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Research Article

Creation of Numerical Pvt-Models for the Bulla-Daniz Gas-Condensate Field Using Laboratory Experiments on Reservoir Fluid Samples

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ABSTRACT

PVT analysis plays a crucial role in optimizing and developing entire fields. It is essential to comprehend the overall behavior of fluids, extending from the reservoir through production and processing facilities to the refinery. The growth of this field as a distinct area of study has been significantly influenced by the utilization of modern computer software employing equation of state (EOS) models. These models simulate experiments, illustrating fluid phase characteristics. Running PVT simulations is integral to identifying operational parameters that maximize surface liquid content, extending the production plateau at the lowest feasible cost. These simulations utilize laboratory-derived data to refine EOS models, and their outcomes are integrated into reservoir simulation and research. The accuracy of data is pivotal for achieving a reliable match between EOS and laboratory data. However, with retrograde gas condensates, characterized by complex phase behavior, achieving this match can be particularly challenging. In reservoir simulations, an inadequate match can lead to computational errors and unreliable results, posing a risk to reservoir management decisions dependent on these findings.

Keywords: Gas-condensate field; Simulation model; PVT model; Equation of state; Adaptation process; Heavy component

Introduction

The oil and gas industry, characterized by its high capital intensity, inherent risks, and dependence on technology, hinges on the need to minimize uncertainties to stay viable. Numerous tests are conducted to evaluate specific parameters, such as well testing and coring, despite their considerable costs, mainly for assessing and verifying permeability quality[1].

No operator would confidently claim to fully understand their fluid until a comprehensive PVT analysis is conducted. Even when basic PVT parameters are estimated on-site using correlations, the resulting judgments are usually limited in scope and short-lived[2].

For retrograde gas condensates, the recommended PVT tests are Constant Composition Expansion (CCE) and Constant Volume Depletion (CVD). CCE replicates fluid behaviors under separator conditions, while CVD mimics events at reservoir conditions[3].

In retrograde gas condensate reservoirs, two temperatures, the critical temperature and cricondentherm, determine whether they are under-saturated/lean or saturated/rich, based on their proximity to the dew point curve. Production at pressures above the dew point results in a single-phase gas, but as pressure drops during depletion, liquids and condensates condense. Capillary-induced forces trap these liquids, presenting a challenge for operators due to their immobility. While they re-vaporize when production pressure decreases, the pressure required for this is often economically unattainable[4-7].

Comprehending retrograde events is crucial due to the strong compositional influence, necessitating PVT measurement and analysis. Comparison of laboratory data with an Equation of

State (EOS) model is essential for accounting or adjusting for unmeasured features[6]. Challenges in EOS tuning/matching and accurate fluid description arise from gathering non-representative fluid samples and uncertainties in lab measurements. This study employed the Tempest PVTx simulator to offer validation techniques for PVT/CVD data and address issues with unrepresentative data[8].

PVT models, typically based on Van der Waals-type equations of state, are commonly used, with the Peng-Robinson equation being widely employed in engineering practice[9]. The equilibrium compositions of vapor and liquid, under specific thermobaric conditions and component composition, can be calculated using the equation of state[10]. This allows the hydrodynamic simulator to sequentially mimic changes in fluid composition, saturations, and properties.

The challenge arises from the potential for significant inaccuracies when directly applying EOS to specific multicomponent hydrocarbon mixtures. Commonly encountered deviations include approximately ±10% for bubble point (dew point) pressure, 5% for density, and 10% for the equilibria of composition phases[11]. These inaccuracies are typically attributed to the following factors:

Insufficient Composition Details: Lack of comprehensive information regarding composition and percentage.

Complexity of Heavy Components: Heavy components in the PVT model (starting from C7) represent a blend of isomers of aromatic hydrocarbons, cycloalkanes, alkanes, and other compounds, rather than a single molecule. PVT simulators default to values obtained for a mixture with a specific ratio of these compounds, which may not accurately reflect the study sample. Pseudo-components, particularly for elements of C7 and higher, are known to have some error in their parameters[5].

Discrepancies in Liquid Property Representation: While modern cubic equations of state effectively describe gas properties, the same cannot be said for liquid properties, where significant inaccuracies (up to 5%) may occur[12].

Errors in Composition Determination and Laboratory Measurement: Inaccuracies in determining composition and/or laboratory measurements can contribute to discrepancies. Confirming composition consistency can be achieved to some extent by comparing laboratory test results, for instance, using the Hoffman-Crump-Hocktot test, with Standing modification, to assess the material balance of the multicomponent system[13].

The equation of state parameters is typically adjusted to align with the observed outcomes of standard PVT experiments, enhancing the accuracy of the PVT model. However, a converse challenge arises in fine-tuning the PVT model to experimental data. The focus of the presented article is to develop technology that addresses this inverse challenge, without delving into concerns related to restoring reservoir composition or feed representativeness[14].

This study centers on the adaptation process involving the Constant Composition Expansion (CCE) and Constant Volume Depletion (CVD) test results from well 78 in the Bulla-Daniz gas-condensate field. Situated in the northern part of the Absheron archipelago, 55 km south of Baku, the Bulla-Deniz field features a sea depth of 18-30 m. Geological-geophysical exploration of the Bulla-Deniz field commenced in 1951, with clarification of fold boundaries achieved through exploration work from 1951 to 1956. In 1965, structural-exploratory drilling commenced, accompanied by deep exploratory drilling in the Bulla-sea area. Significant milestones include the industrial extraction of gas-condensate from horizon VII (well No. 18) in 1973 and from horizon V (well No.) in 1974. Full-scale industrial development of the field commenced in 1975. Geological exploration and drilling efforts revealed hydrocarbon accumulations in horizons V, VII, VIII, and NKQ. Thermodynamic and PVT studies on gas-condensate samples were conducted based on the products of initial exploration wells. Notably, the measured initial pressures were 69.0 MPa at a depth of 5350 m for horizon V, 71.3 MPa at a depth of 5750 m for horizon VII, and 80 MPa at a depth of 6000 m for horizon VIII. Thermodynamic studies were conducted in wells No. 14, 20, and 22 at the Bulla-Sea field, which were operational in the early years of development.

(**Tables 1,2**) display the system parameters for the PVT test prior to the adaptation process.

(**Figures 1, 2, 3, and 4**) depict various parameters in relation to changes in pressure.

Table1: System Properties before adaptation process.

Component Properties					
Comp.	Mw	Tc (C)	Pc (bar)	Acf	Zc
N2	28.013	-146.89	33.9912	0.045	0.29162
CO2	44.01	31.0556	73.8153	0.231	0.27421
C1	16	-82.594	46.0432	0.012	0.29473
C2	30.1	32.2944	48.8011	0.091	0.29233
C3	44.1	96.6833	42.4924	0.145	0.28906
IC4	58.1	135.017	36.4802	0.176	0.28617
C4	58.1	152.017	37.9694	0.193	0.27914
IC5	72.2	187.294	33.8119	0.227	0.27017
C5	72.2	196.517	33.6878	0.251	0.26389
C6	84	234.628	32.819	0.2738	0.27176
C7+(1)	115.772	325.168	28.0194	0.30871	0.2579
C7+(2)	227.691	477	18.8	0.58518	0.25487
C7+(3)	300	549.2	16.5	1.0326	0.35108

Table 2: Characteristics of the system prior to undergoing the adaptation process.

	Component Properties						
	Vc (ft3/lb-mole)	Sg (sg (Water=1))	Tb (F)	Ωa	Ωb	Para	Sv
N2	1.4427	0.47	-320.4	1	1	41	-0.193
CO2	1.5051	0.5072	-109.3	1	1	70	-0.082
C1	1.62457	0.33	-258.67	1	1	77	-0.36
C2	2.43685	0.45	-127.47	1	1	108	-0.113
C3	3.35067	0.508	-43.67	1	1	150.3	-0.086
IC4	4.26449	0.561	10.93	1	1	181.5	-0.084
C4	4.16295	0.584	31.13	1	1	189.9	-0.067
IC5	4.9	0.627	82.13	1	1	225	-0.061
C5	4.9	0.63	96.93	1	1	231.5	-0.039
C6	5.6	0.69	147.33	1	1	271	-0.01936
C7+(1)	7.33474	0.76983	272.67	1	1	355.855	0.05
C7+(2)	13.5447	0.84991	557.428	1	1	632.788	0.15
C7+(3)	23.3039	0.92035	892.673	1	1	1038.54	0.4

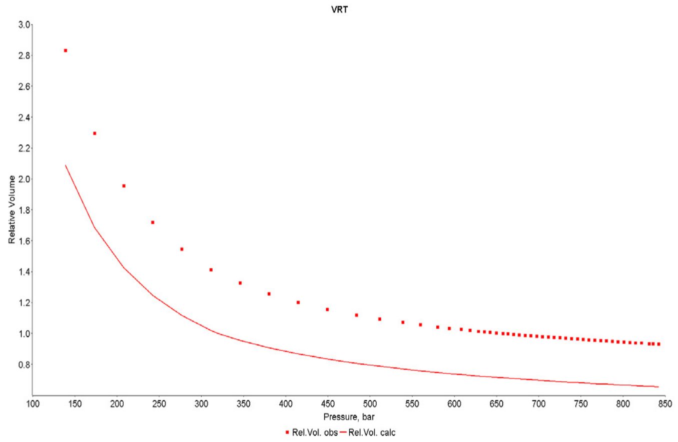

Figure 1: Relationship between relative volume and pressure prior to the adaptation process.

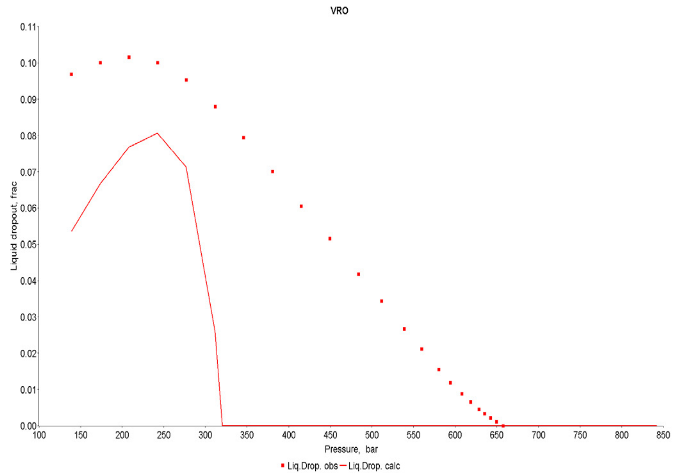

Figure 2: Relationship between liquid dropout and pressure prior to the adaptation process.

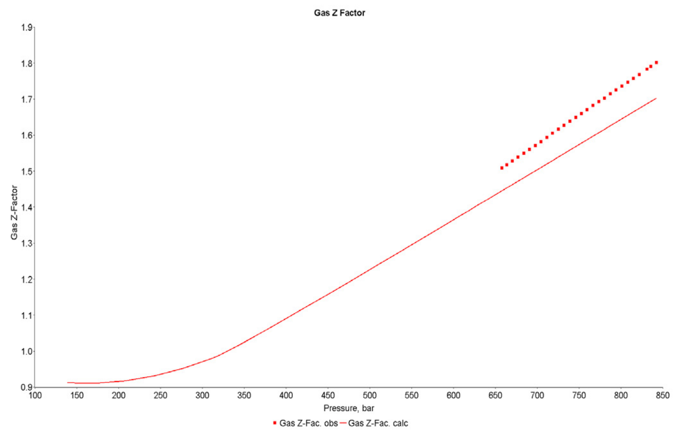

Figure 3: Relationship between the Gas Z Factor and pressure before the adaptation process.

Following Yushchenko's proposal[1], the final fraction of C16+ was subdivided into three pseudo-components using the Whitson gamma-distribution model[14]. This led to a mole fraction of the ultimate pseudo-component being less than 0.1%. Subsequently, real data from experiments, encompassing saturated condensate losses (CCE, CVD, Z-factor change, and Condensate to Gas Ratio (CGR)) in a one-stage separation experiment, was considered.

Regression analysis was employed to fine-tune the pressure at the onset of condensation in the initial stage. Subsequent adjustments involved varying the critical temperature and pressure, the binary interaction coefficients, and the shift parameter for the final three pseudo-fractions, with regression applied to adapt the actual data in the CCE, CVD, and separation tests. Additionally, the shift parameter and binary interaction coefficients for components were used as modifiers due to their significant mole fraction in the overall composition. (**Table 3,4**) present system parameters for the PVT test after the adaptation process, while (**Figures 5, 6, 7, 8**) showcase the optimal outcomes resulting from multiple regression iterations.

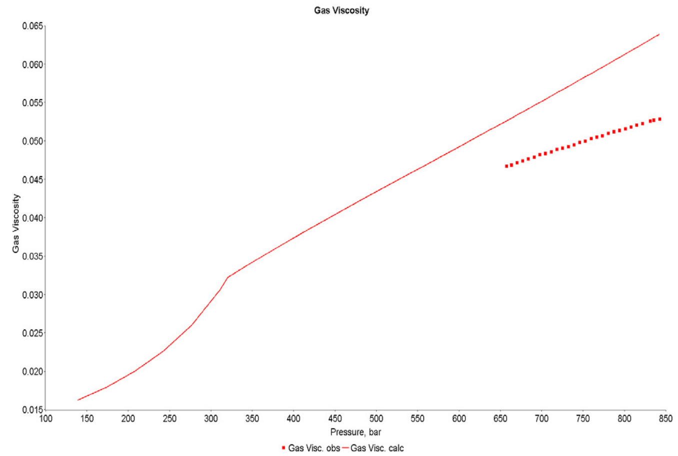

Figure 4: Graph illustrating the correlation between gas viscosity and pressure before the adaptation process.

Table 3: System properties after adaptation process.

Component Properties						
Comp.	Mw	Tc (C)	Pc (psia)	Pc (bar)	Acf	Zc
N2	28.013	-146.89	493	33.9912	0.045	0.29162
CO2	44.01	31.0556	1070.6	73.8153	0.231	0.27421
C1	16.043	-82.572	667.8	46.0432	0.0115	0.28841
C2	30.07	32.2722	707.8	48.8011	0.0908	0.28427
C3	44.097	96.6722	616.3	42.4924	0.1454	0.28037
IC4	58.124	134.989	529.1	36.4802	0.1756	0.28242
C4	58.124	152.028	550.7	37.9694	0.1928	0.27359
IC5	72.151	187.278	490.4	33.8119	0.2273	0.27013
C5	72.151	196.5	488.6	33.6878	0.251	0.26229
C6	86.178	234.278	436.9	30.1232	0.2957	0.26427
C7+	166.887	400.862	258.467	17.8207	0.65032	0.26984

Table 4: Characteristics of the system following the completion of the adaptation process.

Component Properties							
	Vc (ft3/ lb-mole)	Sg (sg (Water=1))	Tb (F)	Ωa	Ωb	Para	Sv
N2	1.4427	0.47	-320.4	1	1	41	-0.193
CO2	1.5051	0.5072	-109.3	1	1	70	-0.082
C1	1.5899	0.33	-258.69	1	1	77	-0.159
C2	2.3695	0.45	-127.48	1	1	108	-0.113
C3	3.2499	0.5077	-43.67	1	1	150.3	-0.086
IC4	4.2082	0.5631	10.9	1	1	181.5	-0.084
C4	4.0803	0.5844	31.1	1	1	189.9	-0.067
IC5	4.8991	0.6247	82.12	1	1	225	-0.061
C5	4.8702	0.631	96.92	1	1	231.5	-0.039
C6	5.929	0.664	155.72	1	1	271	-0.008
C7+	13.5927	0.75107	462.682	0.87042	0.97313	476.296	0.14948

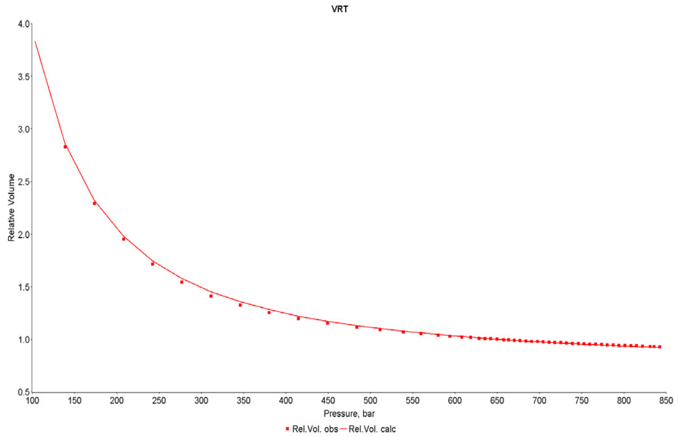

Figure 5: Curve demonstrating the correlation between relative volume and pressure after the adaptation process.

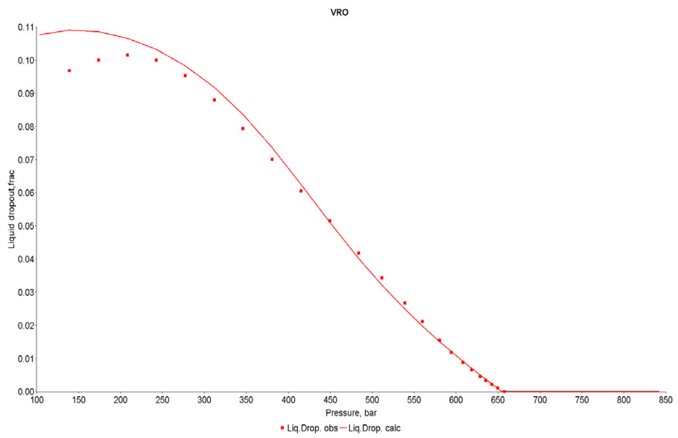

Figure 6: Graph depicting the relationship between liquid dropout and pressure after the adaptation process.

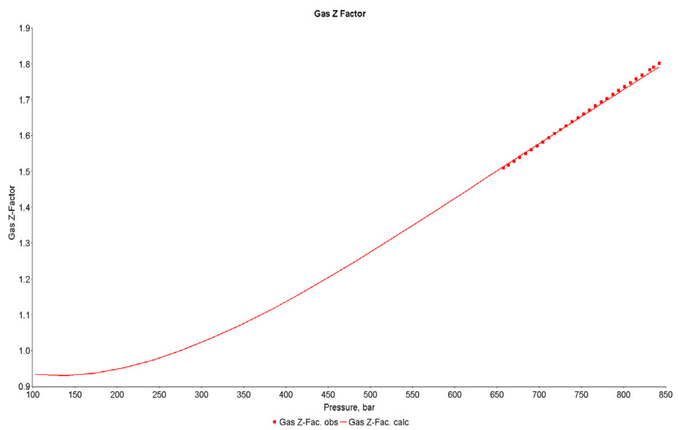

Figure 7: Relationship between Gas Z Factor and pressure after the adaptation process

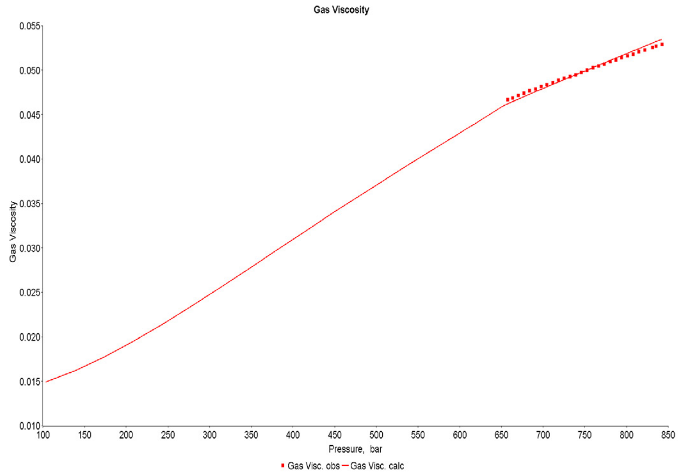

Figure 8: Correlation between gas viscosity and pressure after the adaptation process.

Conclusion

The adaptation process initiates with the grouping of C7+ heavy components, with the initial case involving components heavier than C16+. Following grouping, the heaviest components are divided into three parts. The next step involves manipulating the component composition of C7(1), C7(2), and C7(3). Additionally, the shift parameter and binary interaction coefficients for components are utilized as modifiers due to their significant mole fraction in the overall composition. Subsequently, adaptation is carried out for various parameters against pressure.

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