Spacer Design for Invert Emulsion Mud Displacements

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Presented At AADE Fluids Management Group Meeting, April 24, 2013
Displacement Technology

Good displacement design practices account for:

- Conditioning the drilling fluid for removal
- Logistics maintenance and pre-planning
- Appropriate use of casing-cleaning tools
- Pipe movement during pumping operation
- Rational spacer design
Displacement Design

Hydraulics
- Pump Output (Horsepower)
- Friction Pressure
- Pump Direction
- Density difference between mud & brine

Spacers
- Flow rate
- Contact Time
- Cleaning Efficiency
- Mud Contamination

Mechanical Aids
- Tools (Scrapers, brushes, circulating ports, debris removal tools)
- Pipe Movement
Deepwater Displacement Design

Single Stage Displacement
- Direct displacement mud-to-brine in entire wellbore (incl riser)
- Allows pipe movement in casing
- May be important in deviated wellbores

2 Stage Displacement
- Indirect for Riser
  Mud-to-seawater-to-brine
- Indirect or Direct for Casing
  Mud-to-seawater-to-brine or mud-to-brine
- No pipe movement in casing
- in GoM new permits may require balanced displacements
Spacer Design

• Every displacement pumped includes a spacer ‘system’
• The functions and objectives of the spacer system as a whole are the same in all cases.
• However, preferences differ from one operator to another and from one service company to another.
• Weighted spacers, viscous pills, base fluids, surfactant type and concentration, solvents, spacer sequence, contact time, volume and effective flow regime are among the many questions that must be addressed by the completion engineer.
Spacer Design

Weighted spacers
Viscous pills
Base fluids
Surfactant Type / Concentration
Solvents
Spacer sequence
Contact time
Volume
Effective flow regime
## Typical Spacer Design

<table>
<thead>
<tr>
<th>OBM</th>
<th>Function</th>
<th>Size$^{(2)}$</th>
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<tbody>
<tr>
<td>Base Oil$^{(1)}$</td>
<td>Thin Mud</td>
<td>250 – 500 ft</td>
</tr>
<tr>
<td>Weighted Viscous Pill</td>
<td>Transition OB -&gt; WB Remove whole mud</td>
<td>10% hole volume</td>
</tr>
<tr>
<td>Wash Pill</td>
<td>Clean Mud film, Water-wet pipe</td>
<td>Modeled for OBM</td>
</tr>
<tr>
<td>Viscous Pill</td>
<td>Carry Solids, Separate from brine</td>
<td>500 – 1000 ft</td>
</tr>
<tr>
<td>Brine</td>
<td>Complete Well</td>
<td>Wellbore</td>
</tr>
</tbody>
</table>

$^{(1)}$: Important when doubt about condition of mud  
$^{(2)}$: In widest annulus
1st Viscous Push Pill (“Transition Spacer”)

Follows immediately after OBM or Base Oil
Prepared in drill water, seawater or brine*
+ Polymer (XC or HEC) for viscosity/suspension
  - prefer XC when possible
+ Barite or brine* for density (1-2 ppg > mud ppg)
+ “Chemistry” for compatibility with OBM
  – Surfactant and solvent

* Compatibility between Mud and Completion brine may be compromised and may need added “chemistry”
Transition Spacer Qualities

Designed to remove whole mud

Compatible with Drilling Fluid

- Provides a ‘smooth transition’ from Mud-to-Spacer
- Prevents large, emulsified interface

Viscosity > mud viscosity

- Take advantage of pipe rotation to overcome yield stress of mud in small annulus
- Exceed yield stress of mud by friction forces

Density > mud density

- Overcome lack of (or insufficient) pipe rotation
- Exceed yield stress of mud by gravitational force
1st Viscous (Transition) Spacer

Requires a **Chemical & Physical** ‘Transition’ from Oil Based Mud to Water Based Spacer

100% OBM  →  100% WB Viscous Spacer
1st Viscous (Transition) Spacer

100% OBM vs. 100% WB Spacer

- Viscous (Transition) SpacerIdeal cP
1st Viscous (Transition) Spacer

Incompatible Spacer (for example, Brine + HEC/XC)
1\textsuperscript{st} Viscous (Transition) Spacer
“Incompatible” Viscous Spacer

Test rheological profile of various mixtures of OBM / Viscous Water Based Spacer
“Compatible” Transition Spacer

Displacement: 
Compat. b/w 11.1 NovaPlus & Seawater-based Spacer
3% SAFE-SOLV OM, 5% SAFE-SURF O

Dial Readings @ 150°F
"Compatible" Transition Spacer

Mud to WB Viscous Spacer “Transition”
Chemical Wash Spacer

The ONLY spacer designed to Clean the Mud from the Pipe Surface!

Leave Entire Pipe Surface
- Free of Whole Mud
- Free of Oil-Film
- Water-Wet

Designed for Largest Annulus
- Contact time, Volume, Flow Rate

What is the Efficiency???
- Contact Time / Spacer Volume / Flow Rate are directly related
- What about efficiency when spacer is contaminated with mud?
Optimize Spacer Composition & Sizing

Size:

500 ft in the largest annulus?
1500 ft in the largest annulus?
5 minutes contact time?
10 minutes contact time?
3 ft/sec in the largest annulus?

Composition:

Concentration versus Volume?
Is 100 bbl of 10% better or worse than 50 bbl of 20%?
How effective is it as it circulates and picks up mud?
Fann 35 Cleaning Test (X-Clean)

Cleaning test is performed to determine:

- Cleaning agent type
- Cleaning agent concentration
- Velocity required for effective mud removal
- Contact time required for effective mud removal
Fann 35 Cleaning Test (X-Clean)

Cleaning test is performed to determine....

- Cleaning agent type
- Cleaning agent concentration
- Velocity required for effective mud removal
- Contact time required for effective mud removal

Cleaning test is repeated with mud contamination
Fann 35 Rheometer with Capped C-Sleeve

RPM / ft/min
600 / 240
300 / 120
200 / 80
100 / 40

Carbon Steel Sleeve

40F - ~150F
X-Clean Test
Chemical Spacer Efficiency vs. Contact Time at 50 ft/min.

- 2% surf
- 5% surf
- 10% surf
- 25% surf

(min)
Chemical Spacer Efficiency vs. Contact Time at 100 ft/min.
Chemical Spacer Efficiency vs. Contact Time at 200 ft/min.

- 2% surf
- 5% surf
- 10% surf
- 25% surf

(min)
Cleaning Efficiency

How is the Cleaning Efficiency of the Chemical Wash Spacer affected by its Circulation around the wellbore??

i.e., How is the Cleaning Efficiency affected by its continual ‘contamination’ by mud??
## Cleaning Efficiency Testing 14 pt Matrix

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<th>Test Data</th>
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<td>Test Temp.</td>
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# Cleaning Efficiency Testing 14 pt Matrix

## Test Data

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5% Surfactant w/ 0% OBM
5% Surfactant w/ 10% OBM

Cleaning Index vs. Velocity (fpm) graph with curves for different times:
- Blue: 0.5 min
- Red: 1.5 min
- Green: 3.7 min
- Pink: 5 min
- Black: 10 min
5% Surfactant w/ 20% OBM
This spreadsheet calculates the volume of mud cake film left on tubulars.

The total bbl of mud film should be at least matched by the chemical spacer volume.

### Company
**Offshore Producing Co**

### Well Info
**Nexen GC 243 #3 (Aspen #3)**

<table>
<thead>
<tr>
<th>Input</th>
<th>Bbl of Mud Cake</th>
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<tbody>
<tr>
<td>Film Thickness (in)*</td>
<td>0.01</td>
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<table>
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<tr>
<th>Casing I</th>
<th>Casing II</th>
<th>Casing III</th>
<th>Casing IV</th>
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<td>I.D. (in)</td>
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<th>Tubing II</th>
<th>Tubing III</th>
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<td>O.D. (in)</td>
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<td>I.D. (in)</td>
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<td>Length (ft)</td>
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</table>

<table>
<thead>
<tr>
<th>Total Volume in Tubing</th>
<th>3.31</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Volume in Casing</td>
<td>11.85</td>
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</tbody>
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**Design Criteria**

- **Mud Cake Volume**: 15.17 bbl
- **Linear Coverage (Annular)**: 15 bbl will cover 255 ft in Widest Annulus
Evaluation Metrics

Brine Clarity (NTU or TSS)

Presence of drilling fluid on drill pipe

Drilling fluid or brine interface volume

Filtration media cycles

Time required for filtration
OBM and Surfactant
Displacement Analyses: Samples from Rig
Displacement Analyses: Samples from Rig
Post-Displacement Analysis

Ref: “Validating the Quality of Mud-to-Brine Displacements”
AADE 04-DF-HO-39 2004 Drilling Fluids Tech Conference, Houston, TX
Displacement FlowBack Plot

- Mud Base
- Viscous Weighted Transition Spacer
- One Pass Spacer
- Hi-Vis Spacer CaBr₂

Mud Base Oil Viscous Weighted Transition Spacer One Pass Spacer Hi-Vis Spacer CaBr₂

Component Percent

Barrels Pumped during Displacement

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A Schlumberger Company
A couple of Lessons Learned

Spacer design criteria which emphasize the wash spacer without regard to the transition spacer are mistaken.

- Transition spacer appears to do most of the whole mud removal.
- Success by the wash spacer depends upon the work of the transition spacer.

3/64 inch is typical for a sheath of mud removed in aqueous spacers.

- Wash spacer size can be calculated from this using results from spindle cleaning test (X-Clean).

Transition spacer can be appropriately sized according to hole volume.

- Recommended 10% of hole-volume-with-pipe appears to correlate with optimized mud removal volume.

Results published as SPE 110589 and presented at 2007 ATCE at Anaheim, CA.
Thank you for your attention