Use of Real-time Monitoring to Minimize Chemical Incompatibility In Hydraulic Fracturing Fluid

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Outline

• Problem Statement
• Gel Compatibility and the Realtime Monitoring
• Slickwater compatibility and the Realtime Monitoring
# Problem Statement

## Water-Based Fracturing Fluid

<table>
<thead>
<tr>
<th>Slickwater</th>
<th>Gel Fluid</th>
</tr>
</thead>
<tbody>
<tr>
<td>• High Retained Conductivity</td>
<td>• May Affect Conductivity</td>
</tr>
<tr>
<td>• Lower Requirement on Water Quality</td>
<td>• Higher Water Quality Requirement</td>
</tr>
<tr>
<td>• Less Chemical, Lower Cost</td>
<td>• More Chemicals, Higher Cost</td>
</tr>
<tr>
<td>• Larger Water Volume</td>
<td>• Lower Water Volume</td>
</tr>
<tr>
<td>• Larger Horsepower</td>
<td>• Smaller Horsepower Requirement</td>
</tr>
<tr>
<td>• Reduced Performance for Larger Proppant</td>
<td>• Transport Large Proppants</td>
</tr>
</tbody>
</table>

- High pump pressure
- Gel failure
- Premature crosslinking
Cross-linked gel fluids

- Borate or Zirconium Crosslinker
- TSS, TDS, Chlorides, Hardness and Boron all affect gel compatibility.
- Once Gel recipe is developed water quality must remain in a narrow range to maintain gel compatibility
- Control of water quality is paramount
Gel Compatibility Testing

Rheology Testing
• Viscosity
• Gel Stability
• Break Time
Crosslink Gel Compatibility

Slide 1 of 2

- Gel Test with Borate Crosslinker
- No Adjustments made
- Purely trying to identify compatibility issues

Viscosity vs. Time
Instantaneous Borate Crosslink System
25ppt Guar

![Viscosity vs. Time Graph]

- 60/40 Fresh / Treated Produced Water
- 60/40 Fresh / Untreated Produced Water
- 100% Untreated Produced Water
- Temperature (F)
Crosslink Gel Compatibility

- Temperature affected stability
- 70/30 Blend showed significant improvement with temperature
- No changes in crosslinker concentration for 70/30 blend
- No pH adjustment for 70/30 blend
- No Buffers

Viscosity vs. Time
Delayed Borate Crosslinked Fluid at 250°F
9-100 and 9-101 Water Samples

- 60/40 Untreated Water
- 60/40 Treated Water
- 60/40 Treated Water, Lower pH
- 60/40 Treated Water, Adjusted Caustic Concentration
- 60/40 Treated Water, Adjusted Crosslinker Concentration
- 70/30 Treated Water
- 70/30 Untreated Water
Real Time Water Quality Monitoring for Crosslinked Gel Frac

- Chloride / TDS
  - Good Indicator of Quality
  - Monitor Blend Consistency
  - For KCl Equivalency
- Boron
  - To Identify Inhibitor Dose Rate
- Bacteria Disinfection Monitoring
  - Test Influent/Effluent
  - Test Working Tanks
- Other Parameters
  - pH / TSS / Hardness etc
## Real Time Water Quality Monitoring

**Keep Water Quality Consistent – Adjust Blend Rate Stage by Stage**

### Water Volume and Production Data

<table>
<thead>
<tr>
<th>Stage</th>
<th>Fresh Water, bbl</th>
<th>Produced Water, bbl</th>
<th>% Produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre*</td>
<td>1690</td>
<td>620</td>
<td>26.8%</td>
</tr>
<tr>
<td>1</td>
<td>7340</td>
<td>2540</td>
<td>25.7%</td>
</tr>
<tr>
<td>2</td>
<td>7360</td>
<td>2300</td>
<td>23.8%</td>
</tr>
<tr>
<td>3</td>
<td>6560</td>
<td>2430</td>
<td>27.0%</td>
</tr>
<tr>
<td>4</td>
<td>6190</td>
<td>2430</td>
<td>29.8%</td>
</tr>
<tr>
<td>5</td>
<td>6020</td>
<td>2630</td>
<td>30.2%</td>
</tr>
<tr>
<td>6</td>
<td>6450</td>
<td>2580</td>
<td>28.6%</td>
</tr>
<tr>
<td>7</td>
<td>6320</td>
<td>2420</td>
<td>27.7%</td>
</tr>
<tr>
<td>8</td>
<td>5890</td>
<td>2620</td>
<td>30.8%</td>
</tr>
<tr>
<td>9</td>
<td>5940</td>
<td>2650</td>
<td>30.8%</td>
</tr>
<tr>
<td>10</td>
<td>5980</td>
<td>2520</td>
<td>29.6%</td>
</tr>
<tr>
<td>11</td>
<td>6670</td>
<td>2480</td>
<td>27.1%</td>
</tr>
<tr>
<td>12</td>
<td>6460</td>
<td>2380</td>
<td>26.9%</td>
</tr>
<tr>
<td>13</td>
<td>6370</td>
<td>2580</td>
<td>28.8%</td>
</tr>
<tr>
<td>14</td>
<td>6010</td>
<td>2490</td>
<td>29.3%</td>
</tr>
<tr>
<td>15</td>
<td>2990</td>
<td>1090</td>
<td>26.7%</td>
</tr>
</tbody>
</table>

### Graphical Representation

- **x-axis**: Stage (1 to 15)
- **y-axis**: Water Volume (bbl)
- **Legend**: Fresh Water, bbl, Produced Water, bbl, % of Produced
Real Time Water Quality Monitoring

Keep Water Quality Consistent

KCl Equivalent of the Treated Water

Chloride, mg/L

KCl Equivalent
Produced Water
Treated Water

Stage Number

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Real Time Water Quality Monitoring

Keep Water Quality Consistent

![Graph showing Boron in Produced Water and Treated Water](image)

- **Boron in Produced Water, mg/L**
- **Boron in Treated Water, mg/L**

- **Stage Number**

- **Pre* to Stage 15**

- **Produced Water**
- **Treated Water**
Bacteria Monitoring

How do we confirm disinfection

- Source Water
  - Bacteria Testing
  - Baseline Testing
- Influent/Effluent of Treatment System
  - Bacteria Testing
  - Continuous Testing
- Residual Disinfection / Working Tanks / Blenders
  - Bacteria Testing
  - Continuous Testing
- Proppant Testing
- Drillout and Flowback Monitoring
What do we use for Bacteria Testing
Real-Time Bacteria Treatment Monitoring

- Testing conducted on location, Real-Time confirmation
- Test the influent and effluent at different stages throughout the frac
Slickwater

Non-ionic

- Three groups of FR
- Reduction of friction by 50% - 60% is possible

Anionic

- May degraded by biocides or oxidants
- May affected by other coexisting chemicals

Cationic
Effect of Ca$^{2+}$ on Anionic FR

Average % Reduction vs. Time in 1/2-in Smooth Pipe
Looking at effects of Ca$^{2+}$ on 2.5 lb/Mgal of Anionic FR

J. Bryant etc, Halliburton
# Selection of Oxidative Biocides

<table>
<thead>
<tr>
<th>Oxidant</th>
<th>Oxidation Potential, V</th>
<th>Half-Life @ 20°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydroxyl Radicals</td>
<td>2.8</td>
<td>&lt; 1 sec</td>
</tr>
<tr>
<td>Ozone</td>
<td>2.3</td>
<td>20 min.</td>
</tr>
<tr>
<td>Hydrogen Peroxide</td>
<td>1.8</td>
<td>Hours</td>
</tr>
<tr>
<td>Chlorine Dioxide</td>
<td>1.5</td>
<td>93 min.</td>
</tr>
<tr>
<td>Chlorine</td>
<td>1.4</td>
<td>140 min.</td>
</tr>
</tbody>
</table>
Realtime Monitoring for Slickwater Frac

Field Friction Loop Test

- Water sample
- Pressure reducing valve
- Shut off valve
- Flow control valve
- 7 kPa pressure sensor
- Test section
- Volumetric Detector
- 7 kPa pressure sensor

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H₂O
Friction Reducer Compatibility

Friction Testing Baseline

Pressure Differential, PSI vs. Time, min

- Baseline
- 0.5 gpt
- 1 gpt
Friction Reducer Compatibility

Friction Testing – Chlorine Dioxide

![Graph showing friction reduction over time for different treatments: Baseline + 0.5 gpt FR, ClO₂ Treated Water, and ClO₂ Treated Water + 0.5 gpt FR. The graph illustrates the percentage of friction reduction over time (in minutes) with various treatments. The x-axis represents time in minutes, ranging from 0 to 20, and the y-axis represents the percentage of friction reduction, ranging from -40% to 40%. The graph shows a decreasing trend in friction reduction over time for all treatments, with the ClO₂ Treated Water + 0.5 gpt FR showing the least reduction at any given time.]

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Friction Reducer Compatibility

Friction Testing – Ozone

-10%  0%  10%  20%  30%  40%  50%  60%
0  5  10  15  20

% Friction Reduction

Time, min

Untreated + 0.5 gpt FR  Treated  Treated + 0.5 gpt FR
Disinfection vs. Compatibility

*Slickwater: HZO vs. Biocide vs. Chlorine Dioxide*

<table>
<thead>
<tr>
<th>Water Treatment Technology</th>
<th># of Wells</th>
<th>FR Concentration, % in mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biocide</td>
<td>22</td>
<td>0.0123</td>
</tr>
<tr>
<td>ClO₂</td>
<td>9</td>
<td>0.0146</td>
</tr>
<tr>
<td>Hydrozonix</td>
<td>27</td>
<td>0.0042</td>
</tr>
</tbody>
</table>

Friction Reducer Concentration, % in mass vs. Fracturing Date

Fracturing Dates:
- 2012/10/18
- 2012/12/7
- 2013/1/26
- 2013/3/17
- 2013/5/6
- 2013/6/25
- 2013/8/14
- 2013/10/3
- 2013/11/22
Friction Reducer Compatibility

Case 1: FR / SI

- FR concentration was at 1.0 gpt, SI concentration was at 0.25 gpt. Both of the chemicals were obtained from ProPetro.
- Test was run at 1.5 L/min, room temperature.
- Clearly, there is the incompatibility of the FR with the SI.
- Ozone treatment reduced the friction factor of the water.
Friction Reducer Compatibility

Case 2: Friction Testing for Two Different FRs

- FR1 vs FR2.
- First 20 minutes was baseline test. FR was added at time 20 min, following by the addition of breaker (XPA) at time 40 min.
- Both FRs were effective.
- No significant difference between untreated and treated water.
- Rapid Increase of pressure after XPA addition
Friction Reducer Compatibility

**Case 2: Friction Testing for Two Different FR**

- FR1 vs FR2.
- First 20 minutes was baseline test. FR was added at time 20 min, following by the addition of breaker (XPA) or SI at time 40 min.
- SI had little impact on the performance of either FR.
- FR1 might have been interfered by other frac chemicals.
Takeaways

• For Gel Fluid
  – Maintain the water quality in a narrow range
  – Gel compatibility test needs to be conducted to determine proper recipe
  – Monitoring of blend rate, chloride, TDS and boron level is necessary
  – Bacteria monitoring is important

• For Slickwater
  – Different types of FR have different tolerances on water quality change
  – Proper selection of disinfection technology
  Field friction loop testing to confirm compatibility
Thank You