Review Well Testing for Western Kentucky Deep Well Project

February 7, 2008
Injectivity Test Objectives  
(First Pass)

• Prove can inject/dispose CO2 in either of the St Peter, Knox or Mt. Simon
• Determine reservoir characteristics of the reservoirs selected for injection
Well Test Study

• Reviewed old test data
• Estimated K ranges for Mt Simon and Knox
• Made PTA* simulations for proposed well
• Designed injectivity test scenarios for test well

*Pressure Transient Analysis
Permeability Estimates

• Permeability estimates for the Mt. Simon and Knox horizons are based on test data from DuPont WAD #1 (~ 40 miles away)
• Mt Simon’s average perm is in the range of .4 to 1.8 md. Knox’s average perm is 0.4 to 3.2 md after test data normalized using porosity and adjusted to new expected depths.
• It is recognized that the bottom 20 ft section of Knox had fractures that contributed to ~ 70% of the injection, which would calculate ~ 95 md equivalent perm.
• Target well will be acid stimulated and expect to tie in to potential fractures network
# PTA Simulation Work Summary

## Mt. Simon

<table>
<thead>
<tr>
<th>Case</th>
<th>K (md)</th>
<th>Perf (ft)</th>
<th>Skin</th>
<th>Max Inj Rate</th>
<th>KvKh</th>
<th>t to IARF</th>
<th>1st Stab</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>md</td>
<td>ft</td>
<td></td>
<td>bpd</td>
<td></td>
<td>Hrs</td>
<td>Days</td>
</tr>
<tr>
<td>1</td>
<td>0.4</td>
<td>700</td>
<td>0</td>
<td>1500</td>
<td>1</td>
<td>10</td>
<td>0.4</td>
</tr>
<tr>
<td>2</td>
<td>1.8</td>
<td>700</td>
<td>0</td>
<td>5500</td>
<td>1</td>
<td>4</td>
<td>0.2</td>
</tr>
<tr>
<td>3</td>
<td>0.4</td>
<td>300</td>
<td>0</td>
<td>600</td>
<td>0.1</td>
<td>800</td>
<td>33.3</td>
</tr>
<tr>
<td>4</td>
<td>1.8</td>
<td>300</td>
<td>0</td>
<td>2800</td>
<td>0.1</td>
<td>200</td>
<td>8.3</td>
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</tbody>
</table>

## Knox

<table>
<thead>
<tr>
<th>Case</th>
<th>K (md)</th>
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<td></td>
<td>bpd</td>
<td></td>
<td>Hrs</td>
<td>Days</td>
</tr>
<tr>
<td>1</td>
<td>0.4</td>
<td>2500</td>
<td>0</td>
<td>5000</td>
<td>1</td>
<td>3</td>
<td>0.1</td>
</tr>
<tr>
<td>2</td>
<td>1.8</td>
<td>2500</td>
<td>0</td>
<td>6000</td>
<td>1</td>
<td>2</td>
<td>0.1</td>
</tr>
<tr>
<td>3</td>
<td>0.4</td>
<td>300</td>
<td>0</td>
<td>1000</td>
<td>0.1</td>
<td>20000</td>
<td>833.3</td>
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<tr>
<td>4</td>
<td>1.8</td>
<td>300</td>
<td>0</td>
<td>4000</td>
<td>0.1</td>
<td>5000</td>
<td>208.3</td>
</tr>
</tbody>
</table>
## Knox Simulations Basis Used for Injectivity Test

<table>
<thead>
<tr>
<th>Case</th>
<th>K (md)</th>
<th>Perf (ft)</th>
<th>Skin</th>
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<td></td>
<td>bpd</td>
<td></td>
<td>Hrs</td>
<td>Days</td>
</tr>
<tr>
<td>1</td>
<td>0.4</td>
<td>2500</td>
<td>0</td>
<td>5000</td>
<td>1</td>
<td>3</td>
<td>0.1</td>
</tr>
<tr>
<td>2</td>
<td>1.8</td>
<td>2500</td>
<td>0</td>
<td>6000</td>
<td>1</td>
<td>2</td>
<td>0.1</td>
</tr>
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<td>3</td>
<td>0.4</td>
<td>300</td>
<td>0</td>
<td>1000</td>
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<td>20000</td>
<td>833.3</td>
</tr>
<tr>
<td>4</td>
<td>1.8</td>
<td>300</td>
<td>0</td>
<td>4000</td>
<td>0.1</td>
<td>5000</td>
<td>208.3</td>
</tr>
</tbody>
</table>
Option 1
Mt Simon and Knox Test

• Drill to TD and run 5-1/2” Long String as planned
• Perf and test Mt Simon
  – Perf a 700-ft section
  – Perf a 300-ft section
• P/A Mt Simon
• Perf and test Knox
  – Perf all 2500ft
  – Perf a 700-ft section
  – Perf a 300-ft and 100-ft section
• P/A Knox
Option 2
Mt Simon and St Peter/Knox Test

• Drill to TD and run 5-1/2” Long String as planned
• Perf and test Mt Simon
  – Perf a 700-ft section
  – Perf a 300-ft section
• P/A Mt Simon
• Perf and test St Peter and Knox
  – Perf St Peter 200-ft section and test
  – Perf a 700-ft section of Knox
  – Commingled Test of Knox and St Peter
• P/A St Peter and Knox
Option 3
Mt Simon and Open-Hole Knox Test

• Drill to TD and run 5-1/2” Long String. Cement the 5-1/2” casing and leave string set for retrieval after first test.
• Perforate and test Mt Simon
  – Perf a 700-ft section
  – Perf a 300-ft section
• P/A Mt Simon
• Cut 5-1/2” casing above Mt Simon and expose all Knox
• Test Knox Open Hole
• P/A Knox
Option 4
Open-Hole Mt Simon Test and Knox Test

• Drill to TD. Run 5-1/2” LS from surface to top of Mt Simon. Cement 5-1/2” string and leave string set for either a cased hole or OH test of the Knox
• Perform OH test on Mt Simon
• P/A Mt Simon
• Test Knox
  – OH after cut/retrieving 5-1/2” section or
  – Perf a 700-ft section
  – Perf a 300-ft section
• P/A Knox
• Test St Peter
• P/A Knox
# Injection Test Rates, Pressures and Volumes

## Planned Tests

<table>
<thead>
<tr>
<th>Formation</th>
<th>Injection hrs</th>
<th>FallOff hrs</th>
<th>Max Rate bwpd</th>
<th>Volume Inj bbls</th>
<th>Max Inj Press psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mt Simon</td>
<td>6</td>
<td>24</td>
<td>6000</td>
<td>1500</td>
<td>5720</td>
</tr>
<tr>
<td>Knox</td>
<td>6</td>
<td>24</td>
<td>6000</td>
<td>1500</td>
<td>4000</td>
</tr>
<tr>
<td>St Peter</td>
<td>6</td>
<td>24</td>
<td>6000</td>
<td>1500</td>
<td>2800?</td>
</tr>
<tr>
<td><strong>(totals)</strong></td>
<td><strong>12</strong></td>
<td><strong>48</strong></td>
<td></td>
<td></td>
<td><strong>3000</strong></td>
</tr>
</tbody>
</table>

Note: Knox data above assumes fractures are present.

## Typical Injectivity Test

<table>
<thead>
<tr>
<th>Pumping Schedule</th>
<th>Fall off Time</th>
<th>Total Hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pumped</td>
<td></td>
<td></td>
</tr>
<tr>
<td>bpm</td>
<td>bpd</td>
<td>min</td>
</tr>
<tr>
<td>1</td>
<td>1440</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>2880</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>5760</td>
<td>20</td>
</tr>
<tr>
<td>4.167</td>
<td>6000</td>
<td>300</td>
</tr>
<tr>
<td><strong>totals</strong></td>
<td><strong>360</strong></td>
<td><strong>6</strong></td>
</tr>
</tbody>
</table>

Note: Knox data above assumes fractures are present.
Envisioned Injectivity Test

Perforate Mt Simon & set up tanks & other testing equipment
Run test packer w/ no go
Swab/test well (pits/frac tank) until cleaned up, take produced water samples
Inject Saltwater as required for injectivity test
SI well for fall-off
Injectivity test for PLT run?
Inject Saltwater as step-rate test to fracture rate
Kill well and abandon zone with BP and bailed cmt
Pressure test BP
Perforate Knox
Acidize as required
Inject Saltwater as required for injectivity test
SI well for fall-off
Injectivity test for PLT run?
Inject CO2 (3 - 6,000 tons)
SI well for fall-off
Inject Saltwater as step-rate test to fracture rate
Flow back well until dead or kill
Kill well and abandon zone with BP and bailed cmt
Special Test Considerations

- Sampling
- Production Log Tests
- Acidizing
- Test sequence
- Interference testing?
Supporting Data
Mt Simon/St Peter Porosity-Permeability Data

\[ y = 576.379533e^{-0.000822x} \]

\[ R^2 = 0.525051 \]
Mt Simon/St Peter Porosity Data

\[ y = 15044e^{-0.1199x} \]

\[ R^2 = 0.9751 \]
END