New water-base drilling fluid makes mark in GOM

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UPON ITS INTRODUCTION in the Gulf of Mexico, a uniquely engineered water-base drilling fluid system that employs a triple inhibition approach to shale and wellbore stabilization has been shown to deliver drilling performance approximating that of its invert emulsion counterpart.

The newly developed fluid system has been employed in wells in both deepwater and on the shelf where it exhibited excellent shale inhibition and water-base stability, low toxicity and very flexible and easy-to-maintain formulations. In each well, the fluid demonstrated consistently impressive performance with good cuttings integrity and very minimal accretion while drilling through highly reactive shales.

The new system essentially eliminated the typical problems associated with the conventional water-base drilling fluids used previously, such as screen blinding caused by unsheared polymer, rapid polymer depletion, high dilution rates and moderate inhibition. Further, there were clear indications that the system approaches the drilling performance and the user-friendliness of a synthetic or oil-base drilling fluid.The results of all these field trials confirmed initial observations that the fluid was easily mixed both at the mixing plant and at the rigsite. In addition, the system has exhibited minimal gumbo handling problems at the surface, with shale cuttings exhibiting good integrity and well encapsulated. Furthermore, the Cation Exchange Capacity (CEC), which is a measure of the reactivity of the clays being drilled, was consistently low (less than 10 lb/bbl) while drilling reactive shales. There were no indications of downhole bit balling nor has there been any appreciable accretion noted on the bit and the bottom-hole assembly after trips.

Photos of bits after full-scale accretion and ROP test results. The new high performance water-base drilling fluid left the cutters clean while the PHPA water-base mud resulted in balled cutter.

TOTAL SYSTEM DEVELOPMENT PROGRAM

Invert emulsion drilling fluids, whether oil or synthetic-base, have long been the systems of choice for technically demanding applications, particularly when targeted formations contain highly reactive shales. The superior inhibitive characteristics of invert emulsion fluids in tandem with their high rates of penetration, good lubricity and reduced risk of stuck pipe make these systems ideal for applications requiring high levels of fluid performance.

When compared to water-base drilling fluids, these systems provide improved wellbore stability, a high degree of contamination tolerance, low coefficient of friction, a thin, lubricated filter cake, low dilution rates and a high degree of re-usability.Yet, the wholesale use of oil-base drilling fluids is under pressure, primarily because of tightening environmental regulations governing the disposal of oil-contaminated drill cuttings. Furthermore, synthetic and oil-base drilling fluids are inherently more expensive than water-base systems.

The economic impact of invert emulsion drilling fluids is especially evident in the deepwater environment. While faster penetration rates and reduced "trouble time" positively influence daily rig costs, the savings are often offset by the low fracture gradients and narrow equivalent circulating densities (ECD) intrinsic of the deepwater environment, which can result in massive downhole losses of these premium fluids. Additionally, higher up-front costs and the expenses associated with environmental compliance as well as the costs of being out of compliance, have made the development of a high-performance, cost-effective water-base drilling fluid the "holy grail" of the drilling fluids industry.

Over the years, a number of attempts have been launched to engineer an aqueous system that would approach the performance levels of an invert emulsion drilling fluid. Aqueous systems designed around silicates, salt/glycol, partially hydrolyzed, polyacrylamide (PHPA), and $CaCl_2$ polymers, among others, have been promising. Nevertheless, they have not been completely successful in inhibiting the hydration of highly water-sensitive clays, all-too-often resulting in bit balling, accretion, wellbore instability and poor penetration rates. While many of these systems demonstrated good inhibition, the range of applications was seriously limited. Thus, a major research effort was undertaken to develop a water-base drilling fluid with the performance characteristics of an invert-emulsion system.

Early in the development program it was concluded that merely creating or revamping additives to enhance existing water-base systems would be insufficient to reach the ultimate goal of engineering a new system that would exhibit the performance flexibility of an oil-base drilling fluid. Consequently, a total system approach was initiated that would focus on the total performance spectrum of an oil-base mud, rather than centering on one characteristic, such as lubricity, inhibition or thermal stability.

The offshoot of this wide-ranging research and development program was a new water-base drilling fluid that in the laboratory exhibited performance characteristics close to those of an oil-base system and far superior to other aqueous systems.

FLUID FORMULATION AND TEST RESULTS

The new system was designed through a triple inhibition approach: shale hydration inhibition, shale dispersion inhibition and accretion inhibition. The drilling fluid comprises five synergistic products, three of which were created specifically for the new system.

A specially developed polyamine liquid additive that acts as a clay hydration suppressant provides shale hydration inhibition. The new product intercalates and reduces the space between clay platelets so that water molecules will not penetrate and cause shale swelling.

Cuttings from the highly reactive gumbo section in the Gulf of Mexico drilled with the new water-base system.

Molecular modeling has shown that the unique molecular structure of this compound provides a perfect fit between clay platelets and tends to collapse hydrated structure of the clays, thereby greatly reducing the tendency of clays to imbibe water from an aqueous environment.

The component is completely water soluble, exhibits low marine toxicity and is compatible with other additives in the new system.

A novel low molecular weight dry copolymer developed especially for the new water-base drilling fluid minimizes shale dispersion to provide cuttings encapsulation with minimal viscosity contribution and enhanced filtration properties. The product has also been shown to be an effective anti-crete.

The new system incorporates a newly developed accretion inhibitor/ROP enhancer, which is a blend of surface-active agents that will keep the bit and the BHA free of solids.

The new suppressant assists in preventing the build-up of drill solids below the bit, allowing the cutters to make good contact with new formation and improve the rates of penetration. The additive also lowers torque and drag by reducing the coefficient of friction and provides general improvement in drilling properties.

In addition to these specially developed products, the new system also includes xanthan gum for rheology control and an ultra-low viscosity cellulosic polymer for optimum filtration control. Fluid loss control additives vary from ultra-low viscosity PAC to starches, depending on conditions and desired fluid properties.

Before initial lab testing, the design of each of these components was fine-tuned to optimize on the synergies of the individual compounds and improve the flexibility of the overall design. Once satisfied, researchers performed a number of tests to evaluate the inhibitive properties of the shale inhibitors and the entire system.

The test methods employed included bentonite inhibition, bulk hardness, slake durability and accretion in various shales and with various base fluids, such as pure seawater, KCL/seawater and sodium chloride/seawater to simulate global applications.

The new system was tested against oil-base mud and a 20% NaCl/PHPA fluid. The results of the extensive laboratory examination showed the system comparable to an oil-base drilling fluid and far superior to the water-base system.

FIELD RESULTS

To date, the system has been used in both deepwater and shelf wells in the Gulf of Mexico. In each, the performance of the system validated the excellent results obtained in laboratory testing. Most of the sections drilled thus far have been shallow, where the rate of penetration is usually controlled to ensure proper hole cleaning and to avoid any borehole stability problems.

Nevertheless, drilling performance comparison was possible using data from the same or adjacent blocks, which showed the ROP of the new system being very similar to a synthetic-base system used earlier, and 60- 70% higher than the conventional water-base drilling fluid used previously in the targeted blocks.

The fluid maintenance was easier than even the most inhibitive water-based muds, and consisted mainly of pre-mix additions to maintain the volume and minimum LGS and MBT. The fluid inhibitive character determined low dilution rates, averaging between 2 and 4 bbl premix/1 bbl cuttings drilled.