Best Practices in Unconventional (Shale) Well Cementing

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Technical Manager
Europe & Sub Saharan Africa Cementing
Agenda

- The Well Construction Process
- The Well Cementing Process
- Quality Assurance
- Cementing Placement & Evaluation
- USA Shale Well Experience
- Basin Specific Shale Best Practices
Well Construction
The Well Cementing Process

“Oil well cementing is the process of mixing a slurry of cement and water and pumping it down through steel casing to critical points in the annulus around the casing or in the open hole below the casing string.”

Source: Society of Petroleum Engineers, Cementing Monograph Volume 4, 1990
Reasons to Use the Cementing Process

- Restrict fluid movement between formations
- Manage formation pressures
- Seal off zones (i.e. water, thief, producing)
- Bond and support the casing
- Protect from corrosion
- Protect from shock loads

Source: Society of Petroleum Engineers, Cementing Monograph Volume 4, 1990
Purpose of Conventional Cementing

- Wellbore stability
- Zonal isolation
  - E.g., Seals annular space to provide hydraulic isolation (especially between fracture stages)
Cementing Process Goal:
Deliver Seal for the Life of the Well

- Long Term Zonal Isolation
- Help Increase Production and minimize the occurrence of sustained casing pressure
- Help Minimize Remedial Costs
- Help Reduce Environmental Impact
Key Elements of the Well Cementing Process

- **Materials**
  - Portland Cement (powder)
  - Cementing Additives
  - Water

- **Equipment**
  - Cement Mixing
  - Well Service Pumps
  - Cement Transport

- **Process Components**
  - Clean drilling fluid from the hole (displacement)
  - Avoid contamination of the cement
  - Cement slurry placement down hole – retain fluid characteristic
  - Quickly form a seal / harden once pumping has stopped – mechanical property development
  - Retain a seal for the life of the well
Cement Placement Planning Considerations

- Condition the Drilling Fluid
- Centralize the Casing
- Utilize Spacers & Flushes
- Move the Pipe
- Maximize Displacement Rate
- Design Slurry for Well Temperature
- Design Cementing System
- Test the Cementing Composition

(OGJ July 2001)
Cementing Quality Assurance Standards

Cement slurries are designed using standards and procedures located in:

- ISO Standards
  - ISO10426-2 Testing of well cements
  - ISO 10426-3 Testing of deepwater well cement formulations
  - ISO 10426-4 Preparation and testing of foam cement slurries at atmospheric pressure
  - ISO 10426-5 Determination of shrinkage and expansion of well cement formulations at atmospheric pressure
  - ISO 10426-6 Methods for determining the static gel strength of cement formulations
## Cementing Quality Assurance Testing

<table>
<thead>
<tr>
<th>Laboratory Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickening Time</td>
</tr>
<tr>
<td>Compressive Strength</td>
</tr>
<tr>
<td>Foam Compressive Strength</td>
</tr>
<tr>
<td>Free Water</td>
</tr>
<tr>
<td>Fluid Loss</td>
</tr>
<tr>
<td>Rheology</td>
</tr>
<tr>
<td>FYSA Rheology</td>
</tr>
<tr>
<td>Transition Time</td>
</tr>
<tr>
<td>Stability</td>
</tr>
<tr>
<td>Mud Balance Density</td>
</tr>
<tr>
<td>Slurry Mixability</td>
</tr>
<tr>
<td>Spacer – Mud Compatibility</td>
</tr>
<tr>
<td>Spacer wettability – conductivity</td>
</tr>
<tr>
<td>Spacer wettability – glass rod</td>
</tr>
</tbody>
</table>
Cement Placement: Operations / Equipment

Control Area

Cement Head

Bulk Material Delivery

Hydraulic Horsepower
Cementing Placement
Implement Operational Plan

Maximize Pump Rate
- Mud Displacement Efficiency
  - Dependent on drilling fluid (SPE 14198)

Hole Cleaning & Mud Properties
- Remove cuttings, Use Sweeps
- Optimize Mud Properties

Spacer Selection
- Density, Viscosity, Volume
- Compatibility/Wettability
- Tuned Spacer IV & V

Mechanical Aids
- Rotation, Reciprocation
- Multiple bottom plugs

Temperature Determination
- WELLCAT™ Software, iCem® service, W. Logs
  - DTS Fiber Optics

Centralization
- Isolation between stages, Perf initiation
  - Getting casing to bottom

ISO/API Standards & Applicable Management Systems
Results Evaluation

Poor cement placement can require remedial cementing operations.

Poor Bond Log

Excellent Bond Log
## US Shale Play Characteristics – High Level Overview

<table>
<thead>
<tr>
<th></th>
<th>Eagle Ford</th>
<th>Woodford</th>
<th>Haynesville</th>
<th>Bakken</th>
<th>Marcellus</th>
<th>Leonard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrocarbon Type</td>
<td>Oil - Gas</td>
<td>Oil-Gas</td>
<td>Gas</td>
<td>Oil</td>
<td>Gas</td>
<td>Oil</td>
</tr>
<tr>
<td>TVD (ft)</td>
<td>4,000-14,000</td>
<td>6,000-9,000</td>
<td>10,000-13,500</td>
<td>9500-11000</td>
<td>4,000-8,000</td>
<td>5,000-10,000</td>
</tr>
<tr>
<td>Thickness (ft)</td>
<td>50-200</td>
<td>100-220</td>
<td>60-300</td>
<td>10-60</td>
<td>50 - 250</td>
<td>750 – 1,000</td>
</tr>
<tr>
<td>Horizontal section</td>
<td>5000-6000</td>
<td>1500-4000</td>
<td>4000-5000</td>
<td>4000 - 10000</td>
<td>2500-5000</td>
<td>2500-6000</td>
</tr>
<tr>
<td>Wellbore Orientation</td>
<td>NW - SE</td>
<td>N - S</td>
<td>N - S</td>
<td>EEN-WWS</td>
<td>NW - SE</td>
<td>N - S</td>
</tr>
<tr>
<td>Well Trajectory</td>
<td>3D</td>
<td>3D</td>
<td>3D</td>
<td>3D</td>
<td>3D</td>
<td>3D</td>
</tr>
<tr>
<td>Production hole</td>
<td>8 ½&quot; - 8 3/4&quot;</td>
<td>8 3/4&quot;</td>
<td>6 1/2&quot; - 6 3/4&quot;</td>
<td>6&quot;</td>
<td>8 3/4&quot;</td>
<td>6 1/8&quot; - 7 7/8&quot;</td>
</tr>
<tr>
<td>DLS deg/100ft</td>
<td>12 - 16</td>
<td>10 - 15</td>
<td>13-18</td>
<td>10 -15</td>
<td>8 - 12</td>
<td>10 - 18</td>
</tr>
<tr>
<td>Mud Type</td>
<td>OBM</td>
<td>OBM</td>
<td>OBM</td>
<td>OBM</td>
<td>KCl</td>
<td>KCL / FW</td>
</tr>
</tbody>
</table>

### All Shale Plays are Different – Influences Cementing Solution
Shale Resource – Well Construction Plans

- Well Construction Plans
- Well Completion Type
- Various Well Operational Activities
- Production Parameters

All Influence Choice on Cementing Solution
Cementing Solutions – Shale Cementing

- Conventional Cement
- Tuned® Light Cement
- Latex Based Cement
- Acid Soluble Cement
- ZoneSeal® Isolation Process
- WellLife® Cement
- WellLock™ Resin System
Eagle Ford Shale Cemented RapidSuite™ Completion Tools

<table>
<thead>
<tr>
<th>Results:</th>
<th><strong>RapidStage™ System enabled 75% time savings and has resulted in higher initial production rates.</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Capability:</td>
<td>RapidStage: 2-7/8” thru 7”, 26 Intervals</td>
</tr>
<tr>
<td>Current Capability:</td>
<td>RapidFrac: 4-1/2” &amp; 5-1/2”, 25 Intervals</td>
</tr>
<tr>
<td>Run History:</td>
<td>570+ RapidSuite™ Tools cemented; 215+ with ASC; 10+ Customers</td>
</tr>
</tbody>
</table>

For more info. on Cemented Sleeves reference “SPE-158490 “
Presenting at SPE ATCE; San Antonio, Oct. 2012
Haynesville Shale and Latex Cement

- Deep, hot, extended reach horizontals
- Bridging issues across the region
  - Optimize fluid velocity through simulations

**TABLE 5—WELLBORE PROPERTIES FROM JOB**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured depth (ft)</td>
<td>19,315</td>
</tr>
<tr>
<td>True vertical depth (ft)</td>
<td>13,400</td>
</tr>
<tr>
<td>Previous casing</td>
<td>7.625 in. 39 lb/ft at 12,344 ft</td>
</tr>
<tr>
<td>Open hole (in.)</td>
<td>6.25</td>
</tr>
<tr>
<td>Production casing</td>
<td>5 in. 23.2 lb/ft at 19,315 ft</td>
</tr>
<tr>
<td>BHCT (°F)</td>
<td>335</td>
</tr>
<tr>
<td>Mud type</td>
<td>Oil-based mud</td>
</tr>
<tr>
<td>Mud weight (lbm/gal)</td>
<td>15.4</td>
</tr>
<tr>
<td>Top of cement (ft)</td>
<td>5,800</td>
</tr>
<tr>
<td>Openhole excess (%)</td>
<td>15</td>
</tr>
<tr>
<td>Hole inclination at TD (°)</td>
<td>89</td>
</tr>
<tr>
<td>Pore pressure (lbm/gal)</td>
<td>15.4</td>
</tr>
<tr>
<td>Fracture gradient (psi/ft)</td>
<td>1.0</td>
</tr>
</tbody>
</table>

SPE 152730 “Latex-Based Cement Design: Meeting the Challenges of the Haynesville Shale,” presentation at Americas Unconventional Resources Conference, June 2012
Cementing Case History: Neuquén Basin Argentina

Major challenge
- Isolation of the layered production zone considering HPHT conditions & reduced pore-fracture pressure window.

Solution
- Use a Tail Acid Soluble Cement, for lower breakdown pressures during the hydraulic fracturing job.
- Use cement design with good technical properties (low fluid loss, good Compression Strength, stable at service temperature and able to prevent retrogression).
  - Also very low rheologies in order to decrease the ECD during pumping.

Results
- Decreased around 1000-1500 psi friction pressure during hydraulic fractures.
- Isolated the productive zones and obtained the required Top Of Cement according to the program.
Shale Well Construction Globally

Cementing Case History: Cooper Basin Australia

Challenge

- HPHT wells - BHST 400°F
- Combination of cyclic heat loading and high fracture pressures

Solution

- Utilize cement job simulator (iCem® service) effectively
- Adhere to and push cementing best practices
- Use an elastic (WellLife) cement system above the reservoir zone to better prevent cement sheath failure
- Use Acid Soluble Cement (ASC) across the reservoir zone to reduce breakdown pressures
Best Practices in Shale Well Cementing

Well Construction/Cementing

Quality Assurance

Experience

Best Practices
THANK YOU