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# Field Results for Encapsulated Oil as an Additive to Water-Based Drilling Fluids: Operational Improvements in the Alliance/Northern Denver-Julesburg and Heath Basins

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## Abstract

As the drilling industry pursues more horizontal wells with increasingly complex design (e.g., extended-reach wells, high angle wells), challenges from high friction (e.g., reduced Rate of Penetration [ROP], stuck pipe, severe doglegs or corkscrews) grow more pronounced. These challenges are particularly pronounced in Water Based Muds (WBMs), which have an inherently higher Coefficient of Friction (CoF) than Oil Based Muds (OBMs) or Synthetic Based Muds (SBMs).

While there are many lubricity additives that are available to reduce frictional force, these additives may present challenges ranging from adversely affecting the properties of the drilling fluid (e.g., liquid lubricants that may change rheology or interact with other additives) to interfering with drilling equipment (e.g., glass beads that plug valves in mud pulse telemetry systems). To address these challenges, we have developed a novel method for encapsulating lubricant for use as a lubricity additive.

Characterization of encapsulated oil in the lab has shown the ability to reduce the CoF of water based mud systems by over 80%. Field characterization of encapsulated oil was corroborated with experimental results; we have observed ROP improvements of 20%, torque reduction of up to 45%, and drag reduction of up to 50% in field scale testing, as well as ROP enhancement of216% in the Alliance/Northern DJ Basin and torque reductions of up to 42% in the Heath Basin. Our field characterization demonstrates the utility of using encapsulated oil in WBMs to improve the operational efficiency of drilling.

## Introduction

In drilling, frictional force can manifest itself in many ways that adversely affect operations. Torsional or angular friction (e.g., friction caused by contact between the rotating drill pipe, drill bit, and Bottomhole Assemby [BHA] and formation) can create high drilling torque, thereby limiting or halting the ability to rotate to increase ROP and break static friction between the drill pipe and casing/formation. Axial friction (e.g., friction caused by contact between the forward-moving drill pipe, drill bit, and BHA and formation) significantly decreases the effective weight on bit, thereby reducing the effective power of the bit to drill through formation. Additionally, substantial torque increases can lead to sinusoidal or helical "buckling" of drill pipe, which increase points of contact (thereby increasing total friction) and can damage drill pipe[1]. As horizontal wells get longer, challenges from frictional force increase significantly as more surface area of drill pipe come into contact with formation and as the cumulative frictional force (e.g., normal force times the coefficient of friction) on horizontal drill pipe increases due to longer sections of pipe being horizontal (thereby increasing the normal force).

Challenges from friction also significantly increase when torsional friction makes it difficult to turn the tool face of the BHA in directional drilling. Inability to keep the drilling path to plan can lead to severe doglegs or corkscrewing from course-correction to achieve the target depth. As these severe geometries lead to more frictional force on the drill pipe and impede a straight path for the weight of the drill string to apply force at the drilling bit, they constrain the potential of the horizontal section of the well.

There are a variety of lubricity additives that have been developed to address challenges from frictional force. Liquid lubricants (e.g., diesel, synthetic esters, polyalphaolefins [PAOs]) are very effective at reducing contact friction (reductions of over 80% have been observed in our laboratory experiments[2]), but also have a tendency to lose efficacy as an additive over time (e.g., due to dilution, chemical breakdown of the lubricant, sticking to cuttings, or loss to formation) and may sometimes adversely affect the properties of the overall mud system (e.g., change rheology). Mechanical lubricants (e.g., glass beads, copolymer beads) are also effective, but may also have negative effects on drilling operations. Beads may create issues in data transmission when using mud pulse telemetry systems for measurement while drilling (MWD) tools if they plug the valve and may also damage formation if not recoverable after use.

To address the limitations with conventional lubricants, we have developed a method to encapsulate biodegradable extreme pressure liquid lubricant in an inert polysaccharide capsule. Due to protection in the polysaccharide "shell," the liquid lubricant is protected from interactions with other additives, harsh conditions (e.g., high or low pH), or the base fluid until the encapsulated oil is subjected to sufficient pressure, friction, and shear to be ruptured and the oil is released (e.g., in areas of high friction between the formation and drill string or between the bit and formation, Figure 1) resulting in a longer effective lifetime than incumbent lubricants as currently used in some fluid systems (Figure 2). In addition, due to encapsulation in a neutral non-reactive shell, the encapsulated oil has not materially changed the drilling fluid rheology, pH, or viscosity in the concentrations used thus far. Finally, because the encapsulated oil is only released in areas of high friction, shear, or pressure, its effective concentration is high at the point of friction, even though it may be a small percentage of the total system.

The laboratory characterization and initial field-scale testing (at Catoosa Testing Facility) of encapsulated oil have previously been described[2]. In this paper, we focus on describing the operational benefits of using encapsulated oil in the field drilling exploratory and commercial wells. We focus on results observed in the Alliance Basin/Northern Denver-Julesburg (DJ) Basin (ROP improvement of 216%) and in the Heath Basin (up to 42% reduction in torque to stay within a very narrow target formation).

## Field Results

### Alliance Basin/Northern DJ Basin Case Study

#### *Background*

An 8 1/2 inch diameter exploratory vertical well was drilled in the Red Shale/Opeche and Wolfcamp Minnelusa formations in the Northern DJ Basin using a bent housing motor. An "S" shaped curve for the build section was planned from an existing vertical well in an attempt to maximize the lateral section length. A window was cut in the 9 5/8" casing and the initial kick off performed. Once sufficient distance was achieved to mitigate directional tool performance interference from the casing, the hole angle was dropped back to vertical. Upon achieving the planned kick off point in the vertical section of the "S" hole, the needed build rates using conventional directional tools proved unsuccessful. The maximum hole angle achieved was 22°. When rotary steerable equipment was employed, the ability to build within the equipment specifications was fine but it was determined the hole was already too deep (~7,450 ft TVD) to enable them to land at the target. Due to these challenges and low ROP, a cement plug was pumped in to 7,100 TVD to provide a new kick-off point to achieve the target depth. Encapsulated oil was never used in this initial hole since the planned point of addition (60°of build angle) had never been achieved.

Subsequently, a conventional bent-housing motor directional assembly was redeployed to to drill the curve to 90 degrees in a saturated sodium chloride fluid system (mud weight of 10.5 lb/gal [ppg], Table 1) in which encapsulated oil was added to a total concentration of approximately 12.0 lb/bbl (ppb). The drilling of this second sidetrack resulted in the creation of a 1,556 feet long build section landing at 89.2°, a tortuous path incorporating up to three severe doglegs of 20°+ were constructed. Additions of encapsulated oil were initiated immediately upon the start of this build section. When 60° of hole angle was achieved, 3% by volume encapsulated oil was incorporated into the drilling fluid and 6 % by the end of the interval. Managed Pressure Drilling (MPD) was employed throughout this interval to maintain a 12.3 ppg mud weight equivalent thereby inducing an axial differential sticking issue.

#### *Anecdotal observations*

Following inclusion of encapsulated oil in the mud system, tool response was observed to be much better relative to the original attempt to drill a curve. Directional drillers anecdotally mentioned that the friction in the first well (without encapsulated oil) led to the inability to transmit directional control to the bit with as much as eleven full wraps in the drill string while attempting to slide and build angle. Following inclusion of encapsulated oil in the second build section, they observed that slight changes at the surface directly translated at the tool face (e.g., "all through the second build section, even 100 feet into the lateral section, as little as ¼ turn in the drill string on surface would immediately transmit to the face of the directional tools down hole while sliding"). Additionally, it was observed that casing slid right to bottom following drilling and a lubricant sweep.

#### *Analysis of ROP improvement*

To determine operational benefits, we compared the average ROP observed for the original vertical well (not the failed curve) to the portion of the curve and lateral drilled with encapsulated oil. To reduce variables, we compared ROP within specific formations (e.g., the Wolfcamp Minnelusa formation) and at equivalent TVD.

In the Wolfcamp Minnelusa formation, we observed an ROP increase of 216% (2.0 ft/hr drilling the vertical well, 6.4 ft/hr drilling with encapsulated oil) (Table 2).

### Heath Basin Case Study

#### *Background*

Two horizontal wells drilled in 2013 by an operator in the Heath Basin were challenged by a very narrow target formation, tacky marls just outside of the target formation, varying degrees of formation dip, faulting and associative high torque. As such, ROP was controlled in these wells to ensure staying within the target formation to the highest degree possible. Despite these precautions, staying within the target formation was demanding and as measured depth (MD) increased, rotational torque amplified up to as much as 11,000 foot pounds in the initial well. Encapsulated oil was used in a cationic mud system to drill the second well targeting the same formation (mud formula is in Table 3).

### *Anecdotal observations*

Following the use of encapsulated oil, it was observed that torque was reduced and it was easier to stay in the target formation. Additionally, the overall stability of the wellbore drilled with the second cationic system incorporating the encapsulated oil was found to be significantly better than the previous well drilled with a different cationic system and no encapsulated oil. Another benefit of the encapsulated oil is an observed reduction in API fluid loss.

### *Analysis of torque reduction*

The recorded torque was compared between the original well and the well drilled with encapsulated oil; focusing on the period from the start of the horizontal section at 4,919 feet MD (hole angle 89.2° falling to 87.7° 1/3rd of the way into the lateral) to 9,700 feet MD where dewatering was performed and changed levels of the product in system.. Figure 3 shows the recorded torque as a function of measured depth at different measurement points throughout the lateral section: an observed 11% reduction in torque overall.

## Conclusions

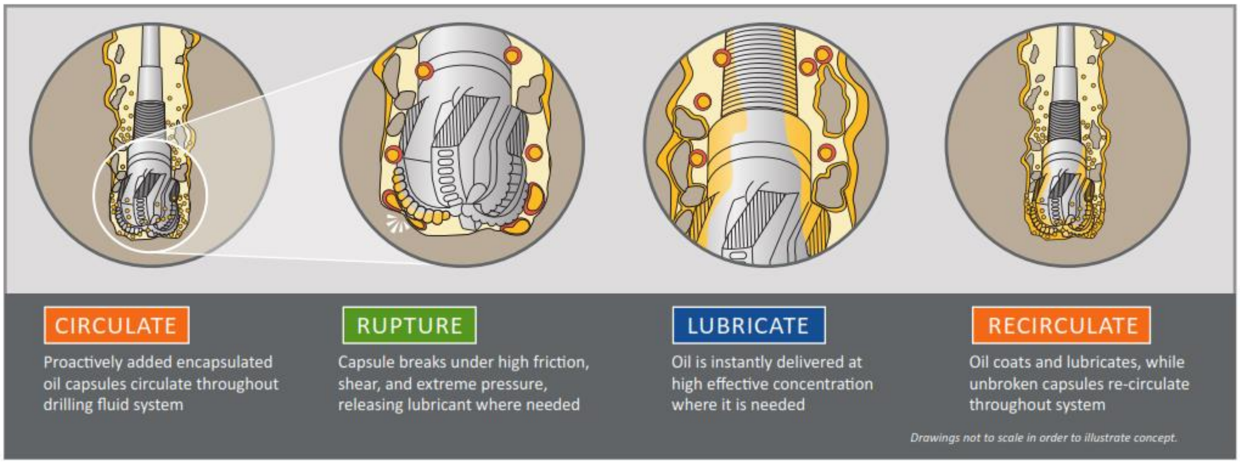
1) Field use of encapsulated oil indicates that it has the ability to provide operational benefits in a variety of different basins with high exploration and production activity.
2) In basins and mud systems where the method of lubrication via encapsulated lubricant (e.g., proactive use, targeted release at high friction points) is able to provide incremental benefits to existing lubricants, use of encapsulated oil may continue to provide operational improvements in Rate of Penetration (ROP) and torque beyond current limitations.
3) When combined with the efficiency (e.g., only releases at friction and stays in system if not ruptured) and longer-lasting benefits of encapsulated oil over multiple uses of the fluid in multiple wells, these benefits could create significant economic benefits for operators.

## References

1. Navarro AR and Daniels WR. “Maximizing Drilling Operations By Mitigating The Adverse Affects of Friction Through Advanced Drilling Fluid Technology.” AADE, 2011
2. Schuh, FJ et al. “Characterization of Encapsulated Oil as an Additive to Water-Based Drilling Fluids: Operational Improvements in Lubricity, Drag and ROP.” SPE 169547, 2014

## Figures

### Figure 1: Hypothesized Mechanism of Action for Encapsulated Oil




### Figure 2: Coefficient of Friction (CoF) over time (minutes)

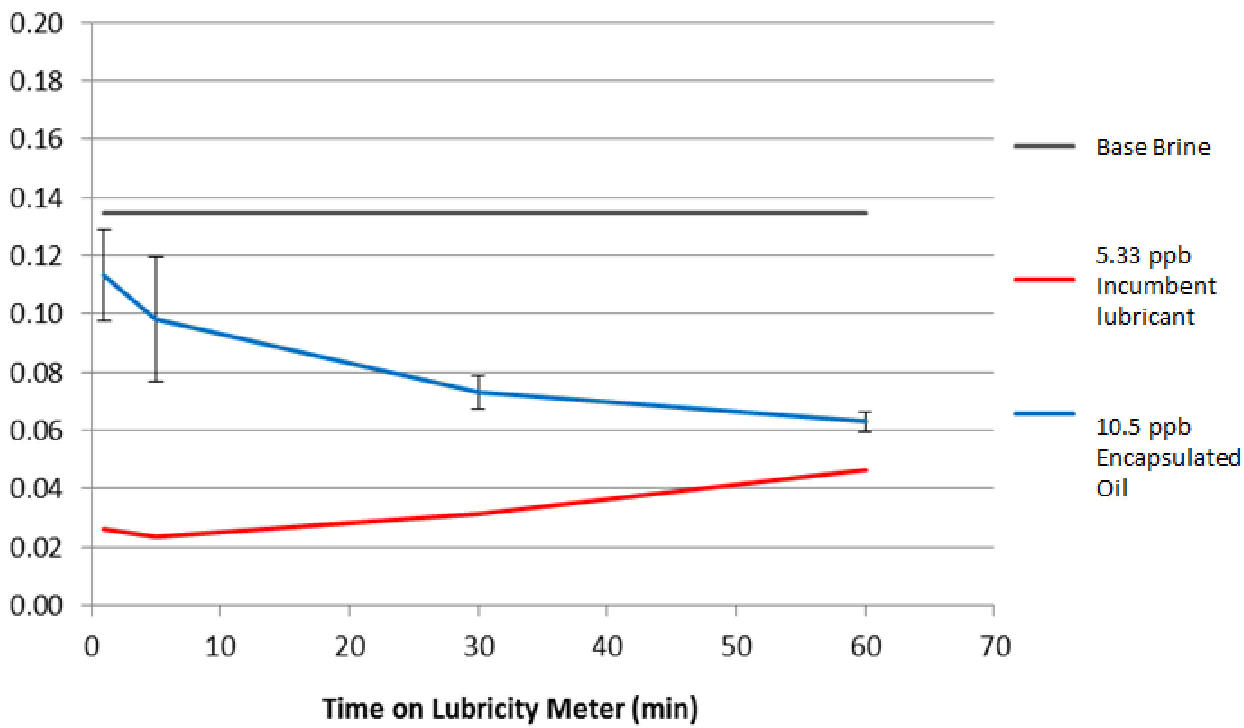
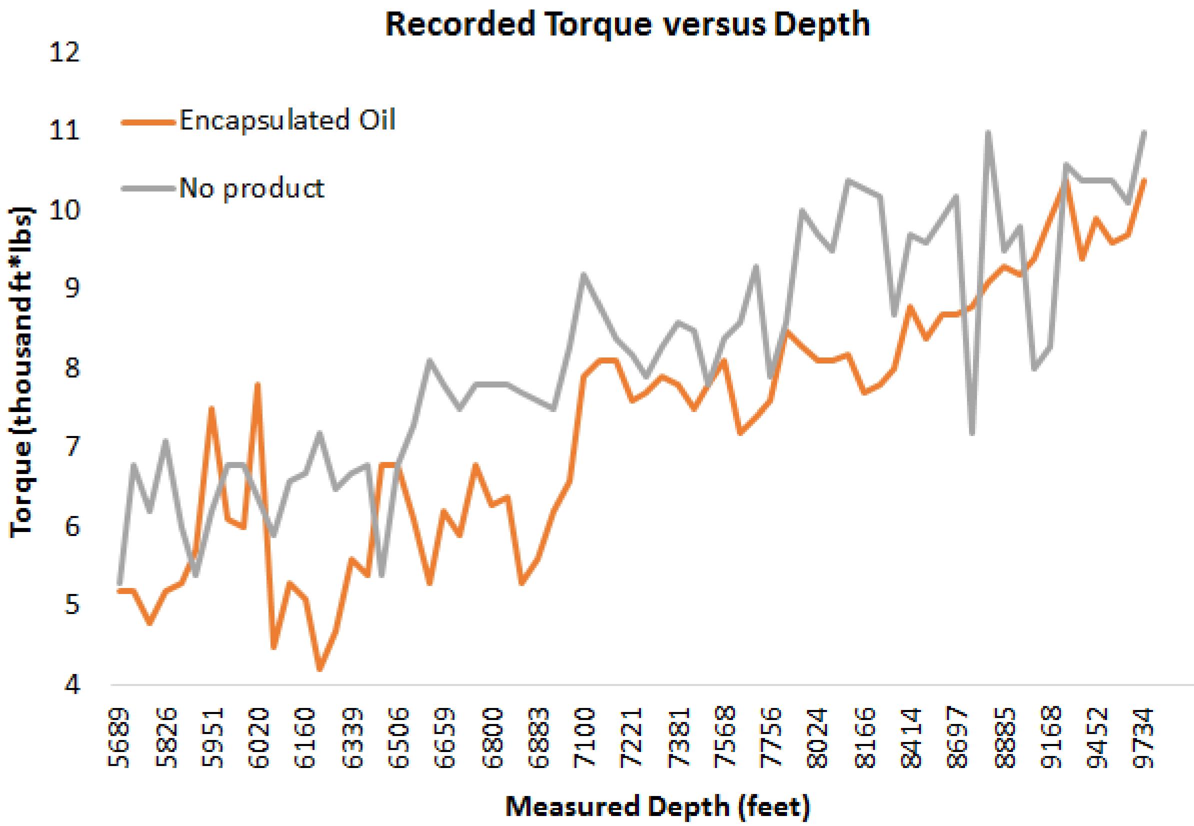


**Figure 3: Recorded Torque vs. Measured Depth**




## Tables

**Table 1: Exploratory Well Water-Based Fluid System**

| Ingredients | Amount |
|---|---|
| Sea Mud | 20.0 ppb |
| Soda Ash | 1.5 ppb |
| White Starch | 4.0 ppb |
| PAC LV | 0.75 ppb |
| Caustic Soda | 0.5 ppb |
| Gluteraldehyde | 0.5 ppb |
| Sodium Chloride | 125.0 ppb |
| Encapsulated oil | 12.0 ppb |

**Table 2: Results from Exploratory Well**

| Well | Formation | Average ROP | Std. Dev of ROP | Percent increase |
|---|---|---|---|---|
| Initial | Wolfcamp Minnelusa | 2.0 | 1.0 | |
| With Encapsulated Oil | Wolfcamp Minnelusa | 6.4 | 2.3 | **216%** |

**Table 3: Heath Well Mud System**

| Ingredients | Amount |
|---|---|
| ARC SS™ | 3.00 ppb |
| ARC Drill-In™ | 1.65 ppb |
| PAC Regular | 0.50 ppb |
| Xanthan | 0.75 ppb |
| White Starch | 5.00 ppb |
| Caustic Soda | 0.50 ppb |
| Gluteraldehyde | 0.50 ppb |
| Encapsulated oil | 12.0 ppb |