



# A consistent method for simultaneous calculation of upper and lower dew point pressures of gas condensate fluids



Elnaz Khodapanah<sup>\*</sup>, Seyyed Alireza Tabatabaei-Nejad

Sahand Oil & Gas Research Institute (SOGRI), Chemical Engineering Faculty, Sahand University of Technology, Sahand New City, Tabriz, Iran

## ARTICLE INFO

### Article history:

Received 8 July 2014

Received in revised form

14 September 2014

Accepted 15 September 2014

Available online

### Keywords:

Upper and lower dew point pressures

Chebyshev polynomials

Gas condensate

Synthetic gas

Characterization

Heavy fraction

## ABSTRACT

Gas condensate reservoir fluids exhibit unique thermodynamic behavior which is considered as the controlling factor to develop these types of reservoirs. In the region between critical and cricondentherm temperature, two dew points are observed called the upper and lower dew pressures. In general, estimating the dew points are performed applying separate algorithms based on initial guesses for upper and lower dew point pressures. In this paper, an efficient and accurate algorithm is developed to simultaneously calculate the upper and lower dew pressures. The new algorithm is based on approximating the objective function for dew points on Chebyshev polynomials to get a closed form expression at a specified temperature which enables one to find all physically meaning roots, i.e., upper and lower dew point pressures. Examining the accuracy of the new technique shows that Chebyshev polynomials approximate the objective function with a high degree of accuracy which in turn is requisite to accurately calculate the dew points. Estimating dew point pressures of different gas condensates exhibits the capability of the new algorithm to accurately predict the upper and lower dew point pressures. A significant feature of the new method is that it is free of estimating an initial guess for dew point pressures. An efficient and adaptive procedure is developed to simultaneously predict the upper and lower dew points curve. The procedure systematically finds the next temperature for dew point calculation. Increasing the temperature, in a specified region of temperature, depending on the system under study, the vertical distance between upper and lower dew points decreases until they become identical at cricondentherm above which no roots are found. The new method successfully predicts the dew points, specially, in the aforementioned region. Applying the newly developed method to predict dew points curve of synthetic gases and gas condensates allows concluding that the new method successfully predicts the dew points boundary. The results also exhibit good agreements when compared to the experimental dew points.

© 2014 Elsevier B.V. All rights reserved.

## 1. Introduction

Phase envelopes of gas condensate reservoir fluids and natural gases are of great interest to petroleum engineers in defining appropriate production schemes. The pressure-temperature (P-T) diagrams of gas condensates are of great importance to petroleum industries in economically designing enhanced oil recovery methods. The location of the temperature and pressure of a reservoir with respect to the phase boundary is an important parameter which determines the feasibility of displacing the reservoir fluid using an efficient method.

<sup>\*</sup> Corresponding author.

E-mail addresses: [khodapanah@sut.ac.ir](mailto:khodapanah@sut.ac.ir), [ekhodapanah@yahoo.com](mailto:ekhodapanah@yahoo.com) (E. Khodapanah), [tabatabaei@sut.ac.ir](mailto:tabatabaei@sut.ac.ir) (S.A. Tabatabaei-Nejad).

If the reservoir temperature and pressure are sufficiently high, relative to this phase envelope, it may economically feasible to miscibly displace the reservoir fluid with less expensive gas. In gas condensate reservoirs, a major challenge is to avoid the drop-out of the heavier fractions. A widely used practice to keep the reservoir fluid above its dew point pressure is the injection of the produced lean gas into the reservoir, known as gas cycling technique. In these cases, it is necessary to take account of the variation of fluid properties and phase envelope not only with pressure, but also with composition (Goldhorpe, 13–15 September 1989). The analysis of the phase behavior allows one to determine the maximum amount and optimum composition of lean gas to be injected in a gas condensate reservoir in order to change its composition and shift the phase envelope to a point where the liquid drop-out can be eliminated or minimized during the isothermal depletion of the reservoir (Pires et al., 19–21 September 1995).

A substantial amount of work has been carried out on the development of multi-component compositional simulators for use in modeling reservoir processes such as miscible gas flooding of oil reservoirs and cycling of gas condensate reservoirs below the dew point. Compositional simulation is of great interest in predicting the performance of a gas condensate reservoir applying different recovery methods. It is most important in compositional reservoir simulation to get satisfactory agreement between EoS results and measured laboratory PVT data relevant to the fluid of the reservoir and its recovery process. Hence, predicting PVT properties of gas condensate reservoirs is very important in evaluating EOR scenarios by means of different methods, e.g., reservoir simulators (Goldhorpe, 13–15 September 1989).

One way to construct P-T diagram of petroleum fluids in the region between critical temperature and the cricondentherm of the mixture is to use expensive PVT experiments. Shariati et al. in 2014, studied the phase behavior of a model gas condensate consisting of five hydrocarbon constituents by measuring the bubble-point and dew-point pressures of a certain composition at different temperatures (Shariati et al., 2014). To avoid high risk and expensive laboratory experiments, other approaches such as numerical modeling and soft computing approaches can be used to calculate the dew/bubble points on the phase envelope based on compositional analysis of the fluids (Kaliappan and Rowe, 1971; Michelsen, 1980; Li and Nghiem, 1982; Arabloo et al., 2013; Nichita, 2008).

In general the phase behavior of gas condensate mixtures is more difficult to model than that of oil mixtures. This is because the phase behavior of a gas condensate mixture is very much dependent on the heaviest constituents of the mixture. The importance of predicting the phase behavior of these types of reservoirs increases when noticing the fact that by decreasing the pressure of the reservoir during the production, the intermediate hydrocarbons will be condensed which has more worth for us (Ahmed, 2001).

In 1970, Kaliappan and Row (Kaliappan and Rowe, 1971) used K-factor correlations as a function of temperature, pressure and convergence pressure to determine the Pressure-Temperature (P-T) envelopes of multi-component systems of fixed overall composition including the retrograde region. They demonstrated that convergence pressure is a phase rule variable for the two phase, three component system at equilibrium. They presented ternary phase diagrams for three component systems. In the work done by Kaliappan and Row, the data for the two component systems were used to demonstrate how the convergence pressure calculations can be employed to construct P-T phase diagrams for multi-component systems. The data required in the algorithm proposed by the same researchers are the system composition, the lower temperature limit to the phase envelope calculations, the spacing between adjacent isotherms, and the molecular weight of the C<sub>7+</sub> fraction (Kaliappan and Rowe, 1971).

Michelsen in 1980 developed an algorithm for pressure-temperature diagram construction. In this algorithm the set of primary variables used to solve non-linear equations of phase equilibrium and the step size to the subsequent point on the diagram were selected internally. They estimated the critical point, cricondentherm and cricondenbar using interpolation (Michelsen, 1980). Li and Nghiem et al. in 1982 extended the Michelsen's algorithm to construct pressure-composition, temperature-composition and composition-composition diagrams. They also determined the loci of mixtures having the same mole fraction or volume fraction of vapor-liquid split (Li and Nghiem, 1982).

The development of a more efficient numerical formulation to construct upper and lower dew boundaries is a crucial objective of research. In this study, we develop a reliable, computer based predictive model for simultaneously predicting the upper and

lower dew pressures. To do so, an accurate and efficient algorithm is developed based on approximating the objective function on Chebyshev polynomials. This allows one to accurately calculate all the roots simultaneously, i.e., one step calculation procedure would only be requires at a specified temperature. Another attractive feature of the proposed algorithm is that it is free of estimating initial guesses to calculate upper and lower dew point pressure. The new algorithm is then used to develop a procedure to simultaneously construct the upper and lower dew points curve. It can accurately predict the cricondentherm of the mixture at which the upper and lower dew point pressures become identical. The PR EOS is used in phase behavior calculations. Several synthetic gas mixtures and gas condensate reservoir fluids are used to examine the efficiency of the proposed algorithm.

A number of characterization procedures are available in open literature. Among them, the widely used characterization methods in the petroleum industry are those proposed by Pedersen et al. (Pedersen et al., 1989) and Whitson (Whitson et al., 1990, 1989; Zuo and Zhang, 16–18 October 2000). In order to get a better match with the experimental data of upper dew point pressures, different characterization methods can be applied when using gas condensate reservoir fluids. These methods are used to split the plus fraction into sub-fractions. In some cases, the single carbon numbers are lumped into pseudocomponents. Experimentally developed correlations available in the literature are used to estimate the critical properties and acentric factors of the pseudocomponents. The Gauss-Laguerre quadrature method which is used to lump the plus fractions into pseudocomponents is applied when representing the molar distribution of plus fraction using the three parameter gamma distribution function. The results also presents the capability of the proposed algorithm in accurately predicting the upper and lower dew point pressures when using characterization methods is required.

## 2. Objective function to calculate dew point(s)

In any problem concerning the equilibrium distribution of some component *i* between two liquid and vapor phases, one must always begin with the fundamental equation of phase equilibrium (Prausnitz et al., 1999):

$$\hat{f}_i^L = \hat{f}_i^V, \quad i = 1, 2, \dots, N_c \quad (1)$$

where  $\hat{f}_i^L$  and  $\hat{f}_i^V$  are the fugacity of component *i* in the equilibrium liquid and vapor phases, respectively.  $N_c$  represents the total number of components.

The fugacity of component *i* in terms of independent variables *V* and *T* is given by the following equations (Prausnitz et al., 1999):

$$RT \ln \hat{\varphi}_i^m = RT \frac{\hat{f}_i^m}{x_i^m P} = \left[ \int_{V^m}^{\infty} \left( \frac{\partial P}{\partial n_i} \right)_{T, V, n_{j \neq i}} - \frac{RT}{V} \right] dV - RT \ln Z^m, \quad (2)$$

$$i = 1, 2, \dots, N_c$$

where  $\hat{\varphi}_i$ ,  $n_i$ , *V* and *Z* are the fugacity coefficient and number of moles of component *i*, volume and compressibility factor,  $x_i^m$  represents the composition of the component *i* in phase *m*. The superscript *m* denotes the liquid and vapor phases.

To use Equation (2), it requires a suitable equation of state that holds for the entire range of possible mole fractions  $x_i^m$  at the system temperature and for the density range between 0 and  $n/V$ .

Download English Version:

<https://daneshyari.com/en/article/8129297>

Download Persian Version:

<https://daneshyari.com/article/8129297>

[Daneshyari.com](https://daneshyari.com)