

# Advanced Premium Lubricant Solution to Reduce Drill String Weight Stacking at Under Balance Coiled Tubing Drilling Operations

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## Abstract

Under Balance Coiled Tubing Drilling (UBCTD) is a drilling technique used to increase the hydrocarbon's productivity, increasing the rate of penetration (ROP) and mitigating risk of losses or wellbore instability. While implementing such drilling technique, usually the ROP is affected by string stacking. This paper describes how after extensive lab testing, an advanced ester based premium lubricant has been utilized at the field to reduce the drill string weight stacking and assisted to free the string at lock up points and during stuck incidents.

Varied lab testing was conducted to identify the optimal premium lubricant selection and concentrations to be used across the tough conditions of the Under Balance Coiled Tubing operations, such as high bottom hole temperature, high pressure, presence of high concentration of Hydrogen Sulfide (H<sub>2</sub>S) and Carbon Dioxide (CO<sub>2</sub>). Lab results revealed that ester-based lubricants were the most appropriate solution to reduce drill string weight stacking and assist to free the string at lock up points and during any stuck incidents. It was validated when the proposed solution was implemented at the field, where more than 500 laterals in the studied area.

Ester-based premium lubricants (EBPL) with concentrations up to 1% by volume were implemented in a treated water drilling fluid to drill more than 500 laterals across heavily faulted formations. The water used as drilling fluid is treated with alkalinity source to increase the pH to 10.5-11, similarly with sodium carbonate to remove the calcium ions below 100 milligram per liter and obtain proper environment for the EBPL and also treated with hydrogen sulfide scavenger to remove any sulfide concentration. This pre-treatment to the water used as drilling fluid helped to avoid any foaming, grease or cheese issues after the EBPL additions. Once UBCTD operations starts, an EBPL concentration of 0.15% by volume is added to enhance the lubricity of the drilling fluid, however, once the string weight increases and starts stacking, the rate of penetration is negatively affected and the EBPL concentration is incremented from 0.15% by volume to 1% by volume as maximum concentration. In multiple occasions, once the lock up point is reached, EBPL pills with 1-1.5% by volume is

pumped to free the string and keep drilling additional length across the reservoir, increasing the reservoir contact and hydrocarbon's productivity. Those field applications demonstrated the benefits of the utilization of the EBPL technology to overcome mentioned challenges at UBCTD applications, in addition to the consequent benefits that were obtained such as nonproductive time reduction.

The drilling industry with the current oil worldwide situation is continuously looking for non-productive time reduction strategies, this innovative premium lubricant solution to Reduce Drill String Weight Stacking at UBCTD operations will definitely aim to minimize non-productive time issues and allow for optimal rates of penetration while drilling in those challenging conditions.

## Introduction

Coiled tubing refers to a constant length of small-diameter steel pipe and connected surface equipment as well as related drilling, completion and workover, or remediation, techniques. Coiled tubing oilfield technology was initially developed for working on live, producing wells. However, in the early 1990s, the industry extended the cover by using coiled tubing for drilling applications, particularly for re-entry wells. This technique was implemented and good results were obtained, but was limited to the slim hole due coiled tubing sizes.

The Middle East is one of the areas that was part of the initial focus and recognized the technology's potential. It is the only area where several coiled tubing drilling (CTD) projects have been completed and developed by various operators in different countries. By gaining more experience, addressing new challenges and developing CTD applications further, this led to improvements in downhole bottom hole assembly technology, rig and under balance equipment, other required operating systems, processes and procedures. (Krueger, et al., Gray, et al., Killip et al., SPE/IADC 166692).

Underbalanced Drilling technology has enabled the commercial development of numerous oil and gas reservoirs worldwide that would have otherwise not been exploited due to technical and/or economic limitations. Under Balance

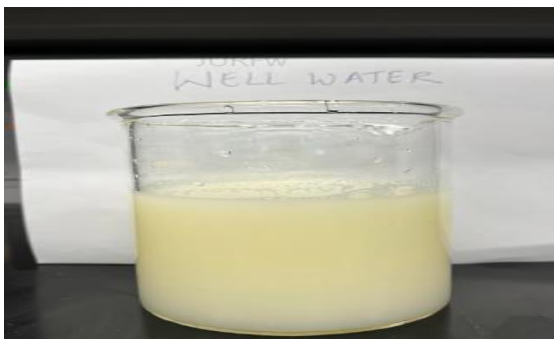
Drilling has only become possible as a result of the integration of many developing technologies that facilitate directional control, measurement and control of the bottom-hole circulating pressures and the safe handling of drilling fluids, production and cuttings at the surface. (Khamees, et al., Ali, et al., Marey et al., Valecillos et al., SPE 168074). While implementing this technique in the studied area, we drill while the well is flowing as the hydrostatic column is maintained below the reservoir pressure. Laterals drilled are horizontal and commonly while drilling, the drill string faced weight stacking issues that negatively affect the rate of penetration. Similarly, detrimental incidents are string stuck incidents can take place depending of the well conditions. In addition to that, those wells present an environment with the presence of several acid gases as Hydrogen Sulfide (4%), Carbon Dioxide (2.5%) an average bottom hole temperature (BHT) of 320°F.

Lubricants are used in drilling fluids to reduce the coefficient of friction while drilling. During under balance coiled tubing drilling (UBCTD) drill string weight stacking issues can be solved with the lubricant utilization. Our lab and field results revealed that Ester-based premium lubricants (EBPL) were the most appropriate solution to reduce drill string weight stacking and assist to free the string at lock up points and during any stuck incidents on mentioned conditions.

**Experimental Evaluation**

Ester-based premium lubricants (EBPL) are environment friendly lubricant and are used to reduce torque and drag in very challenging drilling and completion operations, e.g. special coiled tubing, under balanced drilling. The product should be compatible for application in seawater and salt brine-based drilling fluids. Samples of EBPL from the field were tested for the quality against product specifications and also for lubricity performance and cheese or grease phase out using two waters, lab water and water from the field.

The water from the field received for laboratory experiment was light yellowish in color with some settled sedimentation which got dispersed after homogenizing the water, as we can observe in Figure 1. Well water was also tested for hardness and was less than 300 ppm.





**Figure 1—Water from the field.**

In order to perform an assessment of the quality concerns, sample was tested in the lab as per our specifications and also for cheese and grease phase out in both lab and field water. No excessive foaming was observed during the mixing of EBPL and well water at 1% by volume of EBPL concentration, as we can observe on Figure 2.



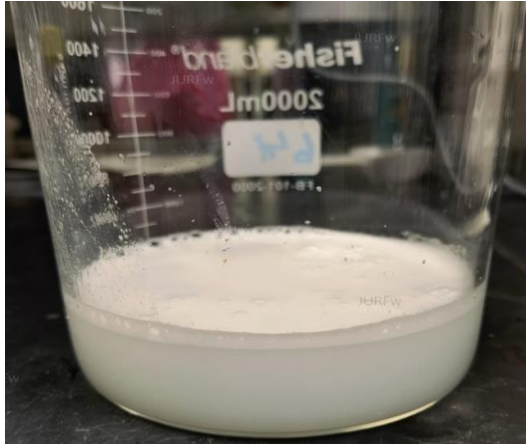
**Figure 2—EBPL mixed into field water.**

Cheese and grease tests were performed both in lab water and well water. EBPL passes cheese and grease phase out test in lab water having calcium hardness adjusted about 300 ppm, while it does not meet acceptable limits with testing in well water. The results below on Table 1.

Test	EBPL	Specifications
Appearance	Yellow to Amber color	Yellow to dark amber
Specific Gravity @ 68 °F (20 °C)	0.95	0.95-1.05
Solubility in water	Insoluble	Insoluble
Flash point, PMCC °F	200 °C (392 °F)	>100 °C (212 °F)
Test Parameter	With lab water	With water from well
Foaming during mixing	Slight foaming	Slight foaming
Cheese and grease out (grams)	0.98	2.01
Cheese and grease out (grams)		

**Table 1—Lab test results.**

Based on the grease and cheese observed during the initial lab testing, the hardness water was treated with 1.2 grams per liter soda ash (Sodium Carbonate) to treat the calcium and then we added the 428 mg/l caustic soda to increase the pH. After the treatment we were able to reduce the water well calcium hardness to 80 ppm and establish the pH at 11. On treated water, we mixed 1% by volume EBPL and got slight foam but no grease and cheese as we can observe on Figure 3.



**Figure 3—EBPL mixed into field water treated.**

### Field Evaluation

UBCTD surface package was designed to work with two stages of separation for the gas and the solid settling tank (SST) system to separate condensate from the water and solids. In this design for normal drilling operations, the fluid return stream comes from the well flow through the primary flow line into the surface system. Before the return stream goes into the separation system, it is cleaned out of big rocks or debris (if present) by the junk catcher, which is located upstream the choke. After passing through the junk catcher, the flow rates and pressures are then regulated by means of the 5K psi choke manifold. At this point, the choke operator adjusts the choke position to control the production rates and pressures of the fluid coming into the separation stages.

From the 5K psia choke manifold, the returns then enter the high stage separator, where most of the gas is separated. From this vessel the gas is diverted into the production line, and the liquids and solids are shipped to the low stage separator driven by the pressure of the recipient.

Once most of the gas has been broken and exported through the high stage gas line, liquids (water and condensate) and solids flow through the high stage water leg and pass through the electric choke (Lancaster) before it enters the low stage. In

the low stage, gas still in the liquid is agitated and separated before sending the liquid phase with cuttings to the SST.

Once the liquid returns still with solids, pass through this measurement skid, the returns are directed to the SST. In the SST condensate is separated and shipped to the condensate storage tank. Water and solids then are shipped to the skimmer tank and subsequently to the waste pit.

The technique used to circulate the drilling fluid at UBCTD wells is “Pump and Dump”. But, for proper evaluation of the lubricant at the field, we established certain key performance indicators (KPI’s) as:

- Mixture/Mixing of the lubricant need to be homogeneous with no issues (Foam, Grease or Cheese)
- Returns from the well need to be easy to separate with no emulsion, foam or any condition that delay the separation process.
- A lateral will be drilled with the approved lubricant and a second lateral will be drilled with the lubricant under trial test and UBCTD will assess and compare effectiveness on performance.
- Maximum expected concentration is 1% by volume (while drilling)
- Lubricant must comply with all above key performance indicators

The EBPL was tested following the above key performance indicators in two wells (Well A & B). During Well A, before we start mixing the EBPL, tested location water for hardness represented in Calcium content and also Chloride content and both were in the accepted limits:

- Calcium content in untreated make up water: 200 ppm
- Calcium content in drilling fluid (treated water with Soda ash & Caustic Soda): 80 ppm
- Chloride content: 400 ppm
- pH: 10.9

Before mix on the pits a quick pilot test was performed and visual inspection for the fluids before and after treatment and adding EBPL indicated no foaming, no greasing and no cheesing.

Started drilling with water and side tracking the well maintaining 89-degree inclination across the lateral section using 0.15% by volume of EBPL with no foaming, no greasing and no cheesing. At deeper depth, increased EBPL concentration from 0.15% by volume to 0.33% by volume due weight stacking, after it was observed low rate of penetration, so a trip to service was performed to check and replace tools. The fluid does not show foaming, cheesing or

greasing. Resumed drilling and increased the concentration of EBPL to 0.66% by volume due weight stacking to improve drilling parameters and ROP. Went deeper and pumped a pill with 1.0% by volume EBPL with positive impact on drilling parameters and ROP after weight stacking. At this concentration the drilling fluid did not have any foaming, cheesing or greasing until reached total depth (TD) without any issues. On Figure 4, we can observe the different EBPL concentrations used by depth on Well A. It's worth to mention that at TD, Hydrogen Sulfide concentration was 4%, Carbon Dioxide concentration was 2% and maximum bottom hole temperature was 318°F. Hydrogen Sulfide scavengers (triazine based) and alkalinity sources were continuously added to the drilling fluid to combat the presence of those acid gases and maintain the required alkalinity.

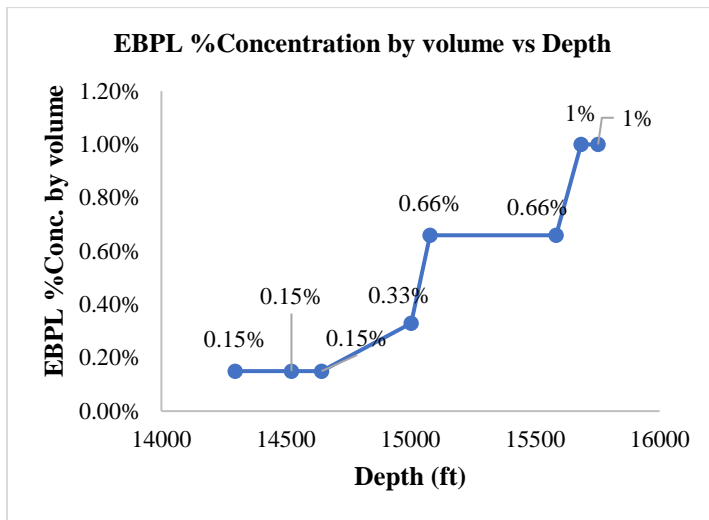


Figure 4—EBPL % Concentration by volume vs Depth on Well A.

Overall on Well A, EBPL performance was good and no big troubles were encountered while mixing and drilling. Very light foams were seen in the separator but did not affect the operation or separation process. Another lateral was drilled with another approved lubricant and was compared the effectiveness on performance, showing acceptable performance after the comparison.

On Well B, started drilling with water with pH: 10.5, calcium content 80 ppm with 87-degree inclination along with nitrogen lifting. Swept the hole with high viscosity pills as required to clean the hole. Going deeper, observed a reduction in Coil tubing weight (weight Stacking) due to the friction that led to difficulty in transmitting the weight to the bit, at this point started to mix 0.15 % by volume EBPL to active water, the inclination at this point was 90 degree and BHT 322 °F, after the lubricated water passes through the bit performed short trip and ran back to bottom, resumed drilling observed the CT weight improved. Continue drilling lateral section and observed

gas flow 2.4% of H<sub>2</sub>S and 1.5% of CO<sub>2</sub>, line up flaring and discontinue pumping nitrogen.

Decision was made to increase EBPL concentration to 0.33 % by volume due to coiled tubing weight stacking. Observing considerable improvement to allow continue drilling operations. At 800 ft off bottom proposed TD, the coiled tubing weight stacked and increased the EBPL concentration to 0.66 % by volume with significant progress reducing the weight stacking. But at 200 ft off proposed TD, another weight stacking issue took place, therefore, was decided to increase it to 1% by volume. We continued drilling up to 23 ft above proposed TD and coiled tubing got stuck, as spotting fluid in order o free the pipe, it was prepared an EBPL pill with 1.5 % by volume and was circulated twice across the bottom hole assembly and string got free. The hole was circulated and wiper trip was performed. We did resume the drilling operations to the targeted TD and complete the well without further problems. On Figure 5, we can observe the different EBPL concentrations used by depth on Well B.

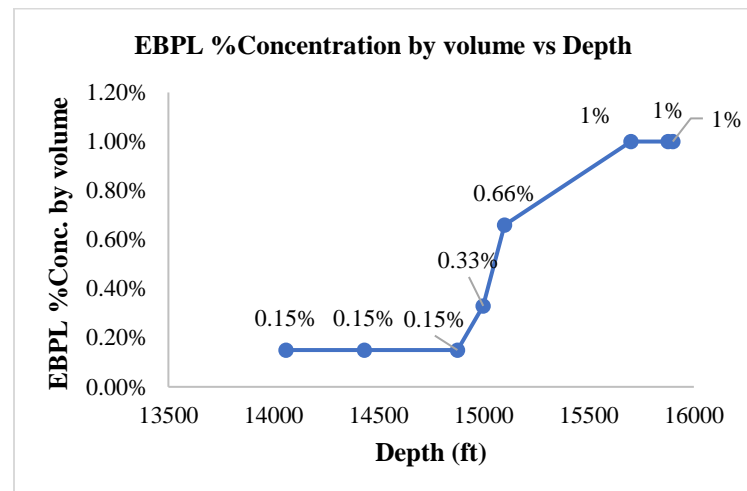


Figure 5—EBPL % Concentration by volume vs Depth on Well B.

Similarly, to Well A, overall on Well B, EBPL performance was good and no big troubles were encountered while mixing and drilling. No foams were seen in the separator or anything that affect the operation or separation process. Another lateral was drilled with another approved lubricant and was compared the effectiveness on performance, showing acceptable performance after the comparison.

Ester-based premium lubricants (EBPL) with concentrations up to 1% by volume were implemented in a treated water drilling fluid to drill more than 500 laterals across heavily faulted formations in the studied area.

## Conclusions

As conclusions, based on the fact that those type of wells are drilled at underbalance conditions, where the hydrostatic pressure is lower than reservoir pressure, water can be used as drilling fluid. The water must be treated with alkalinity source (caustic soda) to increase the pH to 10.5-11, similarly with sodium carbonate to remove the calcium ions below 100 milligram per liter and obtain proper environment for the EBPL to avoid foaming or grease and cheese issues. Similarly, water must be treated with hydrogen sulfide scavenger to remove any sulfide concentration that affect the EBPL performance.

Once UBCTD operations starts, an EBPL concentration of 0.15% by volume is added to enhance the lubricity of the drilling fluid, however, once the string weight increases and starts stacking, the rate of penetration is negatively affected and the EBPL concentration must be incremented from 0.15% by volume to 0.33% by volume, then to 0.66% by volume, up to 1% by volume as maximum concentration if required. In multiple occasions, once the lock up point is reached, we can't drill further, at this moment EBPL pills with 1-1.5% by volume must be pumped to free the string and keep drilling additional length across the reservoir, increasing the reservoir contact and hydrocarbon's productivity. Additionally, during the stuck incidents the EBPL must be used at 1-1.5% by volume to free the coiled tubing pipe.

## Nomenclature

*UBCTD: Under Balance Coiled Tubing Drilling*

*ROP: Rate of Penetration*

*H<sub>2</sub>S: Hydrogen Sulfide*

*CO<sub>2</sub>: Carbon Dioxide*

*EBPL: Ester-Based Premium Lubricants*

*CTD: Coiled Tubing Drilling*

*BHT: Bottom Hole Temperature*

*ppm: parts per million*

*°F: Fahrenheit degrees*

*°C: Centigrade degrees*

*mg/l: milligrams per liter*

*SST: Solid Settling Tank*

*TD: Total Depth*

2. SPE 168074, Fit for Purpose Underbalanced Coil Tubing Surface Equipment Permits Safe Drilling of High H<sub>2</sub>S Horizontal Gas Wells in Saudi Arabia with Higher Productivity Results. Shaker Khamees, Mohammed Ali, Saudi Aramco; Ayman Marey and Juan C. Valecillos, Weatherford International. This paper was prepared for presentation at the SPE Saudi Arabia section Annual Technical Symposium and Exhibition held in Khobar, Saudi Arabia, 19–22 May 2013.

## References

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