Field Trials of Plugging Oil and Gas Wells with Hydrated Bentonite

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Outline

• Introduction
• Advantages of Bentonite Plugs
• California Field Trials
• West Texas Field Trials
• Oklahoma Field Trial

• New Mexico Field Trial
• Barrow Island Trial
• Wyoming Field Trials
• Queensland Field Trial
• Conclusions
Advantages of Bentonite Plugs

• Heals itself if disturbed
• Immune to seismic events, deformation of casing, salt intrusion etc.
• Workover rig often not required
• Cheaper and more reliable plugging operation
Field Trials in California

• Performed in Coalinga Field, by Chevron Environmental Management Company in 2001

• 19 total wells, including primary producers, waterflood producers/injectors, and steamflood producers
Typical Abandonment Design

- Freshwater present
- Cement in annulus covers freshwater
- 100’ bentonite needs to cover freshwater interface
Field Results

• All 19 of the plugs met California’s DOGGR approval

• Hydrating time of bentonite was observed to be affected by water temperature

• Bridging observed with bentonite, particularly in hot water

• Bridging observed with gravel, particularly in cold water

• Hydrated well in the presence of oil and water
Chevron Further Experience in California

• Have been plugging 500-1000 wells per year for 15 years

• 8,000-10,000 wells have been plugged with bentonite nodules

• Failures are rare and fixable
West Texas Field Trials

- Chevron, Texaco, Apache and Phillips jointly conducted some plugging trials on a series of wells in West Texas in 2002.
- The results of these tests have not been previously published but the these details were reported to the Texas Railroad Commission.
- The 21 wells were completed in highly saline formations and so represented a more severe test for bentonite plugging effectively in saline water.
- The wells were spread between the McElroy, Penwell, Spraberry, North Robertson and North Ward-Estes fields.
West Texas Field Trials

The wells were primarily perforated in the San Andres formation or the Grayburg or the Glorietta formation with the Rustler, Yates and Queen formations further up-hole and bentonite plugs were usually set across each of these formations.
West Texas Field Trials

- There was also a shallow fresh water formation (at 500-700 ft), usually the Ogalala or the Santa Rosa, to be protected with a fifth plug, and a sixth plug was set at surface.

- The bentonite plugs were set on top of slick-line set wiper plugs.

- All of the 21 wells were successfully plugged and tested. Up to seven plugs were set in some of the wells.
Field Trial in Australia

- Barrow Island field, Windalia Reservoir
- Single well field trial in 2002
- Planned to apply it to a 100 well abandonment program
Barrow Island Field Trial

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reservoir depth (ft)</td>
<td>2100</td>
</tr>
<tr>
<td>Formation temperature (Deg. F)</td>
<td>146</td>
</tr>
<tr>
<td>Initial reservoir pressure (psia)</td>
<td>995</td>
</tr>
<tr>
<td>Bubble point (psia)</td>
<td>978</td>
</tr>
<tr>
<td>Oil viscosity @ bubble point (cp)</td>
<td>0.653</td>
</tr>
<tr>
<td>Fluid gravity @ 60 deg F (Deg. API)</td>
<td>36</td>
</tr>
<tr>
<td>GOR (scf/stb)</td>
<td>250</td>
</tr>
<tr>
<td>Average sand thickness (ft)</td>
<td>100</td>
</tr>
<tr>
<td>Average net/gross</td>
<td>0.74</td>
</tr>
<tr>
<td>Average permeability (md)</td>
<td>5</td>
</tr>
<tr>
<td>Average porosity (%)</td>
<td>28</td>
</tr>
</tbody>
</table>
## Barrow Island Field Trial

### Table 2: Barrow Island well status (October 2002)

<table>
<thead>
<tr>
<th>Well type</th>
<th>Active</th>
<th>Shut-in</th>
<th>Abandoned</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Producers</td>
<td>469</td>
<td>115</td>
<td>23</td>
<td>607</td>
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<tr>
<td>Water source</td>
<td>2</td>
<td>5</td>
<td>0</td>
<td>7</td>
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<tr>
<td>Water injectors</td>
<td>246</td>
<td>24</td>
<td>0</td>
<td>270</td>
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<tr>
<td>Water disposal</td>
<td>4</td>
<td>9</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>721</strong></td>
<td><strong>153</strong></td>
<td><strong>23</strong></td>
<td><strong>897</strong></td>
</tr>
</tbody>
</table>
Barrow Island Field Trial
Plugging cost comparison (Australia)

<table>
<thead>
<tr>
<th></th>
<th>Cement</th>
<th>Zonite</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time (hrs)</td>
<td>Cost ($000)</td>
</tr>
<tr>
<td>MIRU, well control</td>
<td>12</td>
<td>2.5</td>
</tr>
<tr>
<td>Running bridge plug</td>
<td>6</td>
<td>2.5</td>
</tr>
<tr>
<td>Deep cement plug</td>
<td>6</td>
<td>7.5</td>
</tr>
<tr>
<td>Waiting on cement</td>
<td>6</td>
<td>2.5</td>
</tr>
<tr>
<td>Pour Zonite</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Shallow Zonite retainer</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Shallow cement plug</td>
<td>6</td>
<td>7.5</td>
</tr>
<tr>
<td>Waiting on cement</td>
<td>6</td>
<td>2.5</td>
</tr>
<tr>
<td>Pour Zonite</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Surface casing cement</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Wellhead removal</td>
<td>6</td>
<td>2.5</td>
</tr>
<tr>
<td>Contingency</td>
<td>6</td>
<td>2.5</td>
</tr>
<tr>
<td>SUB TOTAL</td>
<td>60</td>
<td>35</td>
</tr>
<tr>
<td>Supervision</td>
<td>48</td>
<td>2.5</td>
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<tr>
<td>GRAND TOTAL</td>
<td>60</td>
<td>37.5</td>
</tr>
</tbody>
</table>
Oklahoma and New Mexico

- Twenty-five wells in New Mexico and six wells in Oklahoma were plugged in separate trials.

- Further details on the Oklahoma and New Mexico trials are contained in the SPE paper.
Chevron Zonite: Problems

1. The size and shape of the nodules make them prone to bridging
2. The final moisture content of the plug, and therefore the plug strength, cannot be controlled or modified
Solution we propose: Bullet shaped Bentonite bars

• Compressed cylindrical bullet shaped bentonite bars are designed to overcome the bridging problem.

• The geometry of the plug can be varied to control the final moisture content and, therefore, the final strength

• Strength has been tested in the lab using dislodgement pressure
Field Trials in Wyoming

- 3 wells in Teapot Dome field, Wyoming have been plugged with bentonite and are monitored every 1 to 5 years.

- 3rd one described here.
3rd Wyoming Field Trial

- At Rocky Mountain Oilfield Testing Center
- Teapot Dome Field
- Just North of Casper Wyoming
- April 15-May 5, 2009
3rd Wyoming Field Trial
Dropping Bottom Plugs (With No Fluid At Surface)
Pressure Testing the Bottom Plug (300psi, 15min)
Towler Sling Plug
3rd Wyoming Field Trial
Queensland Field Trial

- University of Queensland has proposed bentonite plugging for CSG wells in Queensland. Research sponsored by Centre for Coal Seam Gas at UQ, funded by QGC (Shell), APLNG, Arrow and Santos
- Field Trial of process was approved by Qld DNRM.
- Trial commenced on 27 July, 2016
- Bellevue GW#3
- Allowed to hydrate for one month and pressure tested on 30 August, 2016. Held an applied surface pressure of 500 psig for one hour. Was tested again on 6th February, with one more test to come.
## Test Well

### Well: Bellevue GW3

#### Surface Casing Cementation
- **Conductor ID**: 0.000 in
- **Conductor Depth**: 0.0 m
- **Open Hole Size**: 17.000 in
- **Casing OD**: 14 in
- **Weight**: 65 lb/ft
- **Casing Type**: X42
- **Shoe depth**: 7.6 m
- **Pumped volume**: 3.9 bbl
- **Calculated volume**: 3.9 bbl
- **OH - Casing (excess)**: 50%
- **Shoe Track (volume)**: 0.5 bbl
- **OH - Casing (with excess)**: 3.4 bbl
- **Conductor - Casing**: 0.0 bbl

### Existing P&A Cement Plug Details

**Cement Details:**
- **1. Plug in Production Casing**
  - **Top**: 0 m
  - **Bottom**: 196 m
  - **Volume**: 25.3 bbl

**Total Volume Required**: 25.3 bbl

**Note**: Reported as cemented to surface

#### Production Casing Cementation
- **Open Hole Size**: 8.500 in
- **Casing OD**: 7.000 in
- **Casing ID**: 6.366 in
- **Weight**: 23 lb/ft
- **Casing Type**: K55 BTC
- **Shoe depth**: 196 m
- **Pumped volume**: 22.0 bbl
- **Calculated volume**: 21.6 bbl
- **Shoe Track (length)**: 12.0 m
- **OH - Casing (excess)**: 25.0%
- **Shoe Track (volume)**: 1.5 bbl
- **OH - Casing (with excess)**: 17.4 bbl
- **Surf casing - Prod Cas**: 2.7 bbl

**Perforations from 42 - 175 m**

### Diagram

- **Existing Cement**: Shade
- **P&A Bentonite**: Stripes
The movie adaptation
Summary Operations I

Wednesday 27th July

• Well was topped up with fresh water
• 5 plugs were dropped at 30 second intervals
• Tagging with CT indicated the plugs were placed at expected depth

Thursday 28th July

• Two batches of 100 plugs each were dropped successfully at 10 second intervals and tagged at expected depth
• Bridging identified after the next 176 plugs dropped
• Pushing on plugs and the use of a jetting tool unsuccessful

Friday 29th July

• Two bridged sections drilled out and top of actual plug tagged
Summary Operations II

Saturday 30\textsuperscript{th} July

- Scraper used to clean the casing above the plug
- Plugs dropped in groups of 50 at 15 second intervals with tagging at the end of each batch
- 443 plugs dropped successfully, with a final tag at 29.57 mGL

Sunday 31\textsuperscript{st} July

- A further 77 plugs dropped, tagged at a depth of 12 mGL, as planned in the program

Pressure testing occurred on 30\textsuperscript{th} August (4 weeks later) and again on February 6\textsuperscript{th}, 2017.
Mud Motor on CTU to drill out bridge
Scraper Run
Possible reason for bridging off

Based on handling issues of the plugs with workers wearing safety gloves, a couple of plugs were damaged by the sharp edges of the thread inside the casing collar while dropping the plugs and may have been broken while falling down the well, tilted, got stuck and finally created bridges.

Solutions:
- Revise the size of plug to make it a smaller diameter.
- Additional training of the workers involved in the dropping process (the trial demonstrated the importance of ensuring that plugs are dropped in the centre of the bore, with no contact with the casing collar)
- Different gloves could be used for plug handling?
- Short term: Design of a PVC attachment covering the casing collar thread and a tube to support/guide vertical dropping
- Long term: Semiautomatic handling system: rotatable revolver/cylinder magazine and conveyor belt
Resumed dropping plugs after clearing bridge
Pressure Testing
August 2016 Pressure Test
February 2017 Pressure Test
Future Activity

- A further pressure test for Bellevue GW#3 in ~ 6 months
- Surface abandonment and government documentation will be completed if test results are satisfactory.
- Currently seeking to identify wells for additional field trials.
Conclusions

• Bentonite has been widely used in USA to plug water wells, seismic shot holes

• ~10,000 shallow oil and gas wells in California’s San Joaquin Basin have been plugged with bentonite

• Field trials have been also successfully conducted in West Texas, Oklahoma, New Mexico, Wyoming, Western Australia and Queensland.
Acknowledgements / Thank You / Questions

Acknowledgements
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Disclosure
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The Centre conducts research across Water, Geoscience, Petroleum Engineering and Social Performance themes.

For more information about the Centre’s activities and governance see…
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