Equations of State for Gas Condensates

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&

PERA

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Key PVT Data

- **Gas Z-factor**

Gas Z-factor is the only PVT property which always needs accurate determination in a gas condensate reservoir.

Initial gas *and condensate* in place.

Gas *and condensate* recovery as a function of pressure during depletion drive.

EOS Modeling

- **C_1 *volume shift***

Don't change without checking against measured Z-factor data.

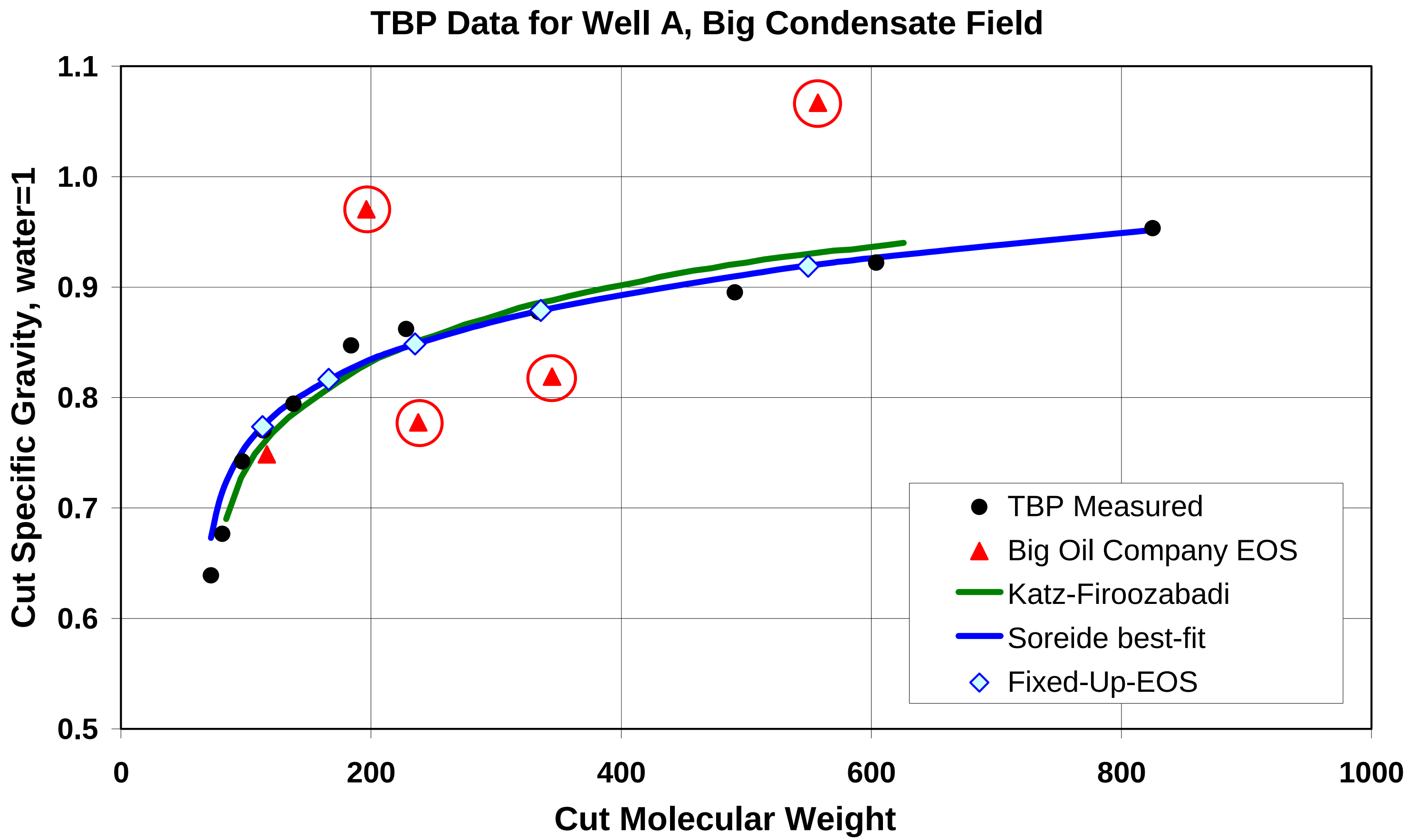
… *for any pure component.*

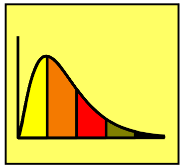
Key PVT Data

- Gas Z-factor
- **Condensate Gravity**

EOS Modeling

- C_1 volume shift
- ***C_{n+} volume shifts***





Key PVT Data

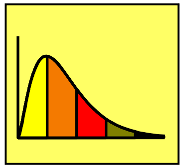
- Gas Z-factor
- Condensate Gravity
- **Dewpoint**

Pressure where wellstream starts becoming significantly leaner.

Pressure where incipient oil first appears.

EOS Modeling

- C_1 *volume shift*
- C_{n+} *volume shifts*
- **C_{n+} & C_1 *K-values***



Key PVT Data

- Gas Z-factor
- Condensate Gravity
- Dewpoint
- **C_{n+} in Equilibrium Gas**

Condensate rate profile.

Condensate recovery.

Define Gas Cycling Potential.

EOS Modeling

- C_1 *volume shift*
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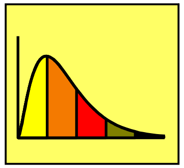
- C_{n+} & C_1 *K-values*
- **C_{n+} *K-values***



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- Gas Z-factor
- Condensate Gravity
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- C_{n+} in Equilibrium Gas
- **Equilibrium Liquids**
  - **"Oil" Composition**
  - **Condensate V_{ro} & μ_o**

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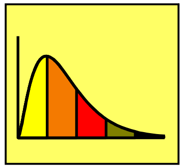

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  - "Oil" Composition
  - Condensate V_{ro} & μ_o
- **Condensate Vaporization**
  - **C_{n+} in Equilibrium Gas**
  - **Moles Equilibrium Oil**

EOS Modeling

- C_1 *volume shift*
- C_{n+} *volume shifts*
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- **C_{n+} & C_1 *K-values***

Key PVT Data

EOS Modeling

Phase Equilibria

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- C_{n+} in Equilibrium Gas
- Equilibrium Liquids
  - "Oil" Composition
  - Condensate V_{ro} & μ_o
- Condensate Vaporization
  - C_{n+} in Equilibrium Gas
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C_{n+} & C_1

K-values

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K-value Control

- C_{n+} Component Properties
  - Critical Pressure
  - Critical Temperature
  - Acentric Factor

} EOS Constants A & B

K-value Control

- C_{n+} Component Properties
  - Critical Pressure
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EOS Constants

A & B

- **Binary Interaction Parameters** (BIPs)
  - $C_1 - C_{n+}$
  - $C_{n+} - C_{n+}$
  - Intermediates $C_1 - C_I$ & $C_I - C_{n+}$
  - Non-hydrocarbons $C_{nHC} - C_{HC}$

K-value Control

- **Understanding Cause-and-Effect**

K-value Control

- Understanding Cause-and-Effect
  - Low-p K-values to $p_v(T)$ to acentric factor (ω) to T_b.

K-value Control

- **Understand Cause-and-Effect**
  - **Low-p K-values to $p_v(T)$ to acentric factor (ω) to T_b.**
  - **Effect of ω on vapor pressure curve *at relevant T*.**
  - **Effect of (T_c,p_c) on vapor pressure curve *at relevant T*.**

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  - **Effect of BIP k_{ij} on K-values K_i & K_j.**

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  - Effect of BIP k_{ij} on K-values K_i & K_j.
  - Rank component's K-value impact on phase equilibria.
  - What causes three-phase behavior.

K-value Control

- Constraints
  - Monotonic *volatility* according to boiling point.
  - Avoid crossing K-values as function of (p,T,x).

K-value Control

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  - Avoid three-phase behavior.

K-value Control

- Constraints
  - Monotonic *volatility* according to boiling point.
  - Avoid crossing K-values as function of (p,T,z).
  - Avoid three-phase behavior.
  - Honor measured K-value data.

K-value Control

- Measured Data
  - K-values practically never available.
    - Maybe from material balance.
    - Critical transition.

K-value Control

- **Measured Data**
  - **K-values practically never available.**
  - **Often, <u>only</u> *indirect* phase behavior data available.**
    - **Dewpoint**
    - **Critical** *(bubblepoint-to-dewpoint)* **transition**
    - **Liquid dropout**

K-value Control

- **Measured Data**
  - K-values practically never available.
  - Usually indirect phase behavior data available.
  - Reliability of & QCing measured compositions?
    - Sampling techniques.
    - GC methods.
    - Material balance.
    - Graphical consistency.

K-value Control

- **Measured Data**
  - K-values practically never available.
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  - Reliability of & QCing measured compositions?
  - Industry – what to do?
    - Know what and why to measure.
    - Demand quality.

K-value Control

- Measured Data
  - K-values practically never available.
  - Usually indirect phase behavior data available.
  - Reliability of & QCing measured compositions?
  - Industry – what to do?
  - Labs – what to do?
    - Measure compositions reliably.
    - Develop better flash-GC methods.
    - Measure flashed-liquid molecular weights.

Conclusions

- Volumetric properties are almost predicted always accurately enough – ***if*** ***volume shift factors are determined properly***.

1. Don’t change pure-component volume shift factors…

   without having measured data for that component.

2. Always determine volume shifts of C_{n+} fractions to honor the individual-fraction specific gravities.

Conclusions

- **Phase equilibria data are often <u>not</u> predicted accurately.**
  - **Phase equilibria is α–Ω for gas condensates.**

Conclusions

- Phase equilibria data are often not predicted accurately.
  - Phase equilibria is α–Ω for gas condensates.
  - **K-values control phase behavior.**

Controlling K-values from an EOS is a non-trivial task requiring measured K-value data, compositions, indirect phase behavior data (e.g. dewpoints), and a phase behavior program that allows all such data to be matched.