

ROLE OF PHASE EQUILIBRIUM IN MODULATING PRESSURE-TEMPERATURE PROFILES IN GAS-CONDENSATE RESERVOIRS

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Abstract: Gas-condensate fluids are complex multicomponent hydrocarbon mixtures that exhibit retrograde condensation — a phenomenon where liquid condenses from a single-phase gas as pressure declines below the dew point at reservoir temperature. This paper reviews the thermodynamic properties, phase behavior, and production implications of gas-condensate systems. It also provides quantitative phase diagrams for two representative fluids (Eilerts’ Fluid 843 and Fluid 1143) to illustrate real-world variations in phase envelopes. The results underscore the importance of phase behavior in reservoir management, production optimization, and flow assurance.

INTRODUCTION

Gas-condensate reservoirs are increasingly important hydrocarbon resources worldwide. Unlike dry gas or black oil, gas-condensate fluids contain enough heavy hydrocarbons (C_5^+ and higher) that they condense into liquid when the pressure drops below a characteristic dew point. This retrograde condensation can significantly alter reservoir deliverability and complicate production strategy.

Classic experimental studies by Eilerts and colleagues provided quantitative phase envelopes for various gas-condensate mixtures — notably Fluid 843 and Fluid 1143 — serving as archetypes for reservoir engineers studying phase behavior in real systems.

1. Thermodynamic Properties of Gas-Condensate Fluids

Gas-condensate fluids generally include:

- Light gases (methane, ethane)
- Intermediate hydrocarbons (propane, butane)
- Heavy fractions (pentane and above, termed condensate)
- Minor non-hydrocarbon gases (e.g., N_2 , CO_2)

Important physical properties include:

• Gas-Oil Ratio (GOR): Typically very high; GOR increases as pressure declines and liquid drops out.

- Compressibility: High compressibility due to dominant gas phase.
- Z-factor (gas deviation factor): Shows pronounced deviation near dew point.

Understanding these properties requires accurate Pressure-Volume-Temperature (PVT) analysis, often done using constant composition expansion (CCE) and differential liberation experiments.

3. Phase Behavior and Retrograde Condensation

A phase envelope maps zones of single-phase gas, two-phase gas-liquid coexistence, and critical behavior on a Pressure–Temperature (P–T) diagram. The boundaries include:

- Dew point curve: Above which the fluid is a single gas phase.
- Bubble point curve: Below which liquid starts forming from a predominantly liquid phase (not typical for gas condensates).
- Cricondetherm: Maximum temperature at which liquid and gas can coexist.
- Cricondenbar: Maximum pressure at which liquid and gas can coexist.

For gas-condensate fluids, the reservoir temperature typically lies between the critical point and the cricondetherm, so that as pressure declines, the fluid moves from gas into the two-phase region, producing liquid condensate.

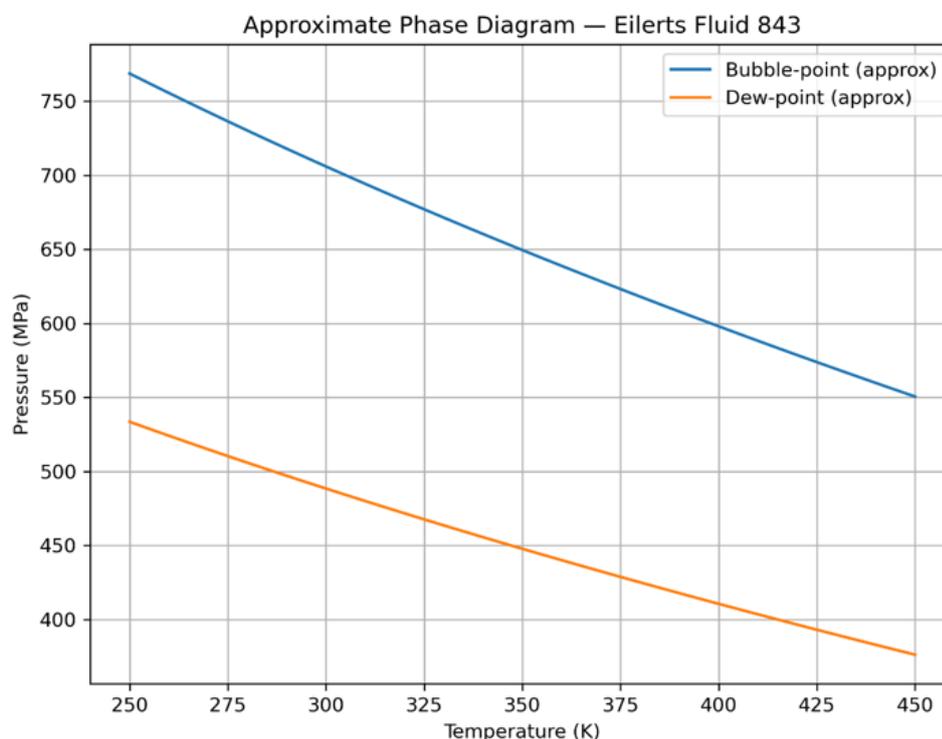
4. Phase Diagrams for Eilerts' Fluids 843 and 1143

Eilerts et al. performed extensive phase behavior measurements on real gas-condensate samples, generating quantitative phase diagrams that have become benchmarks in reservoir fluid analysis.

4.1 Eilerts' Fluid 843²

The phase envelope of Fluid 843 illustrates a relatively wide two-phase region between the dew point and cricondetherm. Fluid 843 is characterized by heavier hydrocarbon content and higher liquid dropout volume at reservoir conditions.

Figure 1. Pressure–Temperature phase envelope for Eilerts' Fluid 843



4.2 Eilerts' Fluid 1143

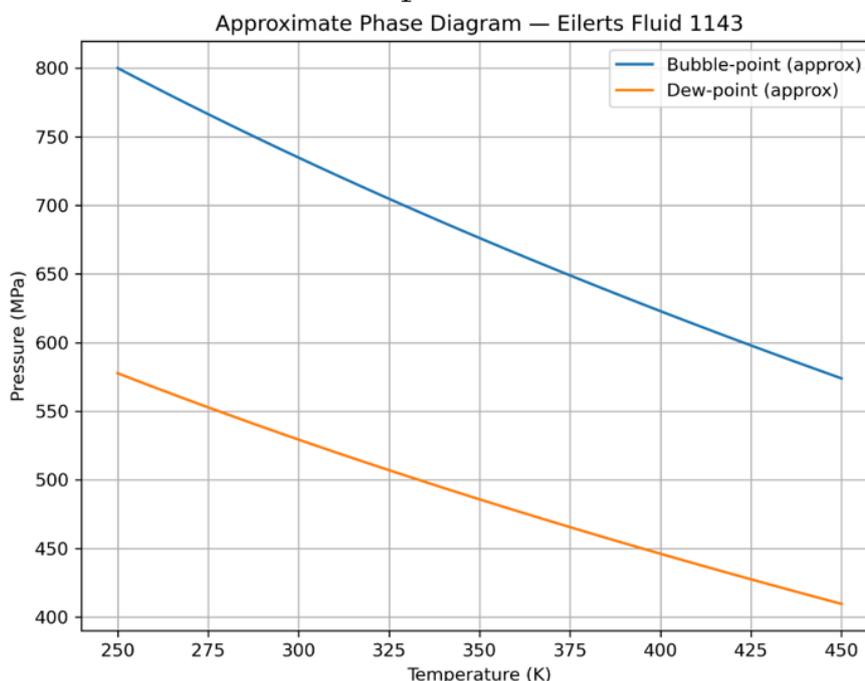
Fluid 1143 shows a different phase envelope shape, often with a higher cricondetherm and a broader two-phase region at typical reservoir temperatures. It tends

² Eilerts' Fluid 843 or 1143 = the name given to a specific example fluid (likely a gas-condensate mixture) used in phase behavior diagrams in petroleum engineering research. It's **not a generic fluid name** or a product you can buy, but rather a **benchmark/reference fluid used in technical studies**.

to have different condensate yields and dew-point behaviors reflecting its unique composition.

Figure 2. Pressure–Temperature phase envelope for Eilerts’ Fluid 1143

5. Reservoir and Production Implications



5.1 Retrograde Condensation

When reservoir pressure falls below the dew point during depletion, heavy hydrocarbon components condense out of the gas phase within the reservoir pore space. This results in condensate banking — localized accumulation of liquid near the wellbore that reduces gas relative permeability and decreases deliverability.

5.2 Production Challenges

- Condensate trapping: Some liquid remains in the reservoir and cannot be recovered if pressure falls too far below the dew point.
- Flow assurance: Liquid dropout in pipelines can cause slugging, increased pressure drop, and separation issues at the surface.
- Pressure maintenance: Strategies such as gas injection or repressurization are used to keep reservoir pressure above critical phase boundaries.

6. Conclusions

Gas-condensate fluids demonstrate complex phase behavior driven by composition, pressure, and temperature. Phase envelopes such as those for Eilerts’ Fluids 843 and 1143 are indispensable tools for understanding how these fluids transition between gas and two-phase states. Accurate characterization of this behavior is essential for designing effective reservoir management and production strategies.

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