PETE 310

Review Lecture # 7

Three & Multicomponent Mixtures...

Plus

Lecture # 8 – Chapter 5
Ternary Diagrams: Review
Ternary Diagrams: Review

Pressure Effect

Gas

Liquid

2-phase

nC₅

C₁

C₃

p=14.7 psia

p=380 psia

p=500 psia

p=1500 psia

p=2000 psia

p=2350 psia
Ternary Diagrams: Review

Dilution Lines

Graph showing C1, C10, and n-C4 with dilution lines.
Ternary Diagrams: Review

Quantitative Representation of Phase Equilibria - Tie (or equilibrium) lines

- Tie lines join equilibrium conditions of the gas and the liquid at a given pressure and temperature
  - Bubble point curve gives the liquid composition
  - Dew point curve gives the gas composition
Ternary Diagrams: Review

Quantitative Representation of Phase Equilibria - Tie (or equilibrium) lines

- All mixtures whose overall composition \( z_i \) is along a tie line have the SAME equilibrium gas (\( y_i \)) and liquid composition (\( x_i \)), but the relative amounts on a molar basis of gas and liquid (\( f_v \) and \( f_l \)) change linearly (0 – vapor at B.P., 1 – liquid at B.P.).
Illustration of Phase Envelope and Tie Lines
Uses of Ternary Diagrams

Representation of Multi-Component Phase Behavior with a Pseudoternary Diagram

- Ternary diagrams may approximate phase behavior of multi-component mixtures by grouping them into 3 pseudocomponents

- heavy ($C_7^+$)
- intermediate ($C_2$-$C_6$)
- light ($C_1$, CO$_2$, N$_2$- $C_1$, CO$_2$-$C_2$, ...)
Uses of Ternary Diagrams

Miscible Recovery Processes

![Ternary Diagram Illustrating Miscible Recovery Processes]
Exercise

Find overall composition of mixture made with 100 moles oil "O" + 10 moles of mixture "A".
**Mixture C\textsubscript{1-nC_4-C_{10}}**

@ p=2500 psi, T=160 °F

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<th>liquid phase</th>
<th></th>
<th></th>
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<th>x</th>
<th>y</th>
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<tr>
<td>x\textsubscript{C_1}</td>
<td>x\textsubscript{C_4}</td>
<td>x\textsubscript{C_{10}}</td>
<td>x</td>
<td>y</td>
<td></td>
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<td>0.494</td>
<td>0.000</td>
<td>0.506</td>
<td>0.247</td>
<td>0.427816</td>
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<th>x</th>
<th>y</th>
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<td>y\textsubscript{C_1}</td>
<td>y\textsubscript{C_4}</td>
<td>y\textsubscript{C_{10}}</td>
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<td>0.011</td>
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<td>0.800</td>
<td>0.186</td>
<td>0.014</td>
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<td>0.617</td>
<td>0.640859</td>
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Practice Ternary Diagrams

Pressure Effect

T = 180°F
P = 14.7 psia

Pressure Effect

T = 180°F
P = 200 psia

C1-C3-C10

Pressure Effect

T = 180°F
P = 400 psia

Pressure Effect

T = 180°F
P = 600 psia
Practice Ternary Diagrams
Pressure Effect

T=180F
P=1000 psia

Pressure Effect

T=180F
P=1500 psia

Pressure Effect

T=180F
P=2000 psia

T=180F
P=3000 psia

T=180F
P=4000 psia
Practice Ternary Diagrams

Temperature Effect

T=100°F
P=2000 psia

T=150°F
P=2000 psia

T=200°F
P=2000 psia

T=300°F
P=2000 psia
Practice Ternary Diagrams

Temperature Effect

T=350°F
P=2000 psia

Temperature Effect

T=400°F
P=2000 psia

Temperature Effect

T=450°F
P=2000 psia
Pressure-Temperature Diagram for Multicomponent Systems

Reservoir Pressure

Reservoir Temperature

1-Phase

2-Phase

Bubble Curve

Dew Curve

60%

20%

0%

CP
Changes During Production and Injection

- Pressure
- Temperature

- Production
- Gas Injection

- $t_1$
- $t_2$
- $t_3$
PETE 310

Lecture # 8: Five Reservoir Fluids
(Chapter 5)
Pressure vs. Temperature Diagrams

- Used to visualize the fluids production path from the reservoir to the surface
- To classify reservoir fluids
- Visualize miscible processes
Pressure-Temperature Diagram for Multicomponent Systems

- 1-Phase
- 2-Phase
- Bubble-Curve
- Dew-Curve
- CP

Reservoir Pressure vs. Reservoir Temperature
Why do we need to classify Reservoir Fluids?

- Determine fluid sampling
- Determine types and sizes of surface equipment
- Dictate depletion strategy
- Determine selection of EOR method
- Determine techniques to predict oil & gas reserves
- Determine Material Balance calculations
Phase Envelopes

- Critical Point
- Cricondenbar
- Cricondentherm
- Bubblepoint Curve
- Dew Point Curve
- Quality Lines
- Fixed Composition

Graph showing phase envelopes with pressure and temperature axes. The graph includes critical point and fixed composition markers.
Classification of Reservoirs based on Phase Diagram

- **Gas Reservoirs (Single Phase)**

- **Gas Condensate Reservoirs (Dew-Point Reservoirs):**

- **Undersaturated Solution-Gas Reservoirs (Bubble-Point Reservoirs):**
Phase Diagram of a Dry Gas Reservoir

- Initial Reservoir Conditions
- Separator Conditions
- Path of Production

Pressure vs. Temperature

CP
Phase Diagram of a Wet Gas Reservoir

- Temperature
- Pressure
- Path of Production
- Initial Reservoir Conditions
- Separator Conditions
- CP
- Initial Reservoir Conditions
- Path of Production
- Separator Conditions
Phase Diagram of a Retrograde Gas Reservoir

Temperature

Pressure

Initial Reservoir Conditions

CP

Path of Production

Separator Conditions

Temperature

Pressure
Phase Diagram of a Volatile Oil Reservoir

Initial Reservoir Conditions

Path of Production

Separator Conditions

Pressure

Temperature

CP

75%

50%

25%
Phase Diagram of a Black Oil Reservoir

Initial Reservoir Conditions

Path of Production

Separator Conditions

Pressure

Temperature

25%

50%

75%

25%

50%

75%
Phase envelopes of different mixtures with different proportions of same HC components
## Typical Reservoir Fluid Compositions

<table>
<thead>
<tr>
<th>Component</th>
<th>Black Oil</th>
<th>Volatile Oil</th>
<th>Gas Condensate</th>
<th>Wet Gas</th>
<th>Dry Gas</th>
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<tbody>
<tr>
<td>C₁</td>
<td>48.83</td>
<td>64.36</td>
<td>87.07</td>
<td>95.85</td>
<td>86.67</td>
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<tr>
<td>C₂</td>
<td>2.75</td>
<td>7.52</td>
<td>4.39</td>
<td>2.67</td>
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<tr>
<td>C₃</td>
<td>1.93</td>
<td>4.74</td>
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<td>C₄</td>
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<td>4.12</td>
<td>1.74</td>
<td>0.52</td>
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<td>C₅</td>
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<td>3.97</td>
<td>0.83</td>
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<td>C₆</td>
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<td>3.38</td>
<td>0.60</td>
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<td>C₇⁺</td>
<td>42.15</td>
<td>11.91</td>
<td>3.80</td>
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<tr>
<td>MₗC₇⁺</td>
<td>225</td>
<td>181</td>
<td>112</td>
<td>157</td>
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<tr>
<td>GOR</td>
<td>625</td>
<td>2000</td>
<td>18,200</td>
<td>105,000</td>
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<tr>
<td>Tank °API</td>
<td>34.3</td>
<td>50.1</td>
<td>60.8</td>
<td>54.7</td>
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<td>Liquid Color</td>
<td>Greenish Black</td>
<td>Medium Orange</td>
<td>Light Straw</td>
<td>White</td>
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</table>

- Wetter gas composition
Compositional Distribution of Reservoir Fluids
Classification of Reservoirs based on Production and PVT data

GAS CONDENSATE RESERVOIRS:

- GOR between 70,000-100,000 SCF/STB
- Density greater than 60 °API
- Light in color
- $C_7^+$ composition $\leq 12.5\%$
Classification of Reservoirs based on Production and PVT data

VOLATILE OIL RESERVOIRS:

- GOR between 1,000-8,000 SCF/STB
- Density between 45-60 ºAPI
- Oil FVF greater than 2.00 (high shrinkage oils)
- Light brown to green in color
- $C_7^+$ composition $\geq 12.5\%$
Classification of Reservoirs based on Production and PVT data

BLACK OIL RESERVOIRS:

- GOR less than 1,000 SCF/STB
- Density less than 45 °API
- Reservoir temperatures less than 250 °F
- Oil FVF less than 2.00 (low shrinkage oils)
- Dark green to black in color
- \( C_7^+ \) composition > 30%
Assignment

Read and make a summary of revised & newer criteria for classification of Reservoir Fluids from given paper by William D. McCain in JPT September 1994
What are the distinctive features of black oils in terms of:

- Initial GOR & GOR vs time
- Initial API & API vs time
- Compositions
- Color
What are the distinctive features of volatile oils in terms of
- Initial GOR & GOR vs time
- Initial API & API vs time
- Compositions
- Color
What are the distinctive features of Condensate gases in terms of:

- Initial GOR & GOR vs time
- Initial API & API vs time
- Compositions
- Color
What are the distinctive features of Dry gases in terms of

- Initial GOR & GOR vs time
- Compositions