



Water-Based Drilling Fluid Helps Achieve Oil-Mud Performance

Charles Cameron, Angus Florence and Colin Temple, Baroid product service line, Halliburton

Copyright 2004 AADE Drilling Fluids Conference

This paper was prepared for presentation at the AADE 2004 Drilling Fluids Conference, held at the Radisson Astrodomo in Houston, Texas, April 6-7, 2004. This conference was sponsored by the Houston Chapter of the American Association of Drilling Engineers. The information presented in this paper does not reflect any position, claim or endorsement made or implied by the American Association of Drilling Engineers, their officers or members. Questions concerning the content of this paper should be directed to the individuals listed as author/s of this work.

Abstract

Oil-based drilling fluids have for many years been the drilling fluid of choice for use in challenging hole sections. These fluid systems can bring many advantages, including optimal shale stability, low torque and drag, resistance to contamination, and high drilling rates. One of the challenges of utilizing an invert emulsion drilling fluid, however, has been the increasing level of environmental concern and legislation associated with their use. These challenges have driven the search for a water-based drilling fluid (WBDF) that will provide oil-based drilling fluid performance and be environmentally acceptable in all offshore areas of the world.

A novel, environmentally compliant WBDF has been developed that has proven to be extremely inhibitive and highly lubricious. The system provides excellent hole stability, and reactive shales remain inhibited after exposure to the fluid. The system is easy to maintain, dilution rates are very low and drilling fluid properties remain remarkably stable while long sections of reactive shale are drilled. Gauge hole and excellent drilling rates through highly reactive formations characterize the system, along with improved filter cake quality and low methylene blue test (MBT) results.

Initial studies showed that the new system surpasses silicates in the degree of shale inhibition achievable and compares favorably with synthetic base drilling fluids. Unlike silicate systems, the new drilling fluid is highly lubricious and not prone to significant cuttings accretion. The system has been rated for use in the North Sea without any component substitution warnings. The system can be formulated to 425°F (220°C), is hardly affected by most contaminants and has no adverse effects on rig-site elastomers. The low plastic viscosity (PV) and low non-progressive gel strengths help minimize equivalent circulating density (ECD) and surge/swab pressures.

Use of this novel WBDF has helped to drill some of the most reactive shales in the North Sea while avoiding the high cost and safety risks associated with "skip and ship" operations. This performance is coupled with excellent cuttings integrity, increased temperature stability and good hole-cleaning properties. In the

application of this system, the engineered approach matches drilling fluid requirements with local clay characteristics, environmental regulations and operational objectives.

Introduction

Environmental regulations covering offshore drilling operations in the North Sea area prevent the discharge of cuttings drilled with synthetic base drilling fluids where the synthetic oil on cuttings is greater than 1%. Since this criterion is not achievable using current technology, there has been a concerted effort within the industry to develop a WBDF that will provide oil-based mud performance combined with environmental acceptability. This is essential for trouble-free drilling of the young, reactive claystones in the UK and Norwegian sectors of the North Sea.

Where oil-based or synthetic base drilling fluid is used in the North Sea, the cuttings are either transported ashore for treatment and disposal at land-fill sites or re-injected into dedicated disposal wells. However, the more troublesome gumbo-generating claystones tend to occur in the large-diameter 17½ in. hole sections. Storage and transportation of the cuttings ashore, commonly referred to as a "skip and ship operation," is considered impractical in this hole size because of the sheer volume of cuttings and the high rate of production.

A new WBDF has been developed that has proven highly effective in field trials conducted in the UK and Norway. The key challenges, drilling the 17½ in. interval in the younger sediments of the central and northern North Sea basins, are:

- Hole stability in reactive smectite or mixed layer (smectite/illite) clays
- Potential for gumbo formation and bit-balling with attendant low drilling rate
- Possibility of differential sticking and seepage losses where sands are encountered

Drilling Fluid System Selection

The new high-performance WBDF system was selected for use in the two initial trial wells in preference to the standard potassium chloride (KCl)/polymer/glycol fluid. This decision was made because superior shale

inhibition characteristics were demonstrated in laboratory studies on representative shale samples. The WBDF is a clay-free non-dispersed, highly inhibitive drilling fluid system designed to provide maximum shale stabilization in highly reactive clays. Clay dispersion and solids breakdown are minimized to a high degree, improving the efficiency of the solids-control equipment.

This drilling fluid is proving to be well suited in those areas of the world where drilling with invert emulsion muds would require zero discharge and total cuttings containment or where the remoteness of the location poses a considerable restraint on logistics. The system has exceptional environmental performance. All the components of the system are listed as PLONOR (Pose Little Or NO Risk to the environment), apart from the key active ingredient, which has been assigned a gold CHARM (Chemical Hazard And Risk Management) rating by the DTI (Department of Trade and Industry) for use in the UK North Sea. Similar chemistries are used in personal care, pharmaceutical and medical applications. Within these applications, the material may be ingested, inhaled or applied to the skin regularly over long periods and hence is considered to pose negligible risk to humans.

Significant health and safety benefits are realized at the rigsite using a WBDF by avoiding the large number of crane lifts associated with cuttings-handling systems and eliminating the need for the extra personnel to dig out oil-laden cuttings from the header box and sand traps. These are labor-intensive, congested, and hazardous operations. In development operations, where intervals may be drilled using the new system on a frequent basis, the possibility exists for salvaged volumes of drilling fluids to be reused on subsequent wells. Reuse of drilling fluids would result in reduced discharge of drilling fluid to the environment.

Drilling Fluid Properties

The WBDF can be maintained in a similar manner to a traditional KCl/polymer system. The system is inherently lubricious, a characteristic attributable to the active components. A thin, slick, tough filter cake is formed, serving to reduce friction between the drillstring and wellbore. Under certain conditions, e.g. extended reach or highly deviated wellbores, using the dedicated lubricant additive may be an advantage. Figure 1 shows the effect of lubricant addition on the system's coefficient of friction.

The main inhibiting component of the WBDF is depleted on the wellbore and drill cuttings. The level of depletion for a given hole section will depend on the nature of the formation and the surface area of the cuttings. The WBDF displays stable rheology and low PV over a wide temperature range, making the system suitable for deepwater and high-temperature applications. Return permeability tests conducted on Berea sandstone showed a return permeability greater

than 85%, a result more typical of specially designed reservoir drill-in fluids.

The system has no known adverse effects on common oilfield elastomers. The system is unaffected by common drilling fluid contaminants, including acid gases, anhydrites or complex salts. This feature avoids the increased chemical usage and occasional system replacement required by other water-based mud systems that become contaminated. One exception is green cement, which has detrimental effects on fluid properties and should be avoided.

The system is highly tolerant of low-gravity solids, and little or no dilution was required on the field trial hole sections. Typical dilution rates range from 0.2 to 0.35 bbl/ft (0.1 to 0.18 m³/m) for 8½ in. hole to 0.3 to 0.5 bbl/ft (0.16 to 0.26 m³/m) for 17½ in. hole. Table 1 details a typical formulation for the new drilling fluid.

Laboratory Testing

To determine the optimum drilling fluid, shale cuttings-dispersion tests were conducted for each of the projects that used this WBDF. This test assesses the ability of the fluid to preserve the integrity of drill cuttings as they are transported up the wellbore to surface and removed at the shale shaker.

The test involves hot rolling a known weight of sized shale (2 to 4 mm) for 16 hr, isolating the remaining shale on a 500-micron sieve, and weighing it. The weight of recovered shale is then reported as a percentage of the original weight. The results of typical shale recovery tests are shown in Figure 2. These tests were conducted using London clay, a highly reactive mixed layer (illite-smectite) clay. Recovery rates ranging from 80 to 95% have been obtained for the WBDF using various types of shale from different parts of the world. The results shown for London clay have been corroborated by independent tests conducted by a major operator.

Tests conducted during the development of this system showed that shale exposed to the system can subsequently be exposed to fresh water with little or no detrimental effect.

Field Results

The first field trial of the WBDF was conducted in the vertical 12 ¼ in. hole section of a Central North Sea well. The lithology sequence penetrated included Cretaceous chalk, highly reactive Cretaceous Cromer Knoll claystone formations and Jurassic shales from the Humber Group. Throughout the entire hole section, the drilled cuttings were firm and discrete, resembling cuttings drilled using synthetic base mud. Two trips were made for changes to the bottomhole assembly (BHA) before reaching total depth (TD) with no hole problems experienced on either trip. Wireline logs were run and successfully completed.

Very little dispersion of formation clay into the drilling fluid was evident. The MBT climbed very slowly from 2.5

lb/bbl (7.1 kg/m³) to a maximum of 10 lb/bbl (28.5 kg/m³) by section TD with negligible effect on the rheology, which remained very stable. The PV stabilized at approximately 19 lb/100 ft² and the yield point (YP) at 28 lb/100 ft². These rheological properties, together with flow rates of 800 to 1,000 gal/min (3000 to 3800 l/min), ensured effective hole cleaning. This was confirmed when viscous pills, circulated prior to pulling out, brought back only slight increases (approximately 15%) in cuttings volume. Filter cake quality was thin, firm, flexible and slick throughout the section; a typical cake can be seen in Figure 3. High-pressure, high-temperature (HPHT) filtrate run at 150°F (66°C) consistently gave a filtrate loss less than 10.0 ml/30 min. The shale shakers were initially fitted with 105- and 120-mesh screens, but these were soon changed to 165- and 200-mesh screens.

The second field trial took place offshore Norway, where 17½ in. hole was drilled through reactive claystones in an area where hole stability, bit-balling, and high-torque problems frequently occurred on offset wells. Using the new WBDF, excellent cuttings quality was achieved in the more reactive smectite-rich zones, with no tendency for the cuttings to stick to the shaker screens. Cuttings transport over the shakers was excellent throughout the section; at no time was it necessary to use water hoses or pressure washers to keep the screens clear. The shaker screens were changed up to 150-mesh screens within a few hours of commencing the section and were changed up in stages to 180-mesh screens on all shakers.

Drilling continued uneventfully to section TD where the hole was circulated clean while conditioning the mud to casing-running specification. The hole was in excellent shape with no high torque, drag, or overpull recorded. Casing was run with no indication of excess drag or resistance

Main Observations

The WBDF performed as designed, inhibiting the highly reactive smectite-rich clays. On both wells, the cuttings remained relatively inert at the shakers and were easily removed from the active system with no tendency for cuttings to stick to the shakers.

On the first field trial, the hole section remained open for 21 days with entirely trouble-free trips. The caliper log showed 97% of the hole in gauge. The WBDF consumption rate averaged 0.23 bbl/ft (0.12 m³/m) with no requirement for dilution. Drilling fluid properties remained exceptionally stable throughout, with minimal requirements for maintenance. The hole was cleaned effectively and no cavings were evident at the shakers.

The 17½ in. hole section on the second trial well was successfully drilled in a single-bit run of approximately 4,500 ft in a hole section with an inclination in excess of 25°. None of the mud-related hole problems experienced on offset wells drilled with a KCl/polymer/glycol drilling fluid system were encountered.

The overall fluid consumption rate proved to be extremely low on each hole section drilled to date, ranging from 0.25 to 0.5 bbl/ft. The average for offset wells drilled with KCl/polymer/glycol systems was in excess of 1.0 bbl/ft. This characteristic of the system significantly reduces the volume of chemicals discharged to the sea. The reactive solids content of the drilling fluid, as determined by the MBT, remained very low and stable on each trial well. The maximum MBT observed was on the second well and only reached 14 lb/bbl (39 kg/m³).

No bit-balling, accretion, or low rate of penetration (ROP) problems were experienced on either trial well. On the second well, it was noted that torque levels were approximately 50% lower than anticipated at approximately 15 to 18 lb/1,000 ft. No differential sticking or losses were seen while drilling, though some losses were experienced during cementing operations on the second well.

Since the drilled solids were so effectively removed from the mud system and the MBT remained low, a large quantity of the WBDF was salvaged for reuse. This further reduced the environmental impact and costs associated with the drilling fluid. Between three and four days of rig time were saved using the WBDF compared with offset well performance using a conventional inhibitive water-based system.

Conclusions

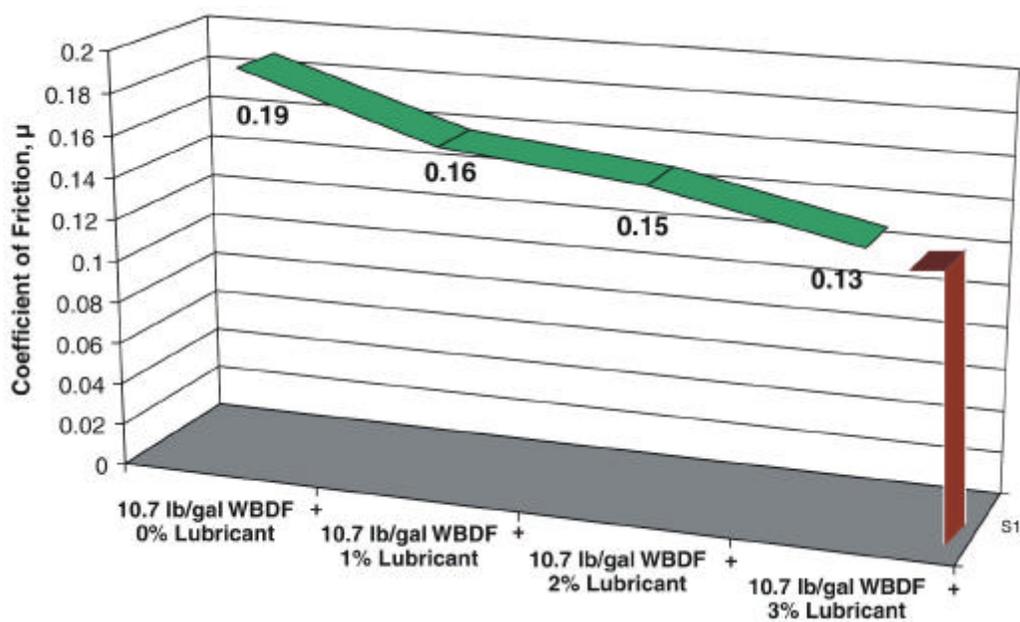
Both field trials in the UK and Norway were highly successful. Drilling performance approached and closely replicated that expected from a synthetic or oil-based fluid, with all drilling targets achieved or exceeded. A stable hole was evident on both wells with no bit-balling or sticking tendencies downhole. Good hole cleaning was achieved along with excellent cuttings separation at the shakers. Low fluid dilution and consumption rates ensured reduced levels of drilling fluid discharge and environmental impact.

Acknowledgements

The author would like to thank the management of Halliburton for permission to publish this paper.

Table 1—Mud Formulation

Material	Amount
KCl, lb/bbl (kg/m ³)	38 (110)
Drill water, gal/bbl (l/m ³)	30 (718)
Soda ash, lb/bbl (kg/m ³)	0.7 (2.0)
Viscosifier, lb/bbl (kg/m ³)	1.05 (3.0)
Filtrate-loss agent, lb/bbl (kg/m ³)	2.1 (6.0)
Polyalkylene glycol, %	3.0
Shake inhibitor, %	3.0
Barite	As required

**Fig. 1—Effect of lubricant addition on coefficient of friction.**

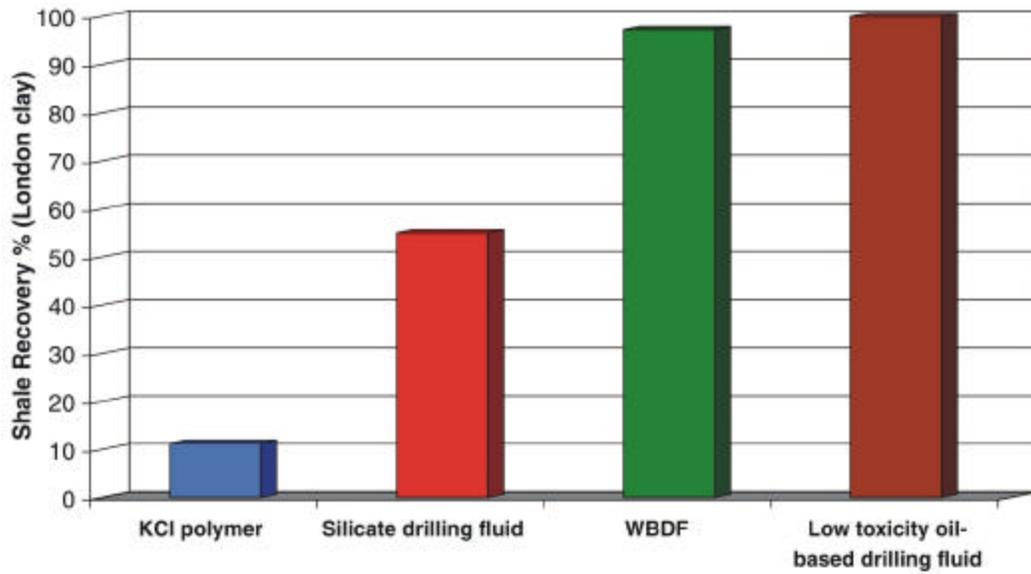


Fig. 2—Shale recovery tests using London clay.



Fig. 3—Typical filter cake using the new WBDF.



Fig. 4—Claystone cuttings from the Cretaceous Valhall formation.



Fig. 5—Cuttings from the Jurassic Kimmeridge formation.