CO₂ Foam Project

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Project Goals

• Provide Support to Wyoming Producer for EOR Operations
  – Design experimental protocols in conjunction with vendor
  – Confirm selected surfactants will create foam during CO₂/brine injection for conformance control
  – Test multiple methods of application
    • Surfactant in CO₂ phase
    • Surfactant in water phase

• Determine Recovery Efficiency
• Determine Foam Stability
Project Tasks

• Construct Core Flood Line
• Perform Core Flood Experiments
  – Conducted at reservoir P&T
  – Range of field-relevant flow rates
  – Experiments at Sor
  – Use reservoir oil, brine and rock
  – Foam formation indicated by increase in apparent viscosity of fluid (pressure increase during constant flow)
Task Matrix

- **CO₂ Foam Project**
  - Apparatus Setup
  - Task 1: Surfactant Sorption
    - Line Construction
    - Data Logging
    - Surfactant #1
    - Surfactant #2
  - Task 2: Two-phase
    - Berea Sandstone
    - Reservoir Core
  - Task 3: Three-phase
  - Calibration Curve: Pendant Drop
  - Adsorption Test: Core Flood on Tensleep Core
  - Surfactant #2 Dissolve in CO₂
  - Surfactant #1 Dissolve in Injection Brine
Berea Baseline Test

- Core Flood with Surfactant #1
  - Brine: LSU #4 + surfactant #1
  - Oil: none
  - Gas: pure CO$_2$
  - Rate: 1.0 mL/min
  - Temperature: 71 ℃
  - Pressure: 2800 psi

Pressure increase indicates foam formation present between inlet and middle of core. Foam quenches quickly after brine injection.

![Graph showing pressure changes over injected PV](image-url)
Berea Baseline Test – Flow Rate Variation

- Core Flood 1 with Surfactant #1
  - Core: 9 inch Berea
  - Brine: LSU #4 + surfactant #1
  - Oil: none
  - Gas: pure CO₂
  - Rate: 1.0~4.0 mL/min
  - Temperature: 71 °C
  - Pressure: 2800 psi

Pressure increase indicates foam formation present between inlet and middle of core with slower flow creating more foam.
Berea Test

- **Berea with Surfactant #2**
  - Core: 9 inch Berea
  - Brine: LSU synthetic brine #4
  - Oil: LSU oil
  - Gas: CO₂+ Surfactant #2
  - Rate: 3.15 mL/hour (1 ft/day)
  - Temperature: 71 °C
  - Pressure: 2800 psi
  - 3 P-transducers

No ΔP with Surfactant #2
Reservoir Core Test – no oil

- Core: 9” Reservoir Sandstone
  - Gas Perm: 44 mD
  - Water Perm: 27.3 mD
  - Porosity: 14.77%
- Brine: LSU #4 + surfactant #1
- Oil: none
- Gas: pure CO₂
- Rate: 1.0 mL/min
- Temperature: 71 °C
- Pressure: 2800 psi

Co-inject CO₂ and water/surfactant
Pressure increase indicates foam formation present between inlet and middle of core
Foam quenches rapidly with brine injection
Reservoir Core and Oil

- Three-Phase Tertiary Flooding:
  - Core: Reservoir
  - Brine: LSU #4 + surfactant #1
  - Oil: LSU oil
  - Gas: pure CO₂
  - Rate: 1.0 mL/min
  - Temperature: 71 °C
  - Pressure: 2800 psi
Summary of Results

- **Task 1 – Adsorption Test:**
  - The results show that the monitored adsorption of surfactant #1 is acceptable, surfactant #2 may be too high

- **Task 2 – Foaming Generation Berea and Reservoir Core:**
  - No foam generation was observed with CO$_2$ soluble surfactant #2
  - Surfactant #1 in brine can generate foam both Berea and Reservoir core when co-injecting 10,000 ppm surfactant solution and CO$_2$ gas at the volumetric ratio of 1:9;
  - Pressure drop (foam formation) increases slowly over 3 PVs after the co-injection, significantly greater after 3 to 4 PVs;
  - Foam was observed to be generated only near the inlet (first half of the 9 inch core) and dissipates after surfactant injection was stopped.

- **Task 3 – Complete Tertiary Foam Flooding:**
  - Foam can be generated in the tertiary injecting mode with the existence of the residual oil, no incremental oil recovery by foam was observed after CO$_2$ flooding.
Moving CO$_2$-Foam Forward

- Continue to test other surfactants
- Build Strategic Relationships with Vendors
  - DOW
  - Huntsman
  - AlessaChemie
- Build Strategic Partnerships with producers performing or interested in CO$_2$ EOR
  - Merit
  - Devon
  - Anadarko
  - Marathon
Thank You!