Session: Overcoming Operational Issues

Chair: Sara Shayegi, Senior Well Engineer, Shell International

SPEAKER:

JUAN CARLOS BELTRAN; Head Quarter, MPD/UBD Technical/Engineering Support
MI SWACO DPM a Schlumberger Company

Co-Authors:

Corrado Pier Maria Lupo Cecconi, MI SWACO DPM a Schlumberger Company
Marcos Adrian Chavarria Chable, MI SWACO DPM a Schlumberger Company
Hermogenes Duno Moreno, MI SWACO DPM a Schlumberger Company
Carlos Andres Ruiz Bonilla, MI SWACO DPM a Schlumberger Company
The Use of Single and Multi-phase MPD and UBD Techniques on Numerous Wells and Hole Sections Have Made it Possible to Drill the Un-Drillable in Mexico

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Single, Multiphase MPD and UBD techniques used to overcome operational problems in more than 400 HPHT, HPLT and LPHT wells in deep reservoirs, have delivered very interesting results and helped to improve the drilling campaign in most of the Mexico fields, enabling also the elimination of NPT compared to wells previously drilled conventionally.
Outlook

• Background

• Multi-phase MPD techniques applied in LPHT deep reservoirs:
  - Gasified direct Injection
  - Foamed drilling fluids
  - Concentric nitrogen injection
  - Wire drill pipe
  - Continuous circulation systems

• Single-phase MPD techniques executed in HPHT and HPLT wells:
  - Manual system
  - Automated systems

• Flow drilling technique used in HPLT reservoirs:
  - Tight sandstones
  - Heavy oil Mature Fields

• Gasified UBD used in mature fields:
  - Low gradient reservoirs
Background

Optimal performance in Mexico’s highly complex geological environments can be attributed to:

- Use of proper drilling fluid
- Latest generation of downhole tools
- MPD and UBD techniques
- Best operational drilling practices
- Multidisciplinary task team working closely with geosciences support.

This has enabled the drilling of more than 400 wells while solving various problems across several regions.

Mexico’s oil provinces and fields where MPD and UBD have been applied
Multi-phase MPD for High-Angle/Horizontal, Deep and Depleted HT Reservoirs

Problems to be overcome in reservoirs with pore pressure ranged 0.30 - 0.35 g/cm³

- Deep and depleted reservoir
- Naturally fractured formations
- Low formation pressure and high temperature
- Differential sticking
- Hole instability
- Severe mud losses and consequent influxes
- Poor directional control

- Directional tool signal losses due to nitrogen injection by drill string
- Premature failure of directional tools due to pressure differentials and rubber swelling
- Temperature effects on down hole tools due to gas friction
- Hole cleaning
Multi-phase MPD for High-Angle/Horizontal, Deep and Depleted HT Reservoirs

Methodology

Feasibility
- Achievable target pressure
- Surface equipment restrictions
- Down hole equipment restrictions

Planning and Design
- Ensure proper hole cleaning optimizing injection rates
- Define MPD operational windows
- Preparation and discussion of HARC (HAZID/HAZOP)

Application and Monitoring
- Monitor drilling parameters for changes
- Optimized tripping strategy
Multi-phase MPD for High-Angle/Horizontal, Deep and Depleted HT Reservoirs

Problems to be overcome in reservoirs with pore pressure ranged 0.30 - 0.35 g/cm³

- Effects of the nitrogen injection flow rates in the mud pulse data transmission quality
  - The telemetry is highly attenuated due to the nitrogen injection through the drill pipe
  - Therefore, neither the directional nor the formation evaluation data necessary to steer within the reservoir can be obtained while drilling
  - The maximum gas/liquid percentage where signal have been lost is by around 32% but signal was regained after considerably reducing this percentage to about 23%.
Multi-phase MPD for High-Angle/Horizontal, Deep and Depleted HT Reservoirs

Problems to be overcome in reservoirs with pore pressure ranged 0.30 - 0.35 g/cm³

- Premature failure of directional tools due to pressure differentials and rubber swelling

Failed mud motor stator which was used in a nitrogen injection MPD application

Chunked elastomer stator due to nitrogen injection

Rubber disappear completely.
Multi-phase MPD for High-Angle/Horizontal, Deep and Depleted HT Reservoirs

Problems to be overcome in reservoirs with pore pressure ranged 0.30 - 0.35 g/cm³

- **Temperature effects on down hole tools due to gas friction**
  - Temperature increments affected M/LWD tools; this is in part attributed to the low heat conductivity of the gas, resulting in a lower dissipation of the heat generated by the friction between tools and open hole mostly
  
  - The large amount of nitrogen injection required to decrease the BHP and avoid mud losses plus the high temperature environments caused the annular temperature to rapidly increase above 150 °C

M/LWD lithium battery explosion due to the high temperature during nitrogen drill string injection
Multi-phase MPD for High-Angle/Horizontal, Deep and Depleted HT Reservoirs

Problems to be overcome in reservoirs with pore pressure ranged 0.30 - 0.35 g/cm³

- Effects on cutting transport in non-Newtonian μ/gas systems1:

2 Different fields of multi-phase flow

(-) as temperature increases
(+) as liquid flow rate is increased
(=) as gas injection rate increase in low viscosity fluids.
(+ as GLR increases for a given liquid flow rate
(-) when cuttings size decreases 0.5 mm in low viscosity fluids.
(=) cutting density has a relatively smaller negative effect
(-) as Inclination angle increase
(+ as based fluid weight is increased

REFERENCES:
1 Zhou, Lei, SPT Group an Schlumberger Company. 98926-PA SPE Journal Paper - 2008
2,Dr. Genick Bar-Meir
Multi-phase MPD for High-Angle/Horizontal, Deep and Depleted HT Reservoirs

Service gas Injection technique comparison and solution

<table>
<thead>
<tr>
<th></th>
<th>Direct Injection</th>
<th>“Wired drill pipe”</th>
<th>N₂ Concentric injection + MPD</th>
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<td>✗</td>
<td>✓</td>
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<tr>
<td>Use directional tools with fewer problems</td>
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<td>✓</td>
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<tr>
<td>Temperature performance</td>
<td>✗</td>
<td>✗</td>
<td>✓</td>
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<tr>
<td>Hole cleaning</td>
<td>✗</td>
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- Telemetry in two phase fluid LWD/MWD/PWD
- Use directional tools with fewer problems
- Temperature performance
- Hole cleaning

Service gas Injection technique comparison and solution:

- Direct Injection
  - Telemetry in two phase fluid LWD/MWD/PWD: ✗
  - Use directional tools with fewer problems: ✗
  - Temperature performance: ✗
  - Hole cleaning: ✗

- “Wired drill pipe”
  - Telemetry in two phase fluid LWD/MWD/PWD: ✓
  - Use directional tools with fewer problems: ✓
  - Temperature performance: ✗
  - Hole cleaning: ✗

- N₂ Concentric injection + MPD
  - Telemetry in two phase fluid LWD/MWD/PWD: ✓
  - Use directional tools with fewer problems: ✓
  - Temperature performance: ✓
  - Hole cleaning: ✓
Single-phase MPD for Deep HPHT and HPLT Reservoirs (Manual and Automated systems)

- Narrow mud weight window
- Differential sticking
- Simultaneous gas influxes
- Drilling fluid losses
- H$_2$S bearing formations
- Mud contamination (fluid from formation)
- Unavailable formation stability data

- Employing conventional drilling techniques here typically results in NPT due to the constant variation of the mud density required to respond to influxes and losses
Single-phase MPD for Deep HPHT and HPLT Reservoirs

MPD Manual vs Automation

**MANUAL CONTROL**
- Minimal sensory input - easier to rig in
- Inconsistent response
- Cannot measure assurance
- Operator fatigue / error
- Error when not standard
- Slow reaction time
- Precision an order less
- Discontinuous control
- Operator has a single task
- Not possible to reduce staff
- Only a few experts.

**AUTOMATED CONTROL**
- Maximum data input – but longer to rig in
- Consistent response
- Can measure assurance
- Fatigue not a concern
- Real time solution
- 50 milliseconds
- Very precise 0.1%, 15 psi.
- Continuous monitoring
- Operator can multitask
- Potential for reduced POB & Remote Operation
- Adds to operators capability
- Designed to be the expert
Single-phase MPD for Deep HPHT and HPLT Reservoirs

- In very narrow mud weight window scenarios, all automated MPD benefits have been applied:
  - Dynamic FITs
  - Dynamic flow checks to detect and control kicks
  - Identify and control ballooning effects
  - Maintain bottom hole pressure within the high-pressure narrow window, and
  - Allow drilling intermediate and production sections, successfully reaching targeted depths
Single-phase MPD for Deep HPHT and HPLT Reservoirs (Manual and Automated systems)

Single-phase MPD Benefits and Lessons Learned

- Most remarkable is the NPT minimization while drilling
- Reduction in well control events during connections, tripping and drilling
- Differential sticking and mud loss mitigation have been successful
- Increased safety for the rig site with its H₂S bearing reservoirs by using a closed circulation system at surface
- Real knowledge of the formation pressure profile in most of the fields
- Allowed effective control of the desired backpressure reducing significant variations on bottom hole pressure
- Personnel exposure time at high pressures has been reduced with the system’s remote control
Single-phase MPD for Deep HPHT and HPLT Reservoirs (Manual and Automated systems)

Single-phase MPD Benefits and Lessons Learned

- Formation instability problems mitigated

- The MPD system allowed tripping to the bottom hole and pulling out to the surface while reducing the possibility of losses and influx events

- Conventional MPD techniques provide an options to drill sections with very narrow mud weight window, but cross flow environments may be better managed by correctly using options like automated MPD systems
Flow Drilling In Tight Sandstones

- Low breakdown gradient
- Cross flow: Gas influx / Lost Circulation events
- Ballooning effect
- Geological uncertainty
- Contingency liners
- Unplanned cement jobs
- Unplanned sidetracks

Drilling in the Mexico’s Northern productive tight zones has proven ineffective and in viable due to the high red money and NPT observed
The results obtained in most of the gasified UBD operations in these fields have shown that even with the highest gas rate considered (500 scfm), the maximum gas fraction in the drill pipe is lower than 15%. Therefore, mud-pulse telemetry worked properly.

- Tectonic fractures in dense limestones (Chalks)
- Depleted formation
List of Wells Drilled from Q1, 2007 to Q4, 2013
By One of Four MPD/UBD Services Contractor
Established in Mexico

<table>
<thead>
<tr>
<th>Type</th>
<th>Wells</th>
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<td>Single-phase MPD</td>
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<tr>
<td>Multi-phase</td>
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<td>Flow Drilling</td>
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<tr>
<td>Foam Drilling MPD</td>
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<tr>
<td>Gasified UBD</td>
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<tr>
<td>Concentric Casing MPD</td>
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<tr>
<td>Automated MPD</td>
<td>3</td>
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