

Novel water-based drilling fluid for HP/HT wells

Dedication to innovation is the key for operational excellence.

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Well construction in deep HP/HT wells has been a major challenge over the years. The conventional understanding was that best results were obtained when low-toxicity, oil-based drilling fluids were used to address the adverse drilling conditions.

However, the motivation to overcome the constraints related with this type of well while ensuring better performances and an enhanced environmental protection has led to research and the development of an innovative solution: a high-lubricity, water-based drilling fluid that could prove to deliver the desired results.

The novel drilling fluid was tested in a well originally drilled in 1989, where a sidetrack well was to be drilled from the original wellbore to penetrate the upper reservoir, which was in an isolated fault block. The results obtained were outstanding both in terms of rig-time savings and reduced environmental impact.

Well situation

The target reservoir in the Mediterranean area lay between 5,500 m and 6,000 m (18,040 ft and 19,680 ft) in a HP/HT zone. Formation pressures above 14,000 psi and temperatures of 160 C (320 F) were expected based on offset well data. The combination of lithology and drilling environment produced predictions of high torque, low ROP and high wellbore instability.

Drilling plans called for a window to be cut in 7-in. casing and a sidetrack wellbore deviated from a whipstock at 4,800 m (15,744 ft) drilled using a 5½-in. bit to the reservoir top at 5,632 m (18,473 ft). Inclination was built to 39 degrees and later to a maximum of 60 degrees before penetrating the reservoir. After setting a 5-in. liner, a 4½-in. bit would drill to total depth (TD), planned for 5,753 m (18,870 ft). An openhole completion was planned in a highly competent dolostone. The drilling plan, based on experience in offset wells, called for 87.84 days to drill the 5½-in. hole section and 28.83 days to drill the 4½-in. section to TD.

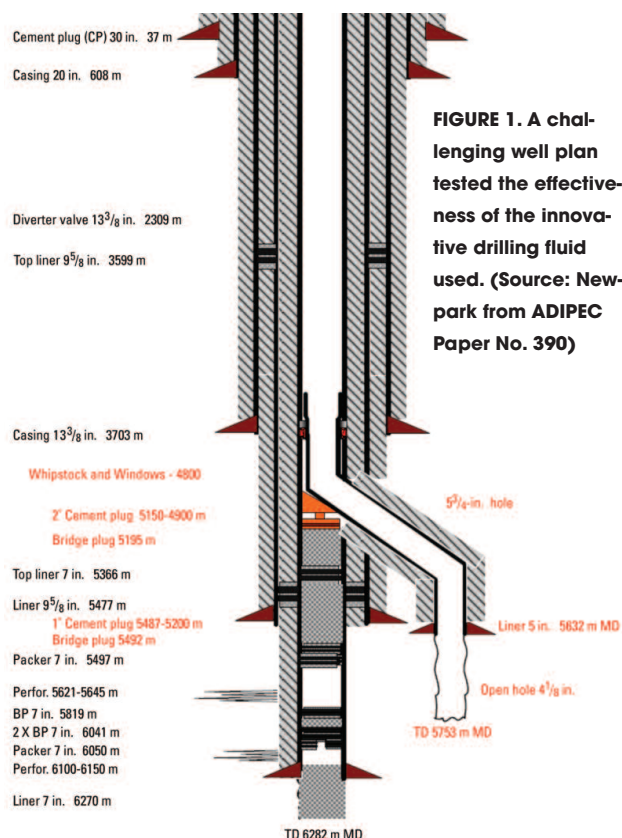


FIGURE 1. A challenging well plan tested the effectiveness of the innovative drilling fluid used. (Source: Newpark from ADIPEC Paper No. 390)

As the drilling plan was being developed, comprehensive laboratory tests were being conducted to establish base data. Later, these data would be complemented by measurements and tests conducted while drilling. It was clear that the well called for a stable drilling fluid of high lubricity capable of being weighted up to 17.2 ppg (2.06 sp gr). A high-temperature rheology modifier was included to improve high-temperature stability.

Mud challenges

Historically, offset wells had been drilled with invert-emulsion low-toxicity oil-based muds using paraffin hydrocarbons as base fluid. These addressed earlier problems with older water-based fluids used in the past, which required continuous reconditioning and dilution—all at great cost.

The switch to invert-emulsion oil-based fluids minimized these issues to an extent. The oil-based fluids also relieved torque and drag, instability, and frequent stuck-pipe incidents experienced with the old water-based fluids.

However, a simpler and environmentally friendly solution was preferable, one that could be quickly and easily tuned onsite using liquid additives when necessary and that could remove the concerns about disposal and the high cost of spent mud and cuttings remediation.

Solution involves new formulation

A new formulation of environmentally friendly water-based drilling fluid was developed and qualified through a battery of exhaustive lab tests. Stability under a wide range of conditions that mirrored the anticipated well conditions was a key issue. Maintenance of constant viscosity while drilling the build and ramp sections also was critical. With a well plan that exceeded 116 days with frequent long-duration trips, the fluid could not degrade with time. Hot rolling and static aging tests were conducted to verify suitability for the proposed conditions.

Rheological properties were tested over the complete range of downhole conditions to ensure efficient cuttings transport. One benefit was the lack of sag of the weighting material that had plagued the invert-emulsion fluid. The new fluid was tested for sag, and it performed to specification.

But laboratory testing, no matter how comprehensive, cannot substitute for actual field experience. Fortunately, the Haynesville Shale of northeast Texas and northwest Louisiana in the U.S. offers conditions similar to the planned well. Field tests of the new drilling fluid could be carried out and its performances verified as expected.

The high-performance water-based drilling fluid system consists of three liquid products with an optional HP/HT rheology modifier, including:

- A synthetic polymer that acts as a primary viscosifier, filtrate reducer and coating agent;
- A performance-enhancing HP/HT lubricant blend that combines reduced friction with thermal stability above 200 C (392 F);
- A surfactant wetting agent that ensures that weighting material remains water-wet under all conditions; and
- An optional rheology modifier that increases low shear viscosity above 135 C (275 F).

With the new system, operators can expect a low environmental impact water-based fluid capable of makeup using freshwater or brine, a highly stable clay-free system and thermal stability to more than 220 C (428 F). Because a minimum number of liquid products make up the formulation, mixing is easy under typical field conditions,

and storage for reuse is straightforward. Thixotropic properties are not affected by long static periods at high temperature. The fluid has a low friction coefficient and resists contamination from solids or CO₂.

Higher ROP, lower NPT

The well was successfully drilled using the innovative water-based fluid. The 5-in. liner point was achieved in 47.71 days as opposed to the planned 87.84 days. Fluid performance

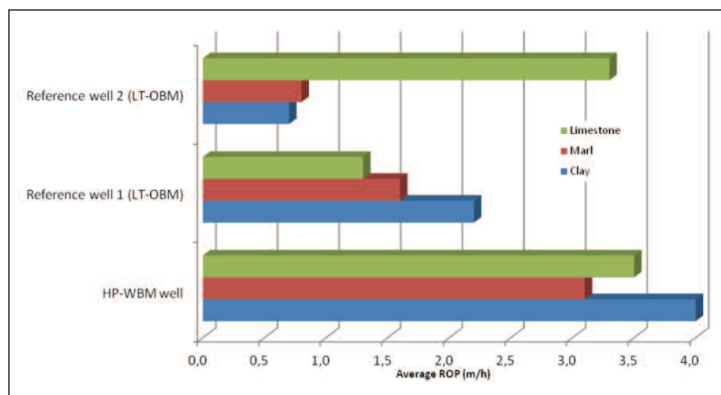


FIGURE 2. The high-performance water-based drilling fluid exceeded ROPs recorded in two comparable offset wells. (Source: Newpark from ADIPEC Paper No. 390)

under static conditions was tested due to the failure of an MWD tool, which caused almost 20 days of nonproductive time (NPT). ROP in the section was 3.1 m/hr (10.2 ft/hr) compared to an expected .8 m/hr (2.6 ft/hr).

During the drilling of the 4½-in. drain hole, two stuck-pipe incidents affected drilling. These were attributed to differential-pressure sticking. Accordingly, total rig time was 34.31 days as opposed to the plan of 28.83 days. Nevertheless, overall time was 34.65 days less than the original plan. Actual costs were estimated at \$11.6 million, compared with the AFE plan of \$15.1 million.

Torque values were low in both hole sections, varying from 2,500 ft-lb to 4,000 ft-lb. Lubricity coefficient of friction was monitored throughout drilling and remained in the range of 0.12 to 0.14, which is well below that typically seen in water-based mud of this density. In future wells that may require further torque reduction, the lubricity can be easily improved. Cuttings transport was good, and there was no evidence of pack-off or overpull.

A comparison of ROP for each lithology was made against ROPs experienced in vertical offset wells. Use of modern drilling tools and the new water-based drilling fluid was credited with achieving the greatly reduced drilling time. The environmental impact and its associated costs also were greatly reduced with no dangerous waste produced. **ESP**