Investigating Gas Phase Productivity in Gas Condensate Reservoir-A Review

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Abstract: The production of gas in condensate reservoir has remained challenge for decades. Operators are focused to drill deeper formations, due to high temperature and pressure more condensate reservoirs are encountered which are difficult to handle due to multiphase behavior of gas-condensate. Several authors have contributed to mitigate the losses and gave concepts of three regions as well as flowing mechanism. The aim of this study is to investigate main causes of loss in gas production due to condensation. Furthermore, to discuss the most suitable method to handle complications in gas condensate reservoirs. In this paper, we discussed main causes for low gas production in condensate reservoirs. Accurate calculations remained a challenge for reservoir engineers to forecast well deliverability in gas-condensate reservoirs. We observed some techniques to forecast well deliverability properly as well as to reduce impact of loss in gas-phase productivity.

Keywords: *Condensate reservoir; liquid dropout; Condensate buildup;* Gas *Condensate production; Productivity losses.*

1. Introduction

Production of gas in condensate reservoir is challenging for reservoir engineers due to its multiphase behavior. It is highly affected by buildup of condensate in the reservoir. Condensate is a liquid hydrocarbon comprises of high API and low density. Initially condensate reservoirs produce only gas phase. When pressure of reservoir falls below dew point, liquid initiates to dropout from gas and accumulates in the portion of reservoir. It is also referred as condensate bank. Accumulation of condensate causes reduction in the gas relative permeability which creates hindrance in the flow of gas phase thereby reducing gas production rapidly. Impact of condensate banking on productivity always remains challenging for reservoir engineers in terms of modeling [1-4].

In 1994, Afidick et al. carried compositional analysis to examine loss in gas phase production due to increase in liquid saturation. It was observed from their study that condensate banking can cause increase in gas rate decline dramatically usually two to four times [5]. To prevent production loss in condensate reservoir accurate understanding of reservoir flow behavior is essential thus the concept of dividing reservoir into three regions is presented [6].

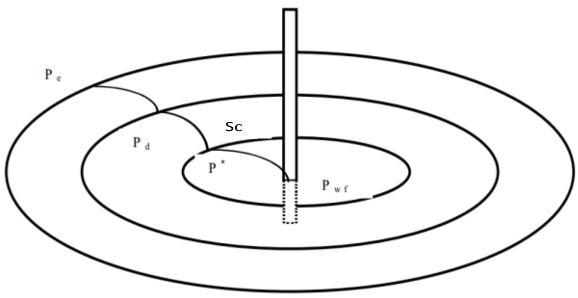

Figure. 1. Sequence of pressure distributions in gas-condensate reservoir [7]

The Figure demonstrates pressure distribution aspect of fluid behavior in gas condensate reservoirs. P_e , P_d , P^* , S_c , P_{wf}

P_e	External boundary reservoir pressure
P_d	Dew point pressure
P^*	Condensate critical saturation pressure
S_c	Critical saturation of condensate
P_{wf}	Wellbore flowing pressure

Reservoir thickness and permeability also plays a vital role in production. In 1995, Barnum et al. reviewed the data from seventeen different fields to estimate the effect of condensate buildup near wellbore and to identify the productivity reduction parameters in reservoirs. Their study showed that the condensate buildup can restrict gas recovery below 50% for reservoirs where $kh < 100$ md-ft, and 20% restriction whose $kh > 1000$ md-ft [8].

The objective of this study is to investigate main causes of loss in gas production. Furthermore, to discuss the most suitable method to handle complications in gas condensate reservoirs.

2. Reservoir Fluids Classification

Phase behavior of the reservoir fluids at reservoir conditions and at surface conditions depends on fluid composition, temperature and pressure. Composition of reservoir fluids are given in Table. 1.

Table. 1. Reservoir Fluids Composition [9].

Components	Gas	Condensate	Volatile Oil	Black Oil
Methane	95.8	87.07	64.36	48.83
Ethane	2.67	4.39	7.52	2.75

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Propane	0.34	2.29	4.74	1.93
Butane	0.52	1.74	4.12	1.6
Pentane	0.08	0.83	2.97	1.15
Hexane	0.12	0.6	1.38	1.59
C7+	0.42	3.8	14.91	42.15

Retrograde condensation will occur in single phase fluid, if temperature reaches at certain conditions and pressure below dew point. The Fluid system will separate into two different phases i.e. liquid and gas phase.

Typically, for lean gas condensate reservoirs it yields about 30 million barrels of condensate per standard cubic feet of gas and for rich gas condensate reservoirs 300 million barrels of condensate per standard cubic feet of gas [10].

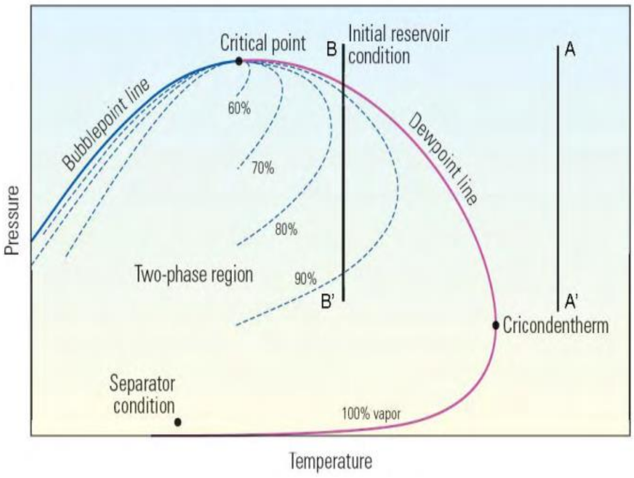

Figure. 2. Gas Condensate system - Phase Diagram [11]

3. Regions

Regions are formed in condensate reservoirs due to pressure difference in the reservoir. Behavior of condensate as well as existence of three regions is verified using compositional simulator [12].

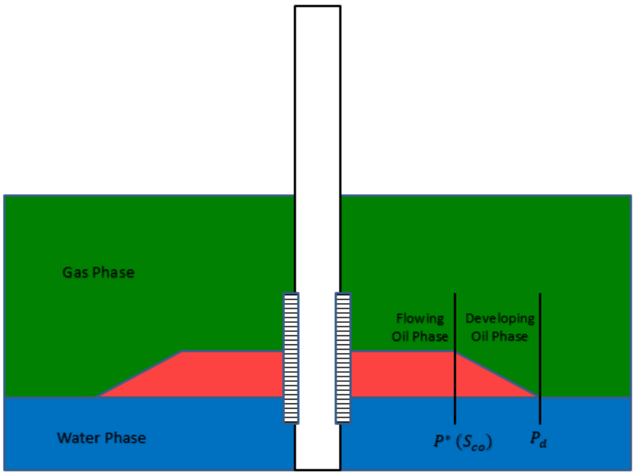

Figure.3. Developing oil phase in three phase system

Estimating total well productivity is a big challenge. Condensate extent must be known to identify the blockage effect and then remedy can be applied [13].

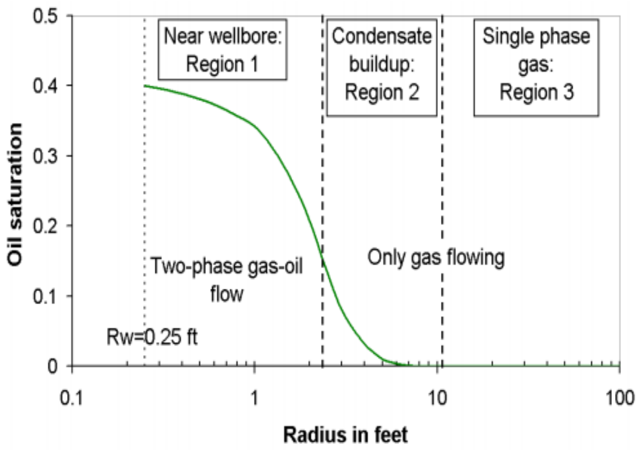

Figure. 4. 2D Radial Reservoir Model: Buildup of Condensate During Drawdown [14]

3.1. Region-1

An inner region nearest to the wellbore in this region where both liquid as well as gas phase are present and mobile. This region begins where condensate achieves critical saturation $\left(P_{wf} - P^*\right)$.

3.2. Region-2

A region where condensate starts to accumulate. In this region two phases exist i.e. both gas and condensate. In this region gas is mobile while the oil is immobile. The oil does not achieves its critical saturation hence it only accumulates. This region lies between critical condensate saturation and dew point pressure $(P^* - P_d)$.

3.3. Region-3

Only one phase is present and mobile i.e. gas phase. This region may exists in whole reservoir if reservoir is under-saturated. For saturated reservoir this region lies between external reservoir pressure and dew point pressure $(P_e - P_d)$.

4. Causes for loss in Productivity and its solution

Production can be affected by mechanical equipment, reservoir rock properties as well as fluid properties. In this paper fluid properties are focused. In condensate reservoirs fluid behavior is not uniform which causes errors in the calculations, Hence the production performance cannot be predicted properly. Liquid drop out is the main reason to hinder in gas flow as well as damage formation near wellbore. Some of the major properties are discussed below.

4.1. Viscosity

Viscosity of condensate is not routinely measured in the laboratory but it causes increase in liquid saturation near the wellbore. It also reduces liquid production which causes condensate bank near the wellbore this phenomenon results impairment on gas flow [15, 16].

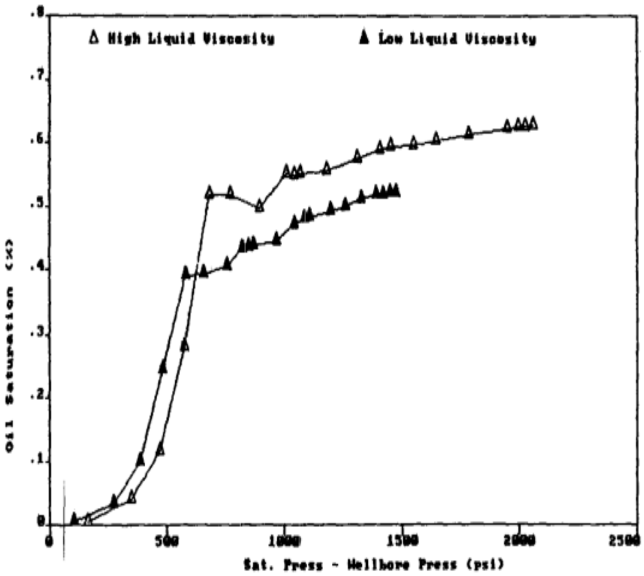

Figure.5. Viscosity sensitivity – near wellbore saturation [15]

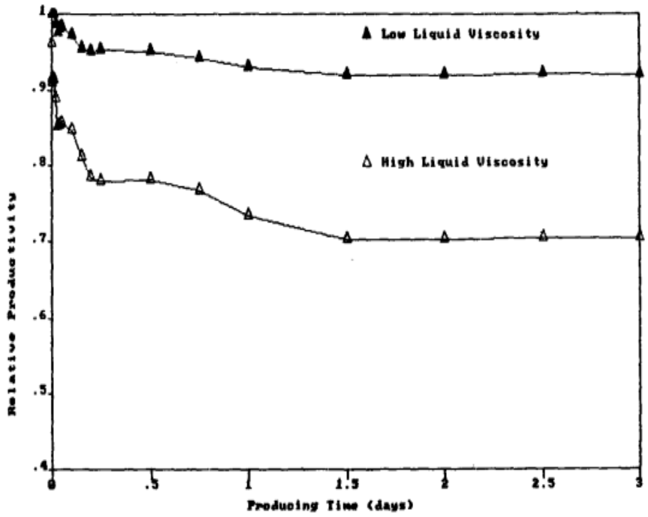

Figure.6. Viscosity sensitivity – productivity rate [15]

To cope with viscosity effect

Increase in viscosity results condensate bank near wellbore. Orodu et al. in 2012, Investigated the effect of liquid near wellbore on well production at low pressure and at condensate unloading pressure. This study showed that the production must be carried out at high flowing pressure as far away as dew point pressure to avoid liquid dropout effects [17].

Evans et al. in 2016, Determined the optimum well location to avoid well productivity loss due to liquid dropout near wellbore region. Working on compositional simulator it was observed that to maintain productivity index for longer time period well must be completed as shallow as possible [18].

4.2. Permeability

Well deliverability mainly depends on the absolute permeability and gas relative permeability (initial liquid saturation and near wellbore saturation) [19].

According to the latest research Khazam et al. in 2017, they forecasted the well deliverability in condensate reservoirs using compositional and modified black oil model. This study showed the impact of liquid dropout on the basis of reservoirs permeability. Results of this study showed that reservoirs having k ≈ 5 md have more impact, k ≈ 50 md have small impact while k ≈ 200 md having negligible impact on well deliverability [20].

4.2.1. Relative permeability

Hinchman and Barree in 1985 inspected the effect of relative permeability of oil and gas as well as composition of fluids on gas productivity. In their study it was observed that relative permeability data is most sensitive and important data to estimate the productivity loss [15].

To cope with relative permeability calculations

Calculation of relative permeability data requires fluid saturation at reservoir condition which is not viable to obtain and time consuming job so the concept of calculating effective permeability as a function of pressure using surface testing data is proposed.

4.2.2. Effective permeability

Sarfraz and Tiab in 2002, gave a new approach to analyze PBU & PDD tests in gas-condensate reservoirs. They introduced integral technique of pseudo pressure function that eliminates the concept of calculating relative permeability as a function of saturation. Phase change in condensate reservoir can be calculated by estimating effective permeability as a function of pressure by well test pressure data [21]. If effective permeability of one phase is known other phase can be easily calculated using pseudo-pressure function [7].

5. Conclusion

In this paper, we discussed the causes for low gas production in condensate reservoirs. Accurate calculations remained a challenge to forecast well deliverability. From the above literature we have observed some techniques to forecast well deliverability properly as well as to reduce the impact of loss in gas phase productivity.

- Well must be completed as shallow as possible.
- Well must be produced at high flowing pressure as far away as dew point pressure to avoid condensate banking effect.
- Relative permeability data is most sensitive and important data to forecast but due to complications in condensate reservoirs accurate saturation cannot be obtained at reservoir condition. So, this can be easily replaced by effective permeability as a function of pressure using pseudo pressure integral technique.
- Data of effective permeability can be obtained from well test data. It eliminates the time consuming and expensive core laboratory experiments to find the

relative permeability, it utilizes the well test data to get the effective permeability to establish the well performance.

- To convert well test data into pseudo-pressure of the other phase, effective permeability of the one phase can be used. This is very convenient in the case where production data of only one-phase is available.

References

[1] D. D. Fussell, "Single-Well Performance Predictions for Gas Condensate Reservoirs," Society of Petroleum Engineers. doi: 10.2118/4072-PA. 1973.

[2] R. M. Aziz, "Deliverability Projection Model for Overpressured Gas-Condensate Reservoirs," Society of Petroleum Engineers. doi: 10.2118/13706-MS. 1985.

[3] T. J. Clark, "The Application of a 2-D Compositional, Radial Model to Predict Single-Well Performance in a Rich Gas Condensate Reservoir," Society of Petroleum Engineers. doi: 10.2118/14413-MS. 1985.

[4] D. T. VO, J. R. Jones, & R. Raghavan, "Performance Predictions for Gas-Condensate Reservoirs," Society of Petroleum Engineers. doi: 10.2118/16984-PA. 1989.

[5] D. Afidick, N. J. Kaczorowski, & S. Bette, "Production Performance of a Retrograde Gas Reservoir: A Case Study of the Arun Field," 1994.

[6] Ø. Fevang, & C. H. Whitson, "Modeling Gas-Condensate Well Deliverability," doi: 10.2118/30714-PA, 1995.

[7] S. A. Jokhio, & D. Tiab, "Pressure Drawdown and Buildup Analysis in Gas Condensate Reservoirs," Society of Petroleum Engineers. doi: 10.2118/76780-MS. 2002.

[8] R. S. Barnum, F. P. Brinkman, T. W. Richardson, & A. G Spillette, "Gas Condensate Reservoir Behaviour: Productivity and Recovery Reduction Due to Condensation," Proceedings - SPE Annual Technical Conference and Exhibition. 10.2118/30767-MS. 1995.

[9] C. G. Wall, "Characterization of gas-condensate reservoirs and traditional production methods, North Sea Gas-condensate Reservoirs and their Development," Oyez scientific and technical service, pp. 1-12. 1982.

[10] J. Kamath, "Deliverability of gas-condensate reservoirs – field experiences and prediction techniques," J. Pet. Tech. V.59 No.4, 94-99. 2007.

[11] L. Fan, B. Harris, A. Jamaluddin, J. Kamath, R. Mott, G. Pope, A. Shandrygin, and C. Whitson, "Understanding gas-condensate reservoirs, Oilfield Review," Schlumberger, Winter 2005/2006, pp. 14-27. 2005.

[12] A. C Gringarten, A. Al-Lamki, S. Daungkaew, R. Mott, & T. M. Whittle, "Well Test Analysis in Gas-Condensate Reservoirs," 2000

[13] Abdallah, M. S., Al-Zawad, M. A., & Fraim, M. L. "Common Misinterpretations of Gas Condensate Reservoirs," 2017.

[14] B. Roussennac, "Gas-condensate well test analysis," M.S. thesis, Stanford University, CA. 2001.

[15] S. B. Hinchman, & R. D. Barree, "Productivity Loss in Gas Condensate Reservoirs," Society of Petroleum Engineers. doi: 10.2118/14203-MS. 1985.

[16] T. Yang, O. Fevang, K. R. Christoffersen, & E. Ivarrud, "LBC Viscosity Modeling of Gas Condensate to Heavy Oil," Society of Petroleum Engineers. doi: 10.2118/109892-MS. 2007.

[17] O. D. Orodu, C. T. Ako, F. A. Makinde, & M. O. Owarume, "Well Deliverability Predictions of Gas Flow in Gas-Condensate Reservoirs, Modelling near-Critical Wellbore Problem of Two Phase Flow in 1 –Dimension," Brazilian Journal of Petroleum and Gas, 6(4), 159-169. doi: 10.5419/bjpg 2012-0013. 2012.

[18] E. Evans, A. Ghalambor, & A. Orangi, "Well Placement Optimization in a Gas Condensate Reservoir to Prevent Condensate Banking," 2016.

[19] M. Bozorgzadeh, & A. C. Gringarten, "Estimating Productivity-Controlling Parameters in Gas/Condensate Wells from Transient Pressure Data," doi: 10.2118/94018-PA. 2007.

[20] M. M. Khazam, Z. Y. Abu Grin, R. R. Elhajjaji, & A. A. Sherik, "The Impact of Condensate Blockage on Gas Well Deliverability - Part 1," 2017.

[21] S. A. Jokhio, & D. Tiab, "Establishing Gas Phase Well Performance for Gas Condensate Wells Producing Under Three-Phase Conditions," Society of Petroleum Engineers. doi: 10.2118/76752-MS. 2002.

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