieve it, instead of relying on the producing gas/oil ratio. The recombined sample is expected to reasonably represent the reservoir oil, as the bubble point is sensitive to the gas/oil ratio and increases with it [4].

Gas coning is a tendency of the gas to drive the oil downward in an opposite cone contour toward the well perforations. Once the gas reaches the well, gas production will dominate the well flow and the oil production will considerably decrease. If gas coning occurs, the well must become conditioned. The well is considered to be conditioned when further reductions in rate of flow have no effect on the stabilized gas-oil ratio. Adequate time must be allowed after each flow rate reduction to ensure that the gas-oil ratio has completely stabilized and the gas cone has eliminated [1]. *Fevang & Whitson* [5] proposed an experimental method (ECM) to obtain original composition from non-representative samples, therefore conditioning well is not required. Their method is in the basis of bringing collected samples to the initial Gas Oil Contact (GOC) conditions.

Recombination and ECM methods are evaluated for wells that are affected by gas coning in this paper to find a method that is accurate enough in this situation for the first time. A synthetic reservoir model is constructed and real fluid properties are imported to it. ECM and recombination methods are modeled by EOS characterization. Obtained results are compared for the purpose.

## METHODOLOGY

### *Modeling recombination methods (Recom.)*

Recombination is used in two ways, (a) using producing GOR, (b) using a test gas/oil ratio that yields initial bubble point conditions. We use EOS characterization for modeling them (modified three-parameter Peng-Robinson EOS and Lohrenz-Bray-Clarck correlation for calculating viscosity are used). An iteration to find the best GOR for recombination to obtain a fluid which has initial bubble point conditions is used.

### *Modeling Equilibrium Contact Mixing (ECM) method*

This method has been introduced for initially saturated reservoirs. In experimental manner, "oil and gas sample containers are brought to single phase condition. The two samples are transferred to a PVT cell in a ratio that results in an oil volume fraction of 50% or greater at equilibrium. The PVT cell is brought to initial reservoir conditions at the Gas-Oil Contact (GOC) and mixed thoroughly to establish equilibrium. The resulting equilibrium oil and equilibrium gas should provide brilliant estimates of the original in situ fluids at the GOC [5].

We change this method for wells that are imposed by gas coning like *Fevang & Whitson* [5]. We mix collected samples from only oil zone with the producing GOR and then separate prepared well stream at initial GOC conditions. For modeling it detailed EOS characterization is used and experimental separator test is simulated.

### *Reservoir model*

The compositional simulator is used for modeling reservoirs in this research. A radial model is selected and fluid properties of each system from real PVT data of Iranian oil reservoirs are entered in it. Fluid properties are obtained from the detailed EOS (modified three-parameter Peng-Robinson EOS with viscosity corrected by Lohrenz-Bray-Clarck correlation) characterization. Some important properties of these models are illustrated in Table 1. In this paper compositional gradient is neglected and reservoir model is homogenous. Original fluid compositions are shown in Table 2. Sampling is performed by the simulator in various times from 1 day to 10 years after beginning of production.

***Table 1: Properties of reservoir model.***

| | |
|---|---|
| Porosity | 0.16 |
| Radial permeability | 202 md |
| Z-permeability | 20.2 md |
| Rock compressibility | $4.0e^{-6}$ |
| Connate water saturation | 0.22 |
| Number of layers in r-direction | 10 layers with logarithmic intervals |
| Number of layers in θ-direction | 1 layer |
| Number of layers in z-direction | 15 layers with 20ft or 30ft depth |
| Oil zone depth | 200 ft |
| Gas cap depth | 200 ft |
| GOC depth | 7200 ft |

***Table 2: Original fluids composition.***

| Component | Original fluid of oil zone (mol percent) | Original fluid of gas zone (mol percent) |
|---|---|---|
| $CO_2$ | 0.623 | 0.62401 |
| $N_2$ | 0.739 | 1.079 |
| $C_1$ | 65.105 | 80.082 |
| $C_2$ | 8.134 | 7.8841 |
| $C_3$ | 3.892 | 3.219 |
| $IC_4$ | 1.163 | 0.86901 |
| $NC_4$ | 1.718 | 1.215 |
| $IC_5$ | 0.65 | 0.413 |
| $NC_5$ | 0.683 | 0.42 |
| $C_6$ | 0.93 | 0.50101 |
| $C^{7+}$ | 16.363 | 3.694 |

## RESULTS AND DISCUSSION

An initially saturated volatile oil reservoir (south west of Iran) with initial temperature and pressure of 248 °F and 4630 Psia is investigated here as one example among wide range of simulated volatile and lack oil systems. Initial GOC and bubble point pressures are 4630 Psia. The producing oil well is drilled 20ft below GOC at depth of 7220 ft, therefore after beginning of production gas coning is occurs in the well. The well is produced with the constant rate of 2000 STB/DAY for almost 1760 days afterwards producing rates are reduced (see Fig. 1). Gas production rate is increased from 3.80 MMSCF/DAY to 86.60 MMSCF/DAY after 1758 days then is decreased to 1.05 MMSCF/DAY in 10 years production (see Fig. 2). The large increase in gas production rate in a short time shows gas coning. This phenomenon is obvious in curve of GOR vs. TIME. Large increase in GOR shows it (see Fig. 3). In one year GOR increases from 1.9 to 4.68 MSCF/DAY. In two and three years reaches to 8.94 and 15.04 MSCF/DAY respectively.

Sampling and determining original compositions from separator samples are performed for 10 years production by ECM and recombination methods. However, it is understood that after more than three years production performing ECM method is impossible. The reason is

***Table 3: Separator samples and synthesized fluids after 2 years oil production with gas coning.***

| Component | Separator oil (mol percent) | Separator gas (mol percent) | Recom. (Producing GOR) (mol percent) | Recom. (Test GOR) (mol percent() | ECM (mol percent) |
|---|---|---|---|---|---|
| $CO_2$ | 0.4365 | 0.6434 | 0.62525 | 0.58414 | 0.6238 |
| $N_2$ | 0.1135 | 1.1459 | 1.0553 | 0.85022 | 0.7373 |
| $C_1$ | 19.113 | 84.953 | 79.177 | 66.097 | 65.1251 |
| $C_2$ | 6.6476 | 8.0335 | 7.9119 | 7.6366 | 8.1468 |
| $C_3$ | 6.2273 | 2.9827 | 3.2674 | 3.912 | 3.8997 |
| $IC_4$ | 2.7996 | 0.7061 | 0.88978 | 1.3057 | 1.1667 |
| $NC_4$ | 4.7729 | 0.9117 | 1.2505 | 2.0175 | 1.7246 |
| $IC_5$ | 2.4079 | 0.2397 | 0.42993 | 0.86067 | 0.6531 |
| $NC_5$ | 2.7161 | 0.2196 | 0.43864 | 0.9346 | 0.6875 |
| $C_6$ | 4.428 | 0.1561 | 0.5309 | 1.3796 | 0.937 |
| $C^{7+}$ | 50.337 | 0.0081 | 4.4239 | 14.422 | 16.2982 |

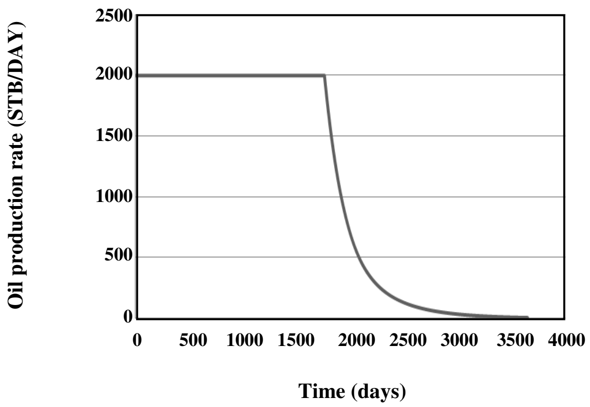


***Fig. 1: Oil production rate vs. time.***

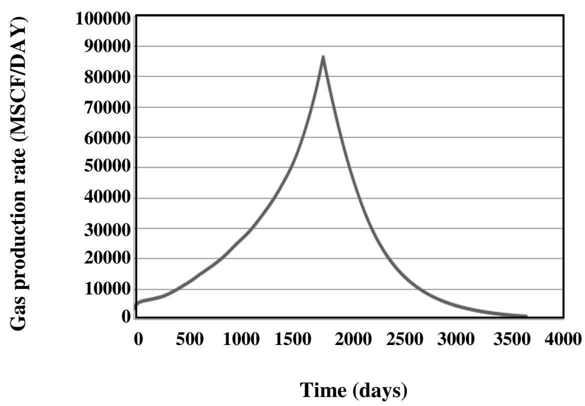


***Fig. 2: Gas production rate vs. time.***

very high gas production rate and in consequence very high GOR in these times, thus separator samples are very lean and mixed fluid in GOC conditions is single phase (gas). Table 3 shows separator samples and determined fluids of oil zone after 2 years oil production. ECM can obtain compositions of gas zone fluid (here is gas condensate) in equilibrium with oil, too. Table 4 shows error percent of each component in each method and absolute average error of each method. From this table can be concluded that ECM is the most accurate method here. Table 5 shows original fluid and determined fluid of gas zone after 2 years oil production also error percent of each component is shown in this figure and high accuracy of ECM method is obvious here. Fig. 4 shows error percents of each method, each component and absolute average error percent for rapid comparison. Fig. 5 shows that the ECM method has more smooth errors and error percents of each component in this method are in a small range in contrast with recombination methods. Fig. 6 certifies obtained results by matching ECM and original fluids phase plots. Phase plot of prepared fluids by ECM is exactly matched on original oil phase plot but recombination phase plots have large offsets.

## CONCLUSIONS

Evaluating ECM and recombination methods in oil reservoirs with gas coning phenomenon concludes that (a) recombination with producing and test GOR isn't an accurate method even in early times of reservoir life (b) ECM method is the most accurate method for preparing

***Table 4: Error percent of each component in each method after 2 years production.***

| Component | ECM error percent | Recombination with test GOR e rror percent | Recombination with producing GOR error percent |
|---|---|---|---|
| $CO_2$ | 0.128411 | 6.23756 | 0.361156 |
| $N_2$ | 0.230041 | 15.05007 | 42.80108 |
| $C_1$ | 0.030873 | 1.523692 | 21.61432 |
| $C_2$ | 0.157364 | 6.115073 | 2.730514 |
| $C_3$ | 0.197842 | 0.513875 | 16.0483 |
| $IC_4$ | 0.318143 | 12.26999 | 23.49269 |
| $NC_4$ | 0.384168 | 17.43306 | 27.21187 |
| $IC_5$ | 0.476923 | 32.41077 | 33.85692 |
| $NC_5$ | 0.658858 | 36.83748 | 35.77745 |
| $C_6$ | 0.752688 | 48.34409 | 42.91398 |
| $C^{7+}$ | 0.396015 | 11.86213 | 72.964 |
| Absolute Average Error Percent | 0.339211 | 17.14525 | 29.07021 |

***Table 5: Gas zone original and synthesized fluids and error percent of ECM method***

| Component | Gas zone (mol percent) | ECM (mol percent) | ECM error percent |
|---|---|---|---|
| $CO_2$ | 0.62401 | 0.6253 | 0.206727 |
| $N_2$ | 1.079 | 1.0745 | 0.417053 |
| $C_1$ | 80.082 | 80.0223 | 0.074549 |
| $C_2$ | 7.8841 | 7.8978 | 0.173767 |
| $C_3$ | 3.219 | 3.2293 | 0.319975 |
| $IC_4$ | 0.86901 | 0.8731 | 0.470651 |
| $NC_4$ | 1.215 | 1.2219 | 0.567901 |
| $IC_5$ | 0.413 | 0.4165 | 0.847458 |
| $NC_5$ | 0.42 | 0.4237 | 0.880952 |
| $C_6$ | 0.50101 | 0.5065 | 1.095787 |
| $C^{7+}$ | 3.694 | 3.7091 | 0.408771 |
| absolute average error percent | | | 0.49669 |

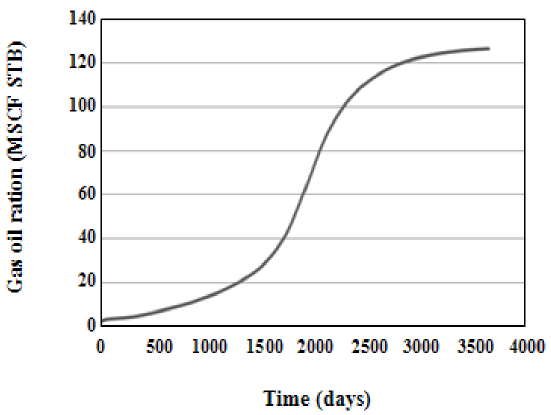


***Fig. 3: GOR vs. time.***

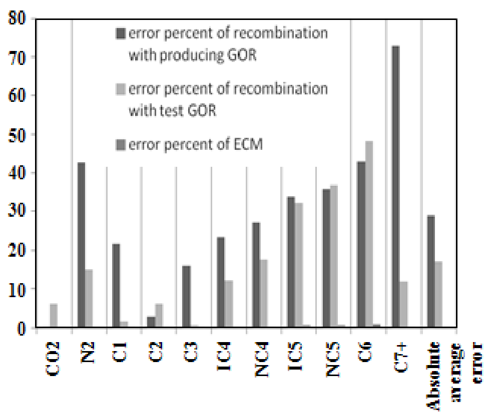


***Fig. 4: Comparison of errors of determining original fluid methods.***

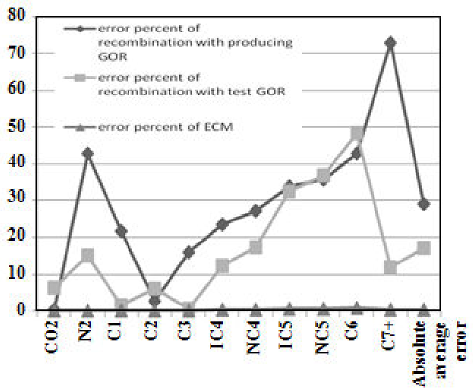


*Fig. 5: Dispersals of recombination methods errors in contrast with ECM method.*

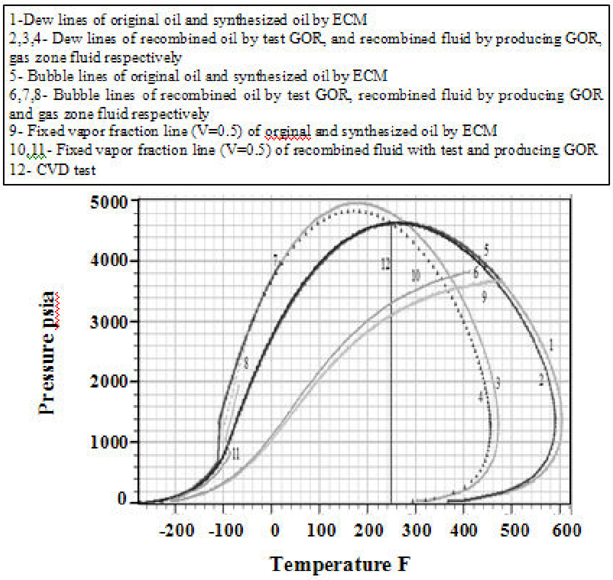


*Fig.6: Phase plots of original and reformed fluids.*

original oil compositions, no time dependence of it makes it unique in sampling procedure. This method has only a limitation on GOR because in large GOR collected samples are very lean; in consequence the mixed well stream in GOC conditions is single phase (gas). The success of ECM method in preparing original in-situ compositions of oil reservoirs with gas coning is made us to recommend it to companies to eliminate uncertainties in this situation.

**Nomenclature**

| | |
|---|---|
| BHP | Bottom Hole Pressure |
| ECM | Equilibrium Contact Mixing |
| EOS | Equation of State |
| GOC | Gas Oil Contact |
| GOR | Gas Oil Ratio |
| P | Pressure |
| PSIA | Pound per Square Inch Absolute |
| PVT | Pressure Volume Temperature |
| STB | Stock Tank Barrel |
| SCF | Standard Cubic Feet |
| T | Temperature |

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