Chemical Flooding the Lansing-Kansas City Formation in Kansas*

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Abstract

The Tertiary Oil Recovery Program at the University of Kansas in cooperation with the Research Partnership to Secure Energy for America (US DOE funded) and industry partners are presently designing a chemical flood for implementation in the Trembley Oilfield, Reno County, KS. The purpose of the project is to test and demonstrate the performance of chemical flooding. An overview of chemical flooding will be presented that will include the basics of the oil-recovery process and considerations for where it might be applied. A summary of the field project and the progress to-date will be reported. The chemical flood design covers laboratory testing to formulate a chemical system that achieves desired performance for the Trembley reservoir (oil, water and rock) and evaluation of the reservoir to design the field implementation. Results of both the laboratory work and the field evaluation will be presented. The Trembley Oilfield produces from a thin bed of oolitic grainstone in the Pennsylvanian Lansing-Kansas City (LKC) interval. Oil production was initially by fluid expansion and like many LKC fields, it has been successfully waterflooded. The Trembley has favorable characteristics to be chemical flooded and good performance should lend promise to the application of chemical flooding of other LKC reservoirs.

References Cited


AAPG Mid-Continent Section Meeting

Chemical Flooding the Lansing-Kansas City Formation in Kansas

Mark Ballard, Petroleum Engineer
Our Partners

Funding
- RPSEA
- BEREXCO

Field Partner
- KU
- TROP
- Tertiary Oil Recovery Program

Surfactant and Formulation
- HUNTSMAN
- Enriching lives through innovation

Polymer and field equipment
- SNF FLOERGER
Capillary Number

Residual oil saturation, %

$k (\Delta p/L) / \sigma$

200 mD
3.0 psi/ft

30 dyne/cm

0.8 dyne/cm

0.3 dyne/cm

0.0075 dyne/cm

Chatzis & Morrow SPEJ, Oct. 1984
Solubilization Ratio $\Rightarrow$ IFT

Salinity

$$IFT = \frac{\text{Solubilization}^2}{\text{Salinity}}$$

IFT $= 0.0075$

Solubilization Ratio $> 10$

Chun Huh, 1979
What does it take?

• Field (target) selection
• Chemical system
• Field implementation
Reservoir Selection

• Field (target) selection
  – Connected Flow Units
  – Volumetric Sweep
Reservoir Selection

Responsive waterflood

Floodable
Significant reservoir sweep
More reservoir data
Available surface facilities
Trembley field

21.6% OOIP
Primary

15.75% OOIP
Secondary

37.35% OOIP
recovered to date
Tracers – connected flow units

- Breakthrough: volume of shortest flow path
- Peak: largest volume flow path
- Mean: calculates Total Swept Volume
Chemical System - Formulation

• Several variables
  – Solubilization (IFT)
  – Salinity
  – WOR
  – Aqueous Phase Stability (APSL)
  – Adsorption
Chemicals

- **Surfactants**
  - mobilize trapped oil
- **Solvents**
  - enhance solubility
- **Sacrificial agents**
  - reduce adsorption
- **Salts**
  - affects behavior
- **Polymer**
  - min. mixing / max. sweep
- **Water**
<table>
<thead>
<tr>
<th>NaCl conc (%)</th>
<th>3.25</th>
<th>3.50</th>
<th>3.75</th>
<th>4.00</th>
<th>4.25</th>
<th>4.50</th>
<th>4.75</th>
<th>5.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5% XOF-100S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1% XOF-600S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0% NaCO₃</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.2% SNF 3330S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Activity Diagram

Graph showing the relationship between Oil Concentration (%) and Salinity (wt% NaCl) with different symbols representing various types. The graph also includes a line representing the Solubilization ratio.
Core 53
(Berea) (includes alkali)

100R10, A10, P20, L42-20
What does it take?

- Field (target) selection
- Chemical system
- Field implementation
  - Injectivity
    - Well workovers
  - Chemical Slug make-up
    - Quality control !!!
  - Production well testing
    - Slug transit & breakthrough
Injection Plant

Block Flow Diagram of Injection Unit

Note that no additional process make-up water is required.
All necessary water enters through the Alkali, Salt, and Polymer stock solutions.

Note that the final metering pumps must be kept in sync to control quality of the Cocktail.

Note that the Alkali, Salt, and Polymer make-up processes can be scaled up by keeping the ratio of inlet water to inlet solid constant.

Polymer Stock Solution concentration was varied to eliminate Make-up Water.
# Injection Plant

## Instructions: Yellow boxes require data entry

1. Enter injection rates
2. Enter wellhead or pump outlet maximum pressure
3. Enter the minimum polymer maturation time
4. Enter the ASP formula
5. Enter data for the state of the delivered chemicals
6. Check the stock solutions for accuracy
7. Enter the actual size of the Polymer Maturation Tank

## 1,900% = 10,000 ppm

### ASP Formula

<table>
<thead>
<tr>
<th>Sulfuric Acid</th>
<th>6,500 ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surfactant 1</td>
<td>2,500 ppm</td>
</tr>
<tr>
<td>Surfactant 2</td>
<td>5,000 ppm</td>
</tr>
<tr>
<td>Alcohol</td>
<td>0 ppm</td>
</tr>
<tr>
<td>Alkali</td>
<td>20,000 ppm</td>
</tr>
<tr>
<td>Polymer</td>
<td>2,000 ppm</td>
</tr>
<tr>
<td>Salt</td>
<td>40,000 ppm</td>
</tr>
</tbody>
</table>

### Chemical Delivered State

<table>
<thead>
<tr>
<th>Phase Form</th>
<th>Activity %</th>
<th>Size</th>
<th>Type</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid</td>
<td>25%</td>
<td>250</td>
<td>gal tote</td>
<td>8.58</td>
</tr>
<tr>
<td>Powder</td>
<td>50%</td>
<td>250</td>
<td>lb super-sack</td>
<td>49.52</td>
</tr>
<tr>
<td>Powder</td>
<td>30%</td>
<td>5.5</td>
<td>lb sack</td>
<td>79.00</td>
</tr>
</tbody>
</table>

### Stock Solutions

<table>
<thead>
<tr>
<th>Sulfuric Acid</th>
<th>5% % active</th>
<th>8.58 lb/gal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surfactant 1</td>
<td>25% % active</td>
<td>8.58 lb/gal</td>
</tr>
<tr>
<td>Surfactant 2</td>
<td>10% % active</td>
<td>6.75 lb/gal</td>
</tr>
<tr>
<td>Surfactant 3</td>
<td>10% % active</td>
<td>8.58 lb/gal</td>
</tr>
<tr>
<td>Alcohol</td>
<td>10% % active</td>
<td>6.75 lb/gal</td>
</tr>
<tr>
<td>Sodium Sulfate</td>
<td>10% % active</td>
<td>9.22 lb/gal</td>
</tr>
<tr>
<td>Polymer</td>
<td>3275 ppm</td>
<td>8.54 lb/gal</td>
</tr>
<tr>
<td>Salt</td>
<td>10% % active</td>
<td>9.60 lb/gal</td>
</tr>
</tbody>
</table>

### Metering Pumps

<table>
<thead>
<tr>
<th>Stock Solution</th>
<th>gal/min</th>
<th>gal/hr</th>
<th>gal/day</th>
<th>lb/hr</th>
<th>lb/day</th>
<th>lb/mo</th>
<th>gal/day</th>
<th>gal/mo</th>
<th>Unknown (as needed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfuric Acid</td>
<td>0.15</td>
<td>8.88</td>
<td>213.1</td>
<td>5.65</td>
<td>75.83</td>
<td>1,313.1</td>
<td>55,508</td>
<td>135.0</td>
<td>6,469</td>
</tr>
<tr>
<td>Surfactant 1</td>
<td>0.06</td>
<td>3.40</td>
<td>81.6</td>
<td>1.94</td>
<td>29.87</td>
<td>700</td>
<td>23,340</td>
<td>10.0</td>
<td>8.46</td>
</tr>
<tr>
<td>Surfactant 2</td>
<td>0.06</td>
<td>3.40</td>
<td>81.6</td>
<td>1.94</td>
<td>29.87</td>
<td>700</td>
<td>23,340</td>
<td>10.0</td>
<td>8.46</td>
</tr>
<tr>
<td>Alcohol</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0</td>
<td>0</td>
<td>0.6</td>
<td>0</td>
</tr>
<tr>
<td>Alum (stock solution)</td>
<td>0.15</td>
<td>9.00</td>
<td>216.1</td>
<td>5.63</td>
<td>75.83</td>
<td>1,313</td>
<td>55,508</td>
<td>135.0</td>
<td>6,469</td>
</tr>
<tr>
<td>Polymer</td>
<td>3.13</td>
<td>133.4</td>
<td>3,166</td>
<td>77.86</td>
<td>530.3</td>
<td>10,606</td>
<td>42,086</td>
<td>1,046</td>
<td>45,887</td>
</tr>
<tr>
<td>Salt</td>
<td>3.01</td>
<td>137.4</td>
<td>3,166</td>
<td>77.86</td>
<td>530.3</td>
<td>10,606</td>
<td>42,086</td>
<td>1,046</td>
<td>45,887</td>
</tr>
</tbody>
</table>

### Dilution Water Rate

<table>
<thead>
<tr>
<th>Rate</th>
<th>gal/min</th>
<th>gal/hr</th>
<th>gal/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

### Main Injection Pump

| Rate | 5,83333 | 350   | 8400   | 200   |

### Polymer Maturation Tank

<table>
<thead>
<tr>
<th>Volume</th>
<th>223.58</th>
<th>5.32</th>
<th>19.89</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>6.65</td>
<td>37.16</td>
<td></td>
</tr>
<tr>
<td>Volume</td>
<td>1.25</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Actual Polymer Maturation Time

| Time | 75.00 minutes | 3.25 hours |
Oil Saturation Profile between Injector and Producer

- **Producer**
- **Injector**

**Oil Bank**

**Surfactant Slug**

**Polymer Push**

**Waterflood**

Sor = 0.35

**ChemFlood**

Sor = 0.05
<table>
<thead>
<tr>
<th>PV</th>
<th>0.052</th>
<th>0.103</th>
<th>0.155</th>
<th>0.207</th>
<th>0.258</th>
<th>0.310</th>
<th>0.362</th>
<th>0.413</th>
<th>0.465</th>
<th>0.517</th>
</tr>
</thead>
</table>

Core 53 effluent collection vials
Concluding Remarks

• Great performance in the lab
• Translating performance to field is challenging
• Advantages for success
  – good waterflood performance
  – inter-well tracer study
  – core material
  – good field data
• Successful demonstration in the Trembley
Thank You

Funding
- RPSEA
- BEREXCO

Field Partner
- KU
- TORP

Surfactant and Formulation
- HUNTSMAN

Polymer and field equipment
- SNF FLOERGER

The University of Kansas

Rock Chalk, JAYHAWK!
Simulation

Grid Thickness (ft) 2013-01-01  K layer: 1
Simulation

All Wells Oil Production

- Actual cumulative oil
- Model cumulative oil
- Actual oil rate
- Model oil rate

Time (Date) vs Cumulative Oil SC (bbl)

Oil Rate SC - Monthly (bbl/day)