Consistent Fluid Management
from Reservoir to Sales Point

Bilal Younus and Mathias Carlsen
Whitson AS

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“Often different fluid models are used to describe the same physical fluid at different points in the system”
"Often different fluid models are used to describe the same physical fluid at different points in the system."

“What can be done to ensure consistency of fluid description throughout the value chain?”
PVT in Value Chain

Consistent Fluid Management from Reservoir to Sales Point

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PVT in Value Chain

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PVT in Value Chain

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- Reservoir
  - Complex Phase Behaviour e.g. EOR
  - Well Classification
  - Fluid Initialization
  - Reserves Estimation
  - Flow Through Porous Media

- PVT
  - Processing
  - Production
Consistent Fluid Management from Reservoir to Sales Point

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PVT in Value Chain

Reservoir
- Flow through porous media
- Reserves Estimation
- Complex Phase Behaviour i.e. EOR
- Well Classification
- Fluid Initialization

PVT
- Processing
  - Facility Design
  - Optimize Facilities
- Production
  - Pipe Flow
  - Wax/Asphalt
  - Flow Assurance
  - Allocation
- Sales Products Characterization

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Problem Explanation

Multi Billion bbl Oil Field in Middle East
Problem Explanation

Multi Billion bbl Oil Field in Middle East
Problem Explanation

Multi Billion bbl Oil Field in Middle East
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Samples

Th-A
Problem Explanation

Consistent Fluid Management from Reservoir to Sales Point

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Problem Explanation

Samples → Lumpening → Tuning → Res. Sim.

Th-A → EOS_n → EOS11 → Th-A

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Problem Explanation

Samples

- Th-A
- Th-B
- Th-G

Lumping

- $\text{EOS}_n$
- $\text{EOS}_m$
- $\text{EOS}_k$

Tuning

Res. Sim.

- EOS11
- EOS10
- EOS12

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Problem Explanation

Samples

- Th-A
- Th-B
- Th-G

Lumping

- $\text{EOS}_n$
- $\text{EOS}_m$
- $\text{EOS}_k$

Tuning

Res. Sim.

- $\text{EOS11}$
- $\text{EOS10}$
- $\text{EOS12}$

Process

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Technical Solution

• Operator Requirement

1. Detailed EOS model with 41 components (EOS41)
2. Tuned EOS41 to "all" PVT samples from "all" different reservoirs (80+ samples)
3. Lumping the detailed EOS model for reservoir simulation (EOS11)
4. EOS11 used in reservoir simulation and EOS41 used in surface process calculations with complete consistency
Technical Solution

• Operator Requirement
  • A PVT model with as good or better quality as current PVT models
Technical Solution

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  • Consistent fluid handling of all reservoirs for condensate allocation purpose

• Our Solution
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• Our Solution – Common detailed EOS model
Technical Solution

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Consistent Fluid Management from Reservoir to Sales Point

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Technical Solution

• Operator Requirement
  • A PVT model with as good or better quality as current PVT models
  • Consistent fluid handling of all reservoirs for condensate allocation purpose

• Our Solution – Common detailed EOS model

- One Common Detailed EOS
- Tuning
- ALL Samples (80+)
- ALL Reservoirs

Consistent Fluid Management from Reservoir to Sales Point

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Technical Solution

- **Operator Requirement**
  - A PVT model with as good or better quality as current PVT models
  - Consistent fluid handling of all reservoirs for condensate allocation purpose

- **Our Solution – Common detailed EOS model**
  
  ![Diagram](Diagram.png)

  - **One Common Detailed EOS**
  - **“Parent EOS”**
  - **Tuning**
  - **ALL Samples (80+)**
  - **ALL Reservoirs**
Technical Solution

Consistent Fluid Management from Reservoir to Sales Point

EOS12

EOS11

EOS10

EOS20

“One Detailed EOS”

“Parent EOS”

“EOS Child Models”

Tuning

ALL Samples

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Common EOS Model – Considerations

Phase Behavior Variation – Reservoir to Surface

- Reservoir Oil
- Oil in Wellbore
- Separator Oil

Saturation Pressure, psia vs Temperature, °F
Common EOS Model – Considerations

- Use all available PVT samples (30-100)

Phase Behavior Variation – Reservoir to Surface

- Reservoir Oil
- Oil in Wellbore
- Separator Oil
Common EOS Model – Considerations

- Use all available PVT samples (30-100)
- Wider the composition range, better the EOS model

Phase Behavior Variation – Reservoir to Surface

- Reservoir Oil
- Oil in Wellbore
- Separator Oil
Common EOS Model – Considerations

- Use all available PVT samples (30-100)
- Wider the composition range, better the EOS model
- Detailed component slate
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Common EOS Model – Considerations

- Use all available PVT samples (30-100)
- Wider the composition range, better the EOS model
- Detailed component slate
- Use all types of PVT data
  - Depletion
  - EOR
  - Crude Distillation
### Common Detailed EOS Model

<table>
<thead>
<tr>
<th>N2</th>
<th>C-C5</th>
<th>C8-SCN</th>
<th>C11</th>
<th>C21</th>
<th>C31</th>
<th>Lump EOS 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2</td>
<td>C6-SCN</td>
<td>C8*</td>
<td>C12</td>
<td>C22</td>
<td>C32</td>
<td></td>
</tr>
<tr>
<td>H2S</td>
<td>C6*</td>
<td>E-Benzene</td>
<td>C13</td>
<td>C23</td>
<td>C33</td>
<td></td>
</tr>
<tr>
<td>C1</td>
<td>MC-C5</td>
<td>m-xylene</td>
<td>C14</td>
<td>C24</td>
<td>C34</td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td>C-C6</td>
<td>o-xylene</td>
<td>C15</td>
<td>C25</td>
<td>C35</td>
<td></td>
</tr>
<tr>
<td>C3</td>
<td>Benzene</td>
<td>C9-SCN</td>
<td>C16</td>
<td>C26</td>
<td>C36p</td>
<td></td>
</tr>
<tr>
<td>I-C4</td>
<td>C7-SCN</td>
<td>C9*</td>
<td>C17</td>
<td>C27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N-C4</td>
<td>C7*</td>
<td>i24TM-BEN</td>
<td>C18</td>
<td>C28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-C5</td>
<td>MC-C6</td>
<td>C10-SCN</td>
<td>C19</td>
<td>C29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N-C5</td>
<td>Toluene</td>
<td>C10*</td>
<td>C20</td>
<td>C30</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Parent**

**Black Oil Tables**

**SCN Char**

**Common EOS Char**

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Integration of Different Parts of Value Chain

Common Detailed EOS Model

- Reservoir Simulation Fluid Model
- Production Fluid Model
- Process Fluid Model
Integration of Different Parts of Value Chain

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- Reservoir Simulation Fluid Model
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- Black Oil Table
- Lumped EOS Model

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  - Single Carbon Number EOS
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Consistent Lumping Delumping – References

**Compositional to BO**

- Consistent Fluid Management from Reservoir to Sales Point
- SPE 10067 “Evaluating constant Volume Depletion Data”

**BO to Compositional**

- SPE 159400 “Dynamic Delumping of Reservoir Simulation”

**Lumping**

- EOS9 $\rightarrow$ EOS4
- SPE 170912 “Global Component Lumping for EOS Calculations”

**Delumping**

- EOS6 $\rightarrow$ EOS14
- SPE 159400 “Dynamic Delumping of Reservoir Simulation”

- Non-trivial Multi-variable Split factor tables
- CO2
- N2
- C1
- C2
- C3
- nC4
- iC4
- nC5
- C6
- C7
- C8
- C9
- C10
- C11p
The fluid that flows from the reservoir is physically the same throughout the system, and should be described by the same fluid model throughout the entire production system, from reservoir to sales.

Why Consistency is Important?

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Consistent Fluid Management from Reservoir to Sales Point

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The fluid that flows from the reservoir is physically the same throughout the system, and should be described by the same fluid model throughout the entire production system, from reservoir to sales.

Despite EOS_A and EOS_B having the same component slate, they are not from a common EOS model.

- EOS_A and EOS_B have the same component slate but are **not** from a common EOS model.

**Why Consistency is Important?**

- Field Development & Design
- Short Term and Long Term Production Optimization
- Decision Support
Why Consistency is Important?

The fluid that flows from the reservoir is physically the same throughout the system, and should be described by the same fluid model throughout the entire production system, from reservoir to sales point. Due to the inconsistency of their predictions, models with inconsistent fluid management are dangerous to use in:

- Field Development & Design
- Short Term and Long Term Production Optimization
- Decision Support

Why Consistency is Important?

Consistent Fluid Management from Reservoir to Sales Point

EOS_A and EOS_B have the same component slate but are not from common EOS model.

- A component say C_{11} in z_i won’t have the same thermodynamic properties at the Reservoir-Well node.
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Why Consistency is Important?

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- A component say C_{11} in z_i won’t have the same thermodynamic properties at the Reservoir-Well node.

- For the same composition z_i, K-values from flash calculation at p_{wf} and T_R will be different.
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EOS\textsubscript{A} and EOS\textsubscript{B} have the same component slate but are \textbf{not} from common EOS model.

- A component say \textit{C}_{11} in \(z_i\) won’t have the same thermodynamic properties at the Reservoir-Well node.

- For the same composition \(z_i\), \(K\)-values from flash calculation at \(p_{wf}\) and \(T_R\) will be different.

\textbf{PVT model inconsistencies can be a serious problem resulting in mass, molar, and volumetric material balance errors in key applications:}

- Field Development & Design
- Short Term and Long Term Production Optimization
- Decision Support
Diluent Injection Optimization for an Offshore Heavy Oil Field in UK
SPE 183802, SPE 184119

Production Allocation for an Onshore Multi-Field Asset in South America
SPE 174843

Integration of Reservoir and Process Models for South Natuna Sea, Indonesia
IPA03-E-068

API Blending Optimization for a Multi-Field Asset in the Middle East
SPE 187471

Condensate Allocation Study for Two Giant Gas Cap-Oil Fields in Middle East
Thank you

Questions?