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Development of a compositional PVT model for a multicomponent, multiphase hydrocarbon reservoir

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ABSTRACT: This paper presents an algorithm for the construction of a compositional PVT model of reservoir fluids in a multicomponent, multiphase hydrocarbon field. The methodology entails a step-by-step calibration of the differential condensation isotherm and the differential depletion curve for reservoir fluids. The algorithm was validated through the development of a compositional PVT model for the gas cap and oil rim of a gas-condensate field in the Republic of Uzbekistan.

I. INTRODUCTION

Currently, one of the primary challenges in designing the development of multicomponent, multiphase hydrocarbon reservoirs is the accurate prediction of key production metrics that account for in-situ phase behavior under depletion drive. Existing approximate mathematical models based on material balance equations [1], as well as three-phase "black-oil" models [2], fail to capture all complexities encountered in such fields, even when using advanced reservoir simulators. A viable solution for this is compositional hydrodynamic modeling [2].

However, constructing a robust PVT model of the reservoir fluid - one that reproduces laboratory PVT-cell (bomb) data and accurately describes the phase behavior of hydrocarbon mixtures in porous media as remains a formidable objective requiring an integrated approach. Such a model must ensure convergence of critical fluid properties, including saturation pressure, gas deviation (Z) and formation volume factors, standard - condition density, dew - point pressure, and initial condensate yield in reservoir gas [3].

In this research paper we propose an algorithm for the sequential calibration of a compositional PVT model for a gas-condensate mixture and oil-based on the known component composition of the reservoir gas and validated against laboratory measurements.

II. METHODOLOGY FOR BUILDING AND TUNING COMPOSITIONAL PVT MODELS OF MULTIPHASE RESERVOIR FLUIDS

This paper demonstrates two algorithms were developed for building compositional PVT models of reservoir fluids in a multicomponent, multiphase hydrocarbon field.

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Algorithm 1: Compositional Modeling of a Gas-Condensate Mixture

1.Import the average reservoir-gas composition - taken from the field development plan - into the simulator's PVT designer.
2.Represent the high-boiling C_5^+ fraction by selecting a homologous alkane from the standard component library whose molecular weight closely matches C_5^+.
3.Subdivide the C_{5+} fraction into pseudocomponents using the Whitson correlation [4], spanning from n-hexane (C_6H_{14}) to the chosen replacement component. In the first iteration, the correlation's exponent parameter α—which controls the exponential distribution of pseudocomponent mole fractions—is set to unity by default.
4.Perform a constant-volume depletion (CVD) test to simulate depletion drive [1]. Compare the model's dew-point pressure, maximum-condensation pressure, initial and minimum potential condensate yields, condensate density at standard conditions, and gas formation-volume factor against values reported in the field development plan.
5.If discrepancies arise, calibrate the PVT model by adjusting one or more of the following parameters:
- The Whitson exponent α (allowed range: 0.5–2.5 [5]);
- The type of correlation used for pseudocomponent critical temperature and acentric factor;
- The critical temperatures of the first and last pseudocomponents (±5% variation);
- Binary interaction coefficients and volume-shift parameters for pseudocomponents (range: –0.25 to +0.25) [6].

Algorithm 2: Compositional Modeling of Reservoir Oil

1.Import the average oil composition from the field development plan, or convert a black-oil model to compositional format using the simulator's built-in tool [2].
2.Select homologous alkanes whose molecular weights approximate the key oil fractions.
3.Subdivide the heaviest fraction (residuum) into pseudocomponents via the Whitson correlation, ensuring that the total number of components matches the gas-condensate model—this consistency is required by most commercial simulators [6].
4.Perform a CVD test on the oil model. Compare the saturation pressure, gas-oil ratio, formation-volume factor, and oil density at standard conditions with reference data from the development plan.
5.If the modeled parameters deviate, adapt the model by tuning:
- The Whitson exponent α (0.5–2.5);
- Mole fractions of the first and last pseudo components;
- Correlation type for pseudo component critical temperature and acentric factor;
- Volume-shift for high-boiling components;
- Critical temperature of the high-molecular-weight pseudocomponent;
- Binary interaction coefficients and volume-shift parameters for pseudocomponents.

III. RESULTS

In this research proposed algorithms have been validated using the fluid from one of the gas-condensate fields under development in the Republic of Uzbekistan. The reservoir gas composition for this field is shown in table 1.

Table 1. Composition of the reservoir gas of the studied field

Component	CH_4	C_2H_6	C_3H_8	i-C_4H_{10}	n-C_4H_{10}	C_5H_{12+}	N_{2+}	CO_2	H_2S
X_i, %	90,64	3,52	0,81	0,13	0,18	0,91	0,46	3,31	0,04

Note that the molar mass of the C5H12+ fraction is 113.596 g/mol; therefore, decane ($C_{10}H_{22}$) was selected as the surrogate component for its representation. Following the proposed methodology, decane was then subdivided into pseudocomponents (in this case, C_6 through C_{10}). The Whitson correlation exponent α was tuned to achieve an accurate pseudocomponent distribution, and appropriate correlations were chosen to calculate the critical temperatures, critical pressures, and acentric factors of each pseudocomponent. A constant volume depletion (CVD) experiment was conducted on the resulting fluid mixture. Figure 3.1 presents the differential condensation isotherm at a reservoir temperature of 91°C, comparing the model prediction against laboratory measurements.

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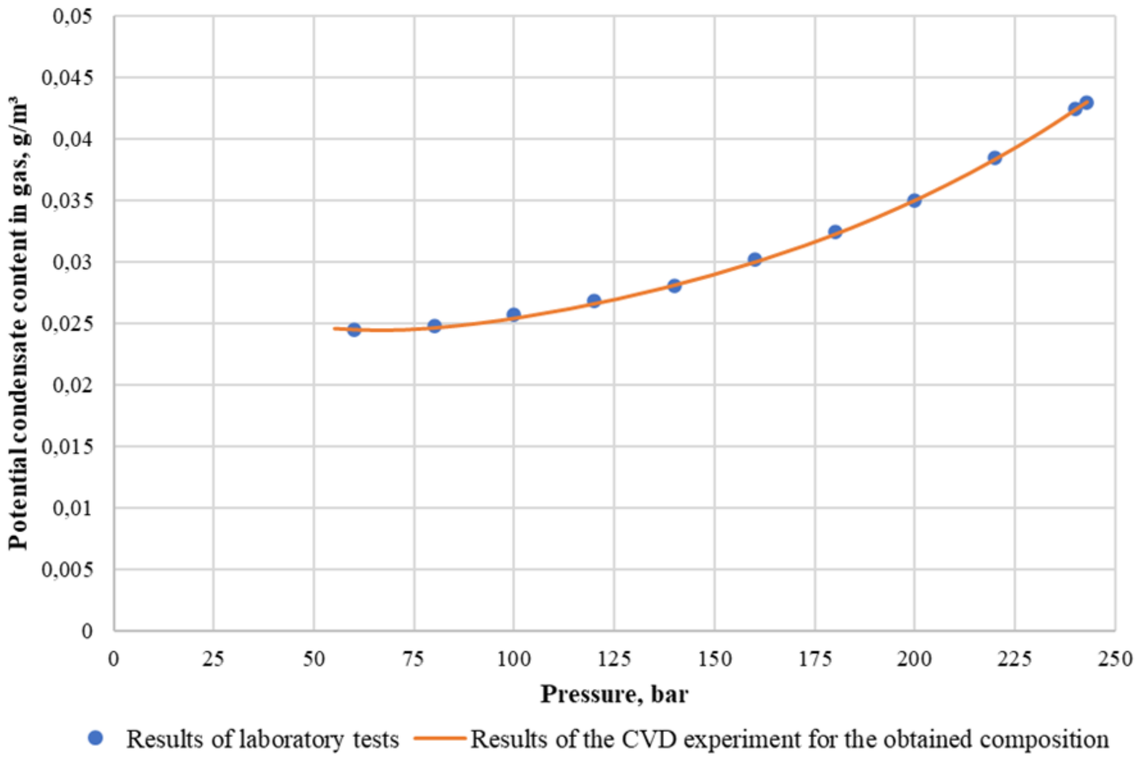

Fig.3.1: Differential condensation isotherm for the reservoir gas of the studied field.

The reservoir fluid composition shown in Table 1 has been used as the basis for modeling the oil of the studied field. Certain components and their properties have been adjusted based on oil property reports for this reservoir. Specifically, a component labeled F1 has been implemented to represent the residue formed during fractional distillation of the oil. Additionally, some alkane-series hydrocarbons have been modified to better represent the heavy fractions. For example, dodecane ($C_{12}H_{26}$) has been used to simulate the C5+ heavy component with a molar mass of 163 g/mol, while eicosane ($C_{20}H_{42}$) has been selected to represent component F1 with a molar mass of 256.455 g/mol.

All subsequent steps have been performed in accordance with the previously developed algorithm. As a result, strong convergence has been achieved between the calculated parameters of the reservoir oil and laboratory measurements of oil samples. A comparison of the laboratory and modeled oil parameters for the field under study is presented in table 2.

Table 2. Comparison of laboratory and modeled oil parameters for the studied field

№	Parameter	Unit of measurement	Laboratory test results	PVT model calculation after tuning	Deviation, %
1	Saturation pressure	bar	152,9	152,814	-0,056
2	Density at standard conditions	kg/m³	892	892,009	0,001
3	Formation volume factor under reservoir conditions	m³/m³	1,06	1,0589	-0,104
4	Oil gas content (GOR)	m³/m³	26	25,87	-0,5

As evidenced by table 2 and figure 3.1, application of the proposed algorithms has yielded accurate PVT models for both the oil and gas-condensate fluids of the studied field.
Mobile type cloud kind computing is defacto emerging as the new kind paradigm primarily for aiding the broad kind and range of those multimedia type services [6]. We have presented the layered kind architecture basically for MCC which defacto clears up the respective functions and those of the protocols. We herein suggest forth a connection in handoff kind mechanism basically among the cloud type lets and discuss the related kind resources, which the management premeditated for the challenges for MCC.

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IV. CONCLUSION

Summing up, this research paper introduces practical algorithms for constructing compositional PVT models of reservoir fluids in multicomponent, multiphase hydrocarbon fields. These algorithms are specifically designed to operate under conditions of limited laboratory PVT data availability. Their implementation can significantly enhance the accuracy of reservoir flow simulations for fields with complex fluid compositions. The proposed methodology complements functioning advanced PVT-model calibration workflows and offers a reliable approach for modeling gas-condensate and oil–gas-condensate fluids with acceptable precision. The effectiveness of the approach is demonstrated through its application to fluids from an active gas-condensate field in the Republic of Uzbekistan.

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