

## The Prevention and Cure of Bit Balling in Water-Based Drilling Fluids

Sashikumar Mettath, Emanuel Stamatakis, Steven Young, and Guido De Stefano, M-I SWACO

Copyright 2011, AADE

This paper was prepared for presentation at the 2011 AADE Fluids Conference and Exhibition held at the Hilton Houston North, Houston, Texas, April 7-9, 2011. 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 authors of this work.

### ABSTRACT

The more stringent environmental demands together with an increasing focus on drilling performance and economics has created a push towards a greater usage of new and more highly inhibitive water-based drilling fluids, often to replace invert emulsion fluids.

The use of novel chemistry to minimize the interaction of the water-based fluid with water sensitive shales is the key to achieving targets of greater levels of wellbore stability, hole gauge, reduced dilution rates and improved drilling economics. One unfortunate result of the use of many of these water based drilling fluids has been an increase in the incidence of bit balling and cuttings accretion, which has resulted in lost time, reduced drilling rates and often expensive remediation operations.

This paper reviews recent developments in the areas of both the remediation and prevention of bit balling and shale accretion in water-based drilling fluids. The paper describes the mechanism of bit balling and cuttings accretion, the influence of clay type, fluid chemistry, and drilling parameters and also gives guidelines for minimization of bit balling potential. In addition to discussing testing protocols for evaluation of bit balling potential, field results obtained from usage of a modern day bit balling prevention additive are presented.

### INTRODUCTION

When using oil-based or synthetic-based drilling fluids, there are often associated costs for cuttings treatment, waste stream processing and compliance testing, all of which must be taken into consideration, as well as the typically higher cost per unit volume of these fluids. However the higher operational costs associated with the use of invert emulsion fluids can sometimes be offset by higher rates of penetration (ROP) and a lower risk of operational problems compared with the majority of water-based drilling fluids

Over the past few years, introduction of new water-based fluid systems and specific additives have been successful in greatly reducing the incidence of wellbore stability problems. The main causes of non-productive time observed with the latest water-based fluids are issues related to bit balling, agglomeration and accretion of drilled cuttings. Slow ROP, high torque and drag, high overpull on tripping, and potential for wellbore packoff and lost circulation are the most immediate problems.

Shale cuttings profiles can be evaluated in terms of soil mechanics. From initial stages as a relatively dry clay-containing material, shales will adsorb water (liquids) in an attempt to relieve their internal stresses. As water is adsorbed, the shales reach a plastic limit where the sticking tendency of shale is very high therefore leading to all the problems described above. The primary differences between invert emulsion fluids and water-based fluids that decrease any tendency for bit balling and accretion in the former are the very high capillary pressures in shales that prevent uptake of base fluid, this inhibiting shale sticking, plus the wetting of shale and steel surfaces with a non-aqueous film that will hinder any shale sticking.

### BACKGROUND

Theories based on the plasticity of the clays explains the accretion that occurred.<sup>1,2</sup> The clay plasticity concept proposes that the rate of hydration of a shale is slowed down such that the cuttings remain in a plastic state over a longer period of time. This plasticity state is believed to contribute towards cuttings becoming molded onto the steel parts of the bottomhole drilling assembly (BHA) and being plastered onto the walls of the wellbore. By using a much less inhibitive drilling fluid, shale cuttings would normally hydrate quickly and tend to be less sticky as they continue to adsorb water thus quickly passing through the plastic stage and into a liquid stage where the shale has little cohesive strength, and readily disperses.

The Attenberg limits of a clay are defined as the liquid limit, plastic limit, and plastic index and are fully described in published literature.<sup>3</sup> The liquid limit (LL) is the moisture content, expressed as a percentage by weight of the oven-dry clay, at which the material will just begin to flow when jarred slightly. The plastic limit (PL) is the lowest moisture content, expressed as a percentage by weight of the oven-dry clay, at which the soil can be rolled into threads one eighth of an inch in diameter without breaking into pieces. The plastic index (PI) is the difference between the liquid limit and the plastic limit. It gives the moisture content range through which a soil is considered to be plastic.

Through extensive studies on a number of clay types, it was determined that for clays that are montmorillonite in nature, the structure of the clay mineral is the most important factor in determining the properties of these clays in contact with aqueous media.<sup>4</sup> The cation associated with the

montmorillonite can alter the structure established by the clay mineral, but is of secondary importance in the hydration behavior. The liquid limit of montmorillonite clays will increase with an increase in the hydrated radius of the predominant clay cation. For kaolinitic clays, the electrical attractive forces and particle orientation in the fabric play a prominent role. Thus kaolinite clays with a high degree of flocculation will have larger void spaces and exhibit higher liquid limit values, whereas those with a low degree of particle flocculation will have smaller void spaces and exhibit lower liquid limit values. Depending on the mineralogical makeup of a shale, the behavior in the presence of a water-based drilling fluid can be entirely different depending on whether the primary clay mineral is kaolinite or montmorillonite.

The conclusion of many studies into clay and shale behavior can be summarized by stating that both the liquid limit and plastic limit of a shale are primarily a function of the percent clay fraction, the clay mineral type and the type of associated cations present.<sup>5</sup> The ratio of PL/LL was seen to increase according to clay type:

$$(Na\text{-montmorillonite} < \text{Illite} < \text{Kaolinite}),$$

and to the valency and hydrated ionic radius of the associated cation:

$$(Na^+ < K^+ < Ca^{2+} < Mg^{2+} < Fe^{3+} < Al^{3+}).$$

The presence of non-clay minerals in a shale will reduce the magnitude of the PL and LL, but the ratio will remain the same. In order for cuttings accretion to occur, the following three criteria must be met:

1. The shale must have sufficient moisture to be in a plastic state when in contact with the drilling fluid. Deformation of the shale structure can readily occur when the plastic state is achieved. Note that some shales can be encountered that are naturally in the plastic state and do not need to take moisture from the drilling fluid.

2. The surface of the shale cutting must be sticky enough to form a bond with other surfaces with which it makes contact. This can be contact with any steel surface of the BHA or with a wellbore surface. The "stickiness" of the shale surface can be enhanced by rapid surface water absorption from the drilling fluid,<sup>3</sup> and also by some drilling fluid polymeric additives.

3. The surfaces of the cuttings must be pushed together with sufficient force to deform the clays and create a bond. This force can be mechanical (e.g. contact of cuttings with a drilling assembly), and can also be hydraulically generated (e.g. forcing cuttings through a narrow aperture). To evaluate these influences on bit balling and cuttings accretion further, a full suite of laboratory testing was conducted.

## LABORATORY STUDIES

Preserved outcrop shale samples were used in the laboratory studies. Shales with a broad range of composition and reactivity were selected from highly swelling (Lillebaelt clay), through mixed (Oxford clay) to highly dispersive (Arne clay)

a) Lillebaelt clay is a fine grained, high montmorillonite, swelling clay sourced from an outcrop in Denmark.

b) Oxford Clay is a swelling and moderately dispersive shale of Jurassic origin sourced from an outcrop in southern England.

c) Arne clay, a ball-clay with high kaolinite content, is highly dispersive in contact with water and is sourced from an outcrop in southern England.

Analysis of these outcrop shales by X-ray diffraction is shown in Table 1 below:

Clay	Quartz	Plagioclase	K-fspar	Calcite
Arne	14.8	1.4	1.5	0.9
Lillebaelt	3.6	1.2	2.6	21.8
Oxford	18.9	1.5	3	8
Clay	Dolomite	Siderite	Pyrite	Anatase
Arne	0	0.3	0	0.5
Lillebaelt	0	0	0	0
Oxford	0.5	1	29	0.4
Clay	Di-octahedral	Tri-octahedral	Anhydr ite	Kaolinite
Arne	44.5	0	0.8	33.9
Lillebaelt	67.6	0	0	8
Oxford	47.3	3.8	0.3	12.8

Cation exchange capacity (CEC) with methylene blue dye was the method used to evaluate the clay mineral fraction of these outcrop shales and determining the reactivity of the clays via yields the results given in Table 2 below.

Clay	Chlorite	Kaolinite	Illite	Illite-smectite	C.E.C (meq/100gram)
Arne	1	35	36	28	7-16
Lillebaelt	1	5	3	91	41
Oxford	2	8	19	72	22

An evaluation was done to determine the native water content of these outcrop shales and determine the required water content to reach the Attenberg limits of these shales. These calculations are expressed as the percentage of water as a percent of the wet shale and are shown in Table 3 below.

Clay	% water at native state	% water at plastic state	% water at liquid state
Arne	3.4	25.7	40.9
Lillebaelt	26.5	36.3	73.2
Oxford	20.5	26.5	41.5

## Rolling Bar Accretion Test Method

Accretion phenomenon was studied in the laboratory using a rolling bar accretion test method. In this test, a mild steel bar of known weight and dimensions was thoroughly sanded and cleaned, and then placed in the center of a 315 stainless steel test cell. The cell was half filled with the test drilling fluid and a weighed 50 grams ( $W_1$ ), of sized shale pieces were

distributed evenly around the bar. The cell was then filled with the test fluid, sealed, then placed horizontally on the bars of a roller oven where it was rolled for a specific time period at room temperature.

After rolling, the cell was opened, the bar removed and quickly washed with a gentle stream of tap water. Excess surface fluid was then gently removed with a paper towel and any accreted solids were then scrapped off, weighed ( $W_2$ ), dried to constant weight at 210°F and then reweighed ( $W_3$ ).

Accretion is calculated from the weight of clay solids adhering to the bar and is expressed as a percentage of the dry clay fraction, (corrected from the native water content of the unexposed cuttings sample,  $M_i$ ).

$$\% \text{ Accretion} = \frac{W_3}{[(100-M_i)/100] \times W_1}$$

The moisture content of any agglomerated solids is also measured to determine the degree of hydration of the agglomerated material.

$$\% \text{ Moisture} = \frac{(W_3 - W_2)}{W_2} \times 100$$

A separate accretion test was run for various time intervals to determine the rate of cuttings accretion onto the bars and to evaluate the effects of the variables measured during this suite of testing. A visual example of how the accretion profile of a shale can alter with exposure time is shown in Figure 1 below.



**Figure 1: Accretion profile over time at 5, 10, 20, 40, 60 and 80 minutes.**

Figure 1 illustrates the test findings which showed that the shale cuttings firstly undergo a deformation and agglomeration process before they are pressed into a more uniform accreted layer. In the later stages (more exposure to time and greater water uptake), the adherence of the cuttings is reduced and the measured accretion rapidly decreases. Maximum accretion in this type of test occurs in the time period of 20 – 30 minutes. From the soil mechanics point of view, clay accretion first begins as the water content passes the plastic limit and continues until the liquid limit is reached, indicating that for this fluid tested, the clays continued to absorb water throughout the test period.

### Shale Type

Figures 2 to 4 below show the rate of accretion and the magnitude of accreted material, for the three outcrop shale types.



**Figure 2: Arne clay accretion profile over time ( 5, 10, 20, 40, 60 and 80 minutes).**



**Figure 3: Oxford clay accretion profile over time ( 5, 10, 20, 40, 60 and 80 minutes).**



**Figure 4: Lillebaelt clay accretion profile over time ( 5, 10, 20, 40, 60 and 80 minutes).**

It can be seen that the highly kaolinitic Arne clay has a much broader accretion profile than the other outcrop shales studied, and that the Lillebaelt and Oxford clays appear to have a longer initiation time prior to the deformation and accretion process occurring. This can be more clearly seen from the graph shown as Figure 5 below, where the accretion rate has been mapped out in more detail.

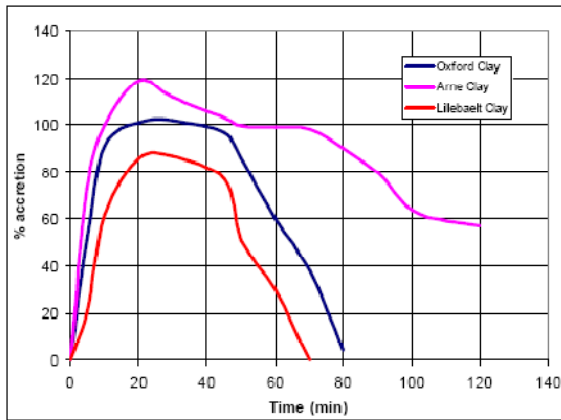


Figure 5: Accretion profiles of the different outcrop clays.

The rate at which water content in these outcrop shales increases is shown in Figure 6 below. This indicates that in all cases water is very rapidly taken up by these outcrop clays.

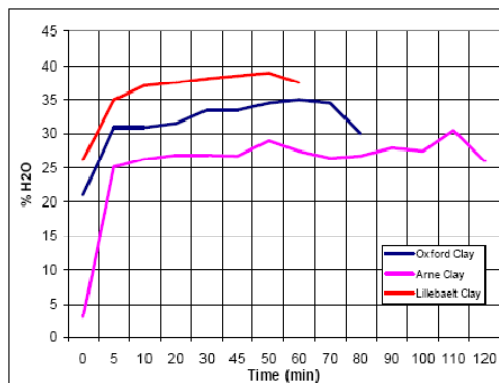


Figure 6: Water contents over time of the different outcrop clays.

The accretion profile for each of these outcrop shales differs greatly. Highly kaolinitic shales (e.g. Arne clay) appear to have a very broad profile in that the onset of accretion is very rapid and the cuttings remain in an accreted state over an extensive period of fluid exposure.

High montmorillonite-containing shales (e.g. Lillebaelt clay) are slower to start accreting, but rapidly and completely accrete thereafter, and then pass through to the liquid limit where accretion is reduced and minimized.

### Other Variables Impacting Accretion

The choice of which type of clay will be encountered in a drilling operation is most commonly a given parameter that cannot be influenced. Some other factors which can influence the accretion behavior of shales were also investigated including cutting size and mechanical force from the drilling operation.

### Cuttings Size

Testing was conducted using various sizes of shale cuttings (from approximately 1.5 mm to 10.0 mm) and was

conducted over a time interval to 60 minutes using Oxford clay. The effect of cuttings size on the accretion profile is shown in Figure 7.

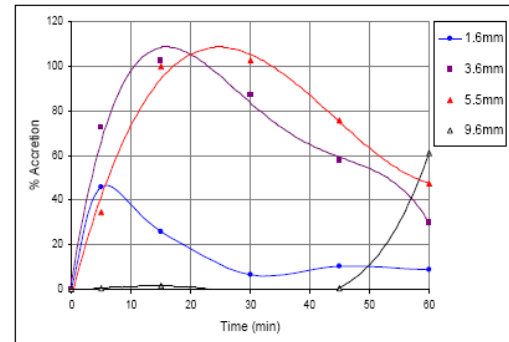


Figure 7: Effect of cuttings size on accretion of Oxford clay.

Generally, as cuttings size increases, overall levels of accretion was observed to decrease, requiring significantly longer time for the accretion process to begin. This may be related to cuttings surface area – a smaller cuttings size will have a greater surface area for water adsorption, and thus will tend to reach the plastic limit faster and begin to accrete faster, particularly after shorter exposure times.

The lower level of accretion observed with the smallest particle size tested is believed to be an artifact of the test because a more rapid disintegration of these cuttings occurred due to their higher surface area.

Choosing a fluid system and drill bit combination that allows for large cuttings to be generated can be advantageous in reducing the tendency for bit balling and accretion. This requires, however, that hydraulics be optimized for removal of the cuttings from around the BHA and for hole cleaning with these larger cuttings. Poor hydraulic hole cleaning will lead to both mechanical deterioration of cuttings over time, and a longer exposure of cuttings to the drilling fluid. Both of these scenarios will contribute to an increased tendency for accretion.

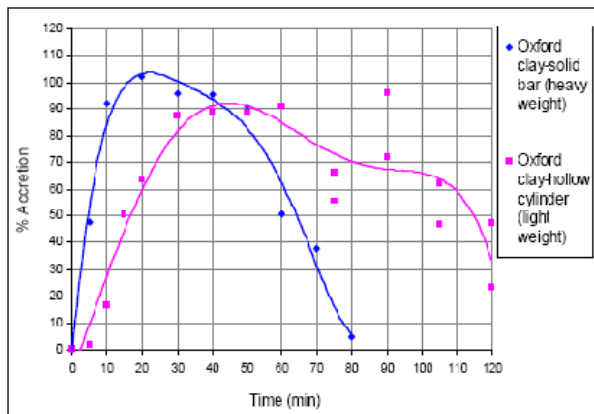
### Mechanical Force

The effect of mechanical force on accretion was studied by using two differing accretion bars – one solid weighing ~530 grams, the other hollow weighing ~140 grams – on Oxford clay. The results of this testing are shown in Figure 8.

With a reduction in mechanical force, the accretion effect is delayed significantly and the overall extent of accretion is reduced. Accretion also eventually occurs over a wider time period even with the lower mechanical force. These results indicate that some mechanical deformation of cuttings must occur before accretion and agglomeration can take place, thus reducing the mechanical forces applied to cuttings will minimize the tendency for accretion.

Good tripping practices, optimized hydraulics and controlled rate of penetration (ROP) to keep the bit face and junk slots clean (as well as maintaining good cuttings removal

from the wellbore), plus stabilizing (maintaining wellbore standoff) the BHA in directional wells will all minimize the mechanical forces applied. Another modification that can be made, and has been applied relatively successfully, is to modify the surface of the bit/BHA components to render them electro-negative. This will reduce the sticking tendency of the shale to the coated steel. This technique is more fully explained in the paper by Smith<sup>6</sup>.



**Figure 8: Effect of mechanical force on accretion of Oxford clay.**

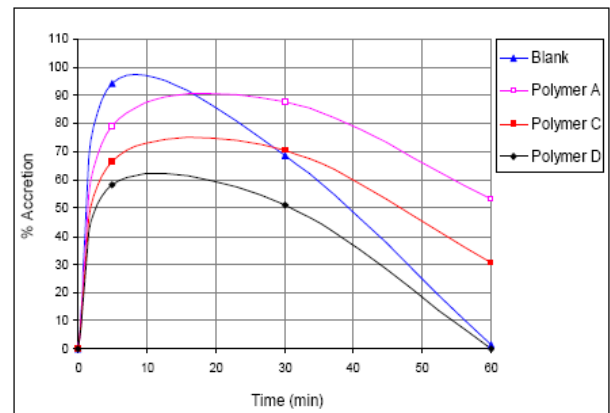
### Drilling Fluid Additives

The effects of varying chemistry and concentrations of specific drilling fluid additives on accretion have been extensively investigated. These investigations have already contributed to the development of some novel chemical solutions to reduce cuttings accretion and agglomeration.

Two examples are the use of encapsulating polymers (typically high-molecular-weight charged polymers that can envelop shale cuttings to prevent dispersion of the shale and hinder uptake of water into the shale) and the use of lubricants (materials typically used to decrease the coefficient of friction of a drilling fluid and often used to alleviate bit balling and accretion).

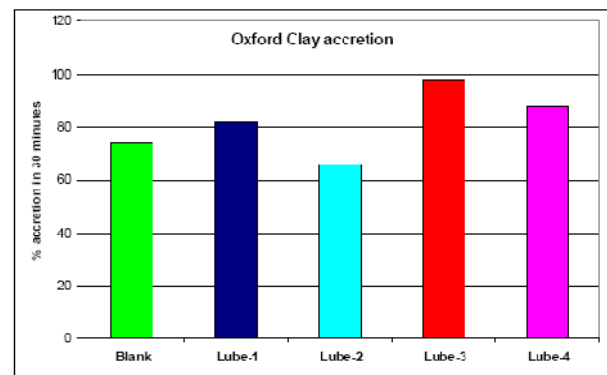
Figure 9 shows the comparative accretion profiles of an inhibitive water-based drilling fluid treated with differing types of encapsulating polymer. Polymer A is a conventional partially hydrolyzed polyacrylamide (PHPA) polymer that is anionically charged. Polymer C is a cationically modified acrylamide-based synthetic polymer. Polymer D is a new synthetic polymer having a mild cationic charge.

From this data it can be seen that choice of the correct encapsulating polymer can have a significant effect on the accretion of shales. The new polymer developed (polymer D) shows a significant reduction in the maximum amount of shale accreted.



**Figure 9: Accretion profiles of differing encapsulating polymers.**

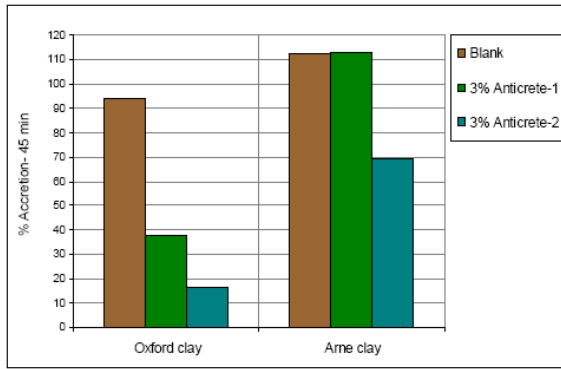
Figure 10 shows the extent of accretion observed after 30 minutes with the addition of 3% volume of a number of different lubricants to the drilling fluid system.



**Figure 10: Accretion after 30 minutes for various lubricants.**

The data showed that the use of a lubricant does not always improve shale accretion, and in fact the choice of the wrong lubricant can lead to a worsening of any potential accretion. Lubricants 2, 3 and 4 all show an increase in accretion tendency. All of these lubricants were based on the traditional fatty acid/fatty ester chemistry used in common lubricants.

A number of specific anticrete additives have been developed over the past decade in an effort to alleviate the incidence of bit balling, accretion, and poor ROP experienced when drilling with more inhibitive water-based drilling fluids. Typically such additives are composed of a blend of lubricants, surfactants and wetting agents. These materials ideally will apply a non-aqueous wetting to the surfaces of both steel and shale as well as chemically hindering the uptake of water by a shale surface. In this way the tendency for shale to accrete will be reduced. Figure 11 shows the effect of two such anticrete products on the accretion of both Oxford and Arne shales after 45 minutes.



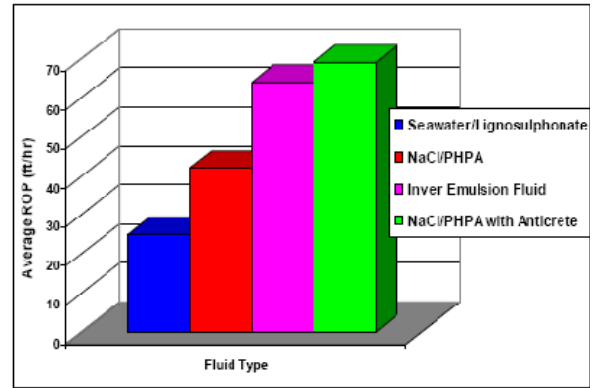
**Figure 10: Accretion after 45 minutes for two anticretes and two shales.**

These results show that anticrete additives can be particularly effective at reducing the tendency for accretion, and confirms that specific shale types (i.e. kaolinitic) pose more of an accretion issue. The development of newer anticrete types that form a much more efficient non-aqueous film on the cuttings surface is a critical step in ensuring that the new generation of higher inhibitive water-based drilling fluids can be successfully applied without high risk of bit and BHA balling and associated problems.

### FIELD TESTING

A field trial was undertaken to evaluate the performance of an anticrete additive designed for general use in water-based drilling fluids. The trial was carried out in the South Pelto area of the Gulf of Mexico, where a good deal of reference data was available from offset wells having been drilled with both alternate water-based fluids and invert emulsion fluids. Previous wells had been drilled with Seawater/Ligno-sulphonate, Diesel invert emulsion and Sodium Chloride/PHPA fluids. For this trial a Sodium Chloride/PHPA fluid was chosen, into which the anticrete additive would be applied. The offset wells drilled with water-based fluids had suffered from significantly lower ROP's than the invert emulsion fluid drilled wells – this was believed to be due to bit balling, with some indications of shale accreted to BHA components being observed.

The 12¼-in. section of this well was drilled out and down to 8,214 ft using a roller cone bit. The fluid was treated with 1.25% of the anticrete prior to running into the hole with a PDC bit, whereupon the section was drilled down to TD at 13,570 ft maintaining the anticrete concentration at ~1.3% volume. There were no indications of bit balling or shale accretion seen during the drilling and final TD tripping phase in this trial. Average ROP's were considerable higher than offset water-based drilling fluid wells, and were comparable to invert emulsion fluid wells (Figure 11).



**Figure 11: Average ROP comparisons by drilling fluid system.**

### CURING BIT BALLING

When bit balling occurs, it is typically accompanied by a reduction in expected ROP, coupled commonly with an increase in pump pressure. Today the most successful method of cleaning the bottomhole assembly is to pull the drillpipe from the hole and clean the pipe and BHA manually with scrapers. This process is time consuming and negatively impacts the overall cost of well construction. Various alternate techniques have been used to minimize the effect of bit balling without resorting to tripping out of hole. These are discussed below along with a novel chemical approach.

### Abrasion

This method is probably the most common used and is typified by pumping a fluid pill containing an abrasive material (sand or nutplug), spotting the pill around the bit and BHA, then rotating rapidly in an effort to erode any accreted shale from the bit and BHA. Some limited success has been reported using this method, the chance of success being greater if the treatment is applied immediately at the onset of accretion, before the shale cuttings have become thoroughly stuck to the steel.

### Dehydration

This method uses chemicals to attempt to dehydrate the accreted shale structure such that the shale water content decreases below the plastic limit and the shale becomes brittle and non-sticky. This, coupled with mechanical abrasion, should clear any accrete shale from the steel. Typically a pill containing a high concentration of salt (e.g. potassium chloride) is pumped along with a pill containing an abrasive agent (e.g. nutplug). The bit/BHA is allowed to soak in the chemical pill for a period of time (2 to 4 hours) before displacing to the abrasive pill and rotating rapidly. Some limited success has been reported using this type of solution.

### Hydration

This method uses chemicals to attempt to hydrate the accreted shale structure such that the shale water content increases beyond the liquid limit and the shale becomes fluid and disperses away from the steel. Typically a pill containing a high concentration of alkali (e.g. caustic soda or potash) is pumped along with a surfactant that aids in dispersion. The bit/BHA is allowed to soak in the chemical pill for a period of time (2 to 4 hours) before rotating rapidly to clear the shale, or alternately displacing to a secondary abrasive pill and rotating rapidly to help clear any remaining accreted shale. Some success has been reported using this type of approach.

### Lubrication

This method uses lubricant or oil wetting (sometimes neat oil) pills to attempt to oil-wet the steel and shale surfaces reducing the tendency for the shales to stick. Typically a pill of neat lubricant or oil is spotted around the accreted area and the drillstring is rotated rapidly. The rotation in the low-viscosity pill aids with a mechanical (hydraulic) erosion. Little success has been reported using this approach.

All of the above methods have shown only very limited to no repeatable success in the field. These methods that employ long soak periods (dehydration, hydration) also run the risk of having the same effect on shale formations that are desired on the accreted shale cuttings, and can result in wellbore instability or excessive washouts that generate more non-productive time. In addition to the risk of wellbore instability, some of the chemical solution employed can also be detrimental to the properties of the drilling fluid as they become incorporated during circulation. Typically flocculation, poor rheology control and loss of efficient filtration control are observed.

An investigation into developing an alternative, more efficient, method of curing shale accretion issues downhole was undertaken.

### Bit Ball Removal Tests

The new approach taken to try and cure shale accretion was to develop a material that would chemically attack the clay causing both chemical dehydration and rapid dispersion. As all clays vary in composition, a chemistry was needed that would interact with a common shale component, thus ensuring that the cure was applicable over all shale types.

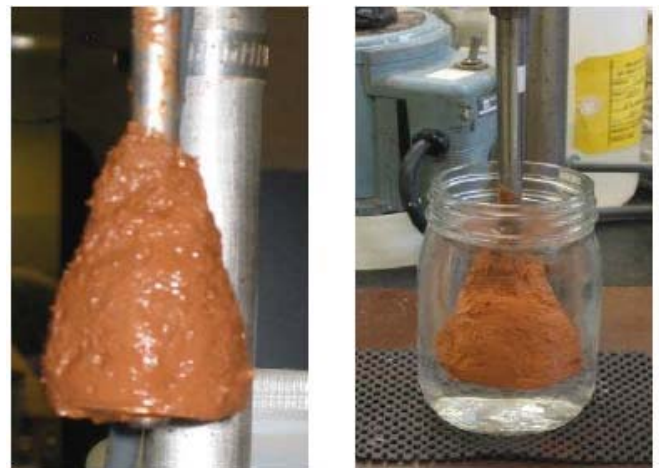
The approach taken was to develop a chemistry that would interact with organic components of the shale (from naturally occurring organic materials, and from organic drilling fluid components (e.g. polymers, inhibitors) that will be associated with any accreted shales. The interaction is catalyzed by the metal cations present in the shale, resulting in a very rapid dehydration and dispersion of the shales. To further improve this performance, the anti-balling chemistry developed was coupled with an effective penetrating surfactant that draws the material rapidly into the accreted shale matrix, assisting in disintegrating the accreted shale both from within as well as from the surface. The effectiveness of this bit balling solution was tested in two ways in the laboratory.

*Method #1.* The first method was to use the accretion bar test method as outlined above to accrete the shale on the bar. The bar plus accreted shale is then removed, placed in a sealed container with the anti-balling pill, and rolled for 30 minutes at room temperature. Results from this testing can be see in Figure 12 below for London clay.



**Figure 12: Effect of new anti-balling pill on accreted London clay.**

*Method #2 – Clay-Ball Removal Test.* In a second experimental design, a large (50-kg) sample of highly sticky (gumbo) field shale was obtained from a well in southern Texas where drilling had been conducted with a bland freshwater/polymer slightly dispersed water-based drilling fluid. A weighed (75 gram) portion of this shale was tightly compressed onto the shaft and blades of a Hamilton Beach mixer, the mixer shaft and gumbo pill was then immersed in the test solution, the timer was started, and the mixer set to rotate at 100 rpm. The weight of shale remaining on the shaft after a 60-minute exposure period, or the time at which all of the shale had been removed from the shaft were recorded. The experimental set-up is shown in Figure 13 with tabulated results from a series of experiments shown in Table 4.



**Figure 13: Experimental set-up with South Texas gumbo clay.**

**Table 4: Results from “Clay-Ball” Removal Test**

Sample Tested	Fresh water	25% KCl	30-lb/bbl NaOH
Clay (at start) g	72.28	71.66	73.4
Clay (at end) g	66.93	65.28	63.71
% reduction in 60 min	7.4%	8.9%	13.2%
Time to 100% removal (min)			
Sample Tested	Saturated CaCl <sub>2</sub>	50-lb/bbl Citric Acid	KCl+KOH
Clay (at start) g	71.66	74.11	72.73
Clay (at end) g	61.62	62.25	64.77
% reduction in 60 min	14.1%	16.0%	11%
Time to 100% removal (min)			
Sample Tested	Novel Anticrete (50%)	Novel Anticrete (25%)	Novel Anticrete (10%)
Clay (at start) g	73.18	72.89	74.03
Clay (at end) g	0.00	0.00	31.83
% reduction in 60 min	100%	100%	57%
Time to 100% removal (min)	22	43	

From the data shown above, an efficient cure for bit balling has been developed which provides a novel solution to this issue. The new chemical solution has also been designed to have minimal impact on the wellbore and fluid properties as the chemistry involved will only become activated when in contact with the shale downhole, and will spend itself by reaction with the accreted shale organics. Some transient rheology decrease and fluid loss increase would be expected in a polymeric water-based drilling fluid.

## CONCLUSIONS

From data gathered from the field and laboratory investigations such as these discussed here, evidence suggests that shales containing a higher percentage of illite and especially kaolinite clay minerals will be more susceptible to accretion when exposed to water-based drilling fluids and will accrete at lower hydration levels than shales containing high percentages of illite-smectite clay minerals.

It was conclusively demonstrated that shale accretion can be significantly reduced by maintaining a low water content of the shale, by generating larger size cuttings and by minimizing cuttings disintegration. By optimizing bit type to both formation type and selection of the best water-based drilling fluid as well as optimizing ROP and hydraulics for bit/BHA cleaning and cuttings transportation, it is possible to minimize the risk of shale accretion.

Design of a true high-performance water-based fluid to match the drilling performance of an invert emulsion fluid will most likely necessitate the inclusion of an additive specifically designed to act as an anticrete.

Traditional approaches to curing a bit/BHA that has accreted shale have been mostly unsuccessful. A new

chemical approach has been developed that promises a much higher rate of success in allowing a downhole treatment to remove accreted shale and allow a return to drilling with improved ROP. It should be noted, however, that unless the drilling or drilling fluid parameters are altered to improve upon the situation, there is a high risk of recurrence of the accretion issues.

## REFERENCES

1. Reid, P.I., Minton, R.C., and Twynam, A. “Field Valuation of a Novel Inhibitive Water-Based Drilling Fluid for Tertiary Shales.” SPE 24979, European Petroleum Conference, Cannes, France, 16-18 November, 1992.
2. Van Oort, E. “On the Physical and Chemical Stability of Shales.” *Journal of Petroleum Science and Engineering*, v38, (2003) 213-235.
3. Allen, H. “Classification of Soils and Control Procedures used in Construction of Embankments.” *Public Roads Journal of Highway Research*, v22, no. 12 (1942) 263-265.
4. White, W.A. “Water Sorption Properties of Homoionic Montmorillonite.” *Clays and Clay Minerals* v3, no.1 (1954), 186-204.
5. Sridharan, A., Rao, P.R., and Miura, N. “Characterisation of Ariake and other Marine Clays.” Proceedings of International Symposium on Lowland Technology, (2004) 53-58.
6. Smith, L., Mody, F.K., Hale, A., and Romslo, N. “Successful Field Application of an Electro-Negative Coating to Reduce Bit Balling Tendencies in Water Based Mud.” SPE 35110, SPE/IADC Drilling Conference, New Orleans, March 12-15, 1996.
7. Young, S. et al. “Organo-Amine Chemistry – An Innovative Key to Achieving Invert Emulsion Performance with Water-Based Drilling Fluids.” SPE 80275, SPE Oilfield Chemistry Symposium, Houston, February 5-8, 2003.