A-to-Z of Preparing Oil & Gas PVT Data for Reservoir Simulation

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NTNU / PERA
Tasks

- Collecting samples.
- Which PVT lab tests to use.
- Designing special PVT studies.
- Quality controlling PVT data.
- Heptanes-plus data and characterization.
- Initial EOS model.
- Tuning an EOS model.
- Viscosities.
- Fluid initialization.
- Minimizing number of EOS components.
- Black-oil PVT tables.
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Collecting Samples

Why?

1. PVT data to develop a model.
Collecting Samples

Why?

1. PVT data to develop a model.

2. Compositions for fluid initialization.
Collecting Samples

**Why?**

1. PVT data to develop a model.
2. Compositions for fluid initialization.
3. Crude assays for process design.
Collecting Samples

How?

Oils
- Bottomhole samples.
- Surface separator samples.
- MDT / RCI

Gas Condensates
- Surface separator samples.
- MDT / RCI
Collecting Samples

How?

Oils
- Bottomhole samples.
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Gas Condensates
- Surface separator samples.
- MDT / RCI

Saturated Gas / Oil Systems
- Gas-cone an oil producer – *perfect*!
- ECM (equilibrium contact mixing)
Open-hole Samplers

MDT / RCI

- Potential Problems
  - Oil-based muds.
    - Oils -- OK for composition.
    - Gas condensates – OK for composition.
  - Surface cooling before removal.
    - Bubblepoint suppression.
MDT Sampling with MPSR bottles

Prior to Sampling

Fire-open valve
Fire-close valve
Dead volume (<10cc) – initially water filled

Manual close valve

Piston

450cc MPSR bottle

Post Sampling but downhole

To pump and formation

Fire-open valve operated to fill
Fire-close valve operated post filling

Dead volume (<10cc) – now gas filled

Manual close valve

450cc of single phase oil at res temp and pressure

Water from dead volume

Post Sampling Now at surface

To pump and formation

Fire-open valve open
Fire-close valve closed

Dead volume (<10cc) – now gas filled and the gas will be lost

Manual close valve now operated to extract MPSR from MDT tool

450cc of 2 phase hydrocarbon at surface temp and some pressure

Water from dead volume

To pump and formation

Piston
Which PVT Lab Tests to Use

What are you simulating?

- Depletion.
- Water injection.
- Condensate blockage.
- Gas injection.
  - Miscible.
  - Immiscible.
Designing Special PVT Studies

- Condensate Blockage.
  - Condensate viscosities.

- Miscible Gas Injection.
  - Through-critical swelling test.
    - $V_{ro}$, compositions and K-values!

- Immiscible Gas Injection.
  - Vaporization tests.
Quality Controlling PVT Data

- Compositions !!!
  - Recombination.
  - Extended GC.
  - Mass-to-mole conversion.
- C\textsubscript{7+} properties.
  - Molecular weight and specific gravity.
- Use trend plots.
  - P\textsubscript{s} vs wt-% methane and/or C\textsubscript{7+}. 
Reported GC extended distribution appears to be in serious error, being much too "light" with apparent M7+ = 130
DON'T USE GC DISTRIBUTION !!!
C$_7$+ Data and Characterization

- Correlate MW and SG of C$_7$+. 
  - Define trends & identify "outliers".
- Use TBP Data.
  - Gamma distribution model fit.
  - SCN MW-SG relationship.
  - Downstream Assay data always available.
- Extended GC Data.
  - Gamma distribution model fit.
  - Ignore heaviest amount and MW.
SoreideFc Correlation

- Bottomhole Samples
- Separator Samples
- Best-Fit Fc=0.287
- Fc=0.28
- Fc=0.27

Becoming More Paraffinic Due to Wax Accumulation in Samples???
C7+ Properties (Watson Correlation)

Decreasing Aromaticity: Asphaltene Loss?

Reported / Determined

Kw=11.2
Kw=11.5
Kw=11.8
Assay Data

TBP Distillation (Well 15-2-RD-2X)

Discontinuity?
Maybe associated with change in distillation pressure.

Riazi Correlation
Soreide (after fit Riazi)
Initial EOS Model

• Default Parameters – *don’t mess with ’em.*
  • $C_6$- properties $M$, $T_c$, $p_c$, $\omega$.
  • $C_6$- properties volume shift $s(=c/b)$.
  • Non-HC / HC BIPs $k_{ij}$.
• C7+ Characterization.
  • Minimum 3 fractions (*not* $C_7$, $C_8$, $C_{9+}$!).
  • Methane-C$_7+$ BIPs.
  • SG-TB-MW relationship; $T_c$, $p_c$, $\omega(T_b)$.
  • Volume shift treatment $s(\gamma)$.
  • *Always keep fraction SGs “fit” by EOS.*
Tuning an EOS Model

- Densities Don’t Need Regressing!

- What’s Left to Fit?
  - Nothing but *K*-values ... *but how ???*

- Check Consistency!
  - Monotonic *K*-values of hydrocarbons.
  - Three-phase existence (from EOS model).
    - *Serious problem for EOS models!*
Viscosities

- **LBC** (Lorenz-Bray-Clark / Jossi-Thodos)
  - Need accurate densities.
  - Modify $C_{7+} V_c$ values.
  - Make sure fraction viscosities are monotonic.
  - LBC polynomial coefficients.
    - *BE CAREFUL!*
- **Pedersen.**
  - Better predictions than LBC.
  - Regression - ?
Fluid Initialization

• Plot C$_{6+}$ versus Depth.
  • Initial Oil in Place plot.
  • Use error bars.
    • Depth and composition.

• Uncertainty Analysis.
  • Use isothermal gradient model.
    • Defines maximum compositional variation.
  • Use constant composition.
    • Defines minimum compositional variation.
Reference Depth
GOC
Field-Data Based Initialization
Isothermal Model

Depth, ft SSL

C\textsubscript{7+} Mole Percent
Fluid Initialization

- **Black-Oil vs Compositional.**
  - Use consistent EOS model.
  - Use consistent surface process.
  - Use solution GOR ($R_s$ and $R_v$) for black-oil model.
    - *Based on EOS model initialization.*
Minimizing Number of EOS Components

• **Basis of Comparison.**
  • Detailed & Tuned EOS model.
  • Stepwise lumping procedure.
  • Check entire relevant p-compositioni space.
    • *Depletion data.*
    • *Gas injection data.*
    • *Miscibility data.*

• **Delumping?**
  • Detailed & Tuned EOS model.
Black-Oil PVT Tables

- Select Depletion Test.
- Define Surface Separation.
- Consistency.
  - Negative compressibilities.
  - Saturated gas / oil systems.
  - Compositional grading.
- Extrapolation.
  - Undersaturated GOC \((ECL100)\).
  - Gas injection.
Black-Oil PVT Tables

- Delumping to Compositional Streams?
Split Factor

**BOz Conversion**

\[ z_i = \sum_{j=1}^{2} S_{ij} \cdot q_j \]

\[ q_1 = q_g \]
\[ q_2 = q_o \]

\[ S_{i1} = \frac{(1 + r_s C_{og})}{k(1-r_s R_s)} y_i - \frac{r_s (C_{oo} + R_s)}{k(1-r_s R_s)} x_i \]

\[ S_{i2} = \frac{(C_{oo} + R_s)}{k(1-r_s R_s)} x_i - \frac{R_s (1 + r_s C_{og})}{k(1-r_s R_s)} y_i \]
North Sea Full-Field

*Black-oil to Compositional conversion*

- 2 Platforms / 2 Processes.
- ~ 50 wells.
- ~ 1000 well-grid connections.
- Gas injection.
- 2 Black-oil PVT regions.
- Huge (GB) summary files.
- > 100,000 stream conversions.
North Sea Full-Field Model

E100-BO
E300-EOS
FFM

Platform A
Process A
~ 30 Wells

Platform B
Process B
~ 15 Wells

Different Surface Processes (BO PVT) in Regions A & B

Gas Injection
Objective

• Run black-oil full-field reservoir model.

• Convert surface rates to compositional streams.
  • Connection level conversions.

• Summarize results.
  • By well, platform, field.
  • Annually, quarterly, cummulatives etc.
**Full-Field Rate Forecast**

(Following history match from 1987)

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Changing Group Gas Rate due to reduced contribution from neighbouring fields.
Full-Field Molar Rate Predictions
(E100 - BOz conversion)
Full-Field Molar Rate Predictions
(E300-BOZ/PSM vs E300 models)
Validation of Conversion Accuracy