Challenges and Solutions in Drilling Fluid Technology for Gas Exploration, Production and Field Development

Dr. József Dormán
MOL Hungarian Oil and Gas Plc.

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Outline

- The tasks
- Key issues in fluid technology
- Shallow gas operations
- Deep gas operations
- Field experience, results
- Summary and conclusions
The tasks

- Advanced DF/RDF technologies, excellent technical performance and operational flexibility
- Optimizing productivity
- Maximized formation damage control (in a complex manner)
- Design and engineering
- Need for continuous learning and development
- Environmental issues
The key issues

- Borehole stability and cuttings integrity (shale/clay inhibition)
- Optimized rheology, hydraulics (hole cleaning, ECD, Swab/Surge)
- Minimizing solid/fluid invasion
- Optimum fluid chemistry, stabilization of clays/fines
- High temperature stability, operational flexibility
- Minimum environmental impact
Shallow gas operations

- High-to-low permeability, shaly sandstones
- Heterogeneity, fresh-water sensitivity, underconsolidation
- Development of RDIFs, based on formation characterization and tailored fluid chemistry
- Maximized formation damage control (in a complex manner)
- Environmental issues
Formation characterization

- Particle and pore size distribution
- Permeability, mineralogy (XRD), morphology (SEM)
- Clay content (CEC), core flow (clay stabilization) tests
Optimized RDIF properties

- Optimized combination of selected polymers to optimize rheology and to minimize fluid loss
- Bridging agents (salt, marble, limestone) of optimized PSD (fit to pore size distribution)
- Cationic polymers, clay stabilization
- Optimization using advanced testing techniques (ceramic and synthetic sand discs, core samples)
- Support/feedback by quite a lot field and lab measurements

![Viscosity vs shear rate profile of field POLY-CAT-SC (DIF) samples at 45 °C]

\[
y = 2310.1x^{-0.658}, \quad R^2 = 0.9997
\]

\[
y = 2415.8x^{-0.6655}, \quad R^2 = 0.9997
\]

\[
y = 2310.1x^{-0.6708}, \quad R^2 = 0.9997
\]
Formation damage control

- Optimized, clean fluid (RDIF)
- Efficient bridging, low invasion
- Controlled non-soluble (drilled) solids content (< 40 kg/m³)
- Designed fluid/filtrate chemistry (based on complex studies)
- Using the same fluid chemistry for each fluid sequence
- Tailored filter cake removal, acid compositions (SC), oxidizers (SS)
- Mild acid and delayed oxidizer (build up into the filter cake)
Deep gas operations

- High-to-ultra-high temperature (160 – 220 °C+)
- Drilling of long shale sections
- High pore pressure intervals (1800 – 2300 kg/m³)
- Narrow operating window
- Complex geology, mineralogy, low permeability
- Environmental issues
Advanced planning

- Use all the informations we have ever learnt
- Consider the technology gap at U-HTHP conditions
- The need for detailed geomechanical analysis
- Continuous technology development (at leading edge)
- Maximized performance and formation damage control
- Minimum risks, environmental impact
Wellbore shear failure

- Underbalanced conditions can lead to wellbore shear failure
- Overbalanced conditions can lead to wellbore tensile failure
- Narrow operating window, low ECD, hydraulic simulation
The role of overpressure

Comparison of caliper and K-salinity logs

Depth (TVD) [m]

Hole size [inch]

K-salinity [kg/MT]
Temperature conditions in HTHP wells

- BHFT
- BHLT-1
- BHLT-2

Temperature [°C] vs Depth [m] graph
HTHP Drilling Fluids

- „Single” fluid type (Ca-based)
- Improved shale inhibition (< 5% borehole enlargement)
- Improved temperature stability (field proven at 200 °C+)
- Good solids tolerance, flexibility, high density (2300 kg/m³+), low ECD
- Good tolerance against contaminants (acid gases, salt, etc.)
## WBM aged at 215 °C

<table>
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<th>Composition</th>
<th>Base</th>
<th>20 % dilution (treatment)</th>
<th>20 % dilution (treatment)</th>
<th>30 % dilution (treatment)</th>
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<th>30 % dilution (treatment)</th>
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<td>After aging</td>
<td>After aging</td>
<td>+ 96 hrs aging</td>
<td>After aging</td>
<td>+ 24 hrs aging</td>
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<td>9</td>
<td>2</td>
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<td>4</td>
<td>8</td>
<td>1</td>
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<td>11,75</td>
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<td>-</td>
<td>5,0</td>
<td>-</td>
<td>-</td>
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Future technical issues

- Further development and optimization of filter cake removal technologies
- Further development and optimization of shale/clay/fines stabilization techniques and chemistry
- Filtration studies of HTHP fluids (shale pore plugging approach)
- Advanced geo-mechanical studies and wellbore pressure prediction
- Overlapping the technology gap (considering extreme temperatures)
- Better planning, cooperation
Fluid Engineer – The key of success

- Responsible to prepare and maintain clean fluid and clean circulating system (while working in harsh conditions)
- Testing, controlling, monitoring, sampling, reporting, documenting
- Feedback, learning
- Special training
Summary and Conclusions

- More than 60 shallow gas wells were drilled and completed successfully in the last 2 years.
- Wells have shown expected production rate.
- Drilling and completion of deep gas wells have created several operational challenges and being successfully solved by advanced engineering approaches.
- Continuous fluid technology and planning methodology developments are required based on optimization issues (shallow gas) and considering technology gap issues (deep gas).
Thank you for your kind attention!