Treating Produced Water for Waterfloods

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Facilities Engineering Team

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Case Study: review the history, challenges, advantages, and opportunities of re-using produced water in a Waterflood. Review what has been learned and what is being implemented to improve this re-use process from an infrastructure reliability and injectivity improvement standpoint. Review needs for treatment, definition of treatment targets, and implementation.
Agenda

- Field Overview
- Field Development
- Surface Infrastructure Description
- Operation Description
- Operation Background
- Why treating / Why improving treating?
- Setting the targets
- Addressing the Needs
- Questions
Monument Butte Field Overview

- Fluvial deltaic lacustrine reservoir
  - First well drilled in 1962
- First water Injection in 1986
- SuperUnit unitized in 2009
- 67.5 MMBO produced
- API: +/- 32 – 39 degF
- Pour Point: +/- 98 degF
Monument Butte Development

- 20AC spacing
- 5-spot waterflood development
- Multiple layers
- Discrete sands

- High variance in petrophysical properties
  - Porosity 9-18%
  - Pore throat size range 0.5-20µm
- Currently water is treated down to 5µm
- In this example, many pore throat sizes fall under 5µm
Surface Infrastructure Description

- **Treating / Injection Facilities**
  - Eight injection facilities
    - Produced water treating capacities from 5,000 - 10,000 BWPD per facility via gravity and enhanced gravity
    - Injection capacities from 10,000 - 18,000 BWPD per facility – Total Injection rate 90K to 100K BPD (2,300 psi discharge at facilities)
  - Make-up water sources
    - Green River
    - Johnson city water

- **Injection Pipe Network**
  - Injection network with more than 600 miles of pipe

- **Produced Water Gathering**
  - Trucking
  - Central tank batteries (CTBs)
Surface Infrastructure Description
Operation Description

PRODUCING WELL

PRODUCING WELL SEPARATION FACILITIES (ON PAD)

TREATING / INJECTION FACILITIES

INJECTION WELLS

Make Up Water (River / City)

Skimmed Oil

Pipe Network

Trucking

CTBs

Make Up Water (River / City)

Skimmed Oil

Pipe Network

Trucking

CTBs
Why Treating / Why Improving Treating

- Environmental Stewardship
- Waterflood performance
- Oil Recovery
- Infrastructure reliability
Why Treating / Why Improving Treating

- Injectivity rates – rapid loss of injection
- Oil carryover / improved separation
- Co-mingling of various water sources (produced and make-up)
- Pipe scaling (hardness / scaling components)
- Corrosion (under scale, oxygen, bacteria, ...)
- Process temperature maintenance
**Why Treating / Why Improving Treating**

- **The Challenge is to Sustain Injectivity**
  - Rapid loss of injection

- **Particulate Plugging in Porous Media**
  - “Injection Water Quality – A Key Factor to Successful Waterflooding,” Bennion et al., JCPT, June 1998
  - Larger particles (>33% $d_{pore}$) are trapped on surface of formation at the wellbore
  - Smaller particles (14% < $d_{pore}$ < 33% $d_{pore}$) invade deeper bridging off pore throats – a few inches into the formation
  - Particles less than 14% $d_{pore}$ pass through pores without blockage
Setting the Targets

- Reduce or eliminate solids and other contaminants that generate or promote solids byproducts such as scale deposition and corrosion
- Provide possible additional and sustained injectivity to the waterflood
- Eliminate oil carryover

<table>
<thead>
<tr>
<th>Analyte of Concern</th>
<th>Newfield Target Spec</th>
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<tbody>
<tr>
<td>Max Solids Particle Size (µm)</td>
<td>&lt; 0.6</td>
</tr>
<tr>
<td>Total Suspended Solids (ppm)</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Iron (ppm)</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Total Hardness (ppm, as CaCO3)</td>
<td>&lt; 20</td>
</tr>
<tr>
<td>Free Oil &amp; Grease (ppm)</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>Dissolved Oxygen (ppb)</td>
<td>&lt; 50</td>
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<tr>
<td>Bacteria, SRBs (c/mL)</td>
<td>0</td>
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</tbody>
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Addressing the Needs

Aligning the targets so they address the needs:

- Accelerate existing waterflood process in current patterns through improved and sustained injectivity and accelerate development (new producers) through improved and sustained injectivity
- Improve oil / water separation to increase oil recovery
- Lower related facility and wellbore maintenance costs and infrastructure reliability
  - Reduce pipe scaling (hardness / scaling components)
  - Reduce corrosion (under scale corrosion)
  - Reduce injection pressure loss (\(\downarrow\) friction in pipes, better hydraulics)
  - Increase power efficiency at facilities (\(\downarrow\) HP req’d to overcome friction)
  - Reduce blinding in injection wells
  - Reduce remedial well work associated with tubing scale and corrosion—acid jobs, tubing replacement and cleanouts
Addressing the Needs

Methods / Technologies evaluation:

*Has it been used in the oil field? – Pilot?*

- Progressive Cavity Pumps
  - Reduced droplet shearing / minimize emulsification (chemical use reduction)
- Gunbarrel Tanks / FWKOs
  - Separation efficiency
- Temperature Control / Improved Separation
  - Heat tracing efficiency to uniformly maintain optimum temperature for improved separation (electric heat tracing, hot oil tracing)
  - Tank size reduction for improved temperature control
- Injection Pipe Distribution Network
  - Internally epoxy coated pipe
  - Non-metallic pipe (need for high pressure rating)
- Deoiling hydrocyclones
  - Set up efficiencies (dp, reject rate measuring)
Addressing the Needs

- Chemical Softening
  - Elevate PH to force precipitation and removal of Fe, Hardness (Ca, Mg, Ba), TSS, O&G

- Ultrafiltration (i.e. ceramic membranes):
  - Final polishing of Fe, TSS, O&G, absolute barrier against upsets. Remove SRB’s, particle size to 0.6µm

- Deaerator / Tubular Membranes:
  - Remove dissolved O2

- Photo Electro Catalytic Oxidation:
  - Chemical free bacteria treatment (chemical cost reduction)
Addressing the Needs
Addressing the Needs
Addressing the Needs
Questions