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Minimization of Residual Oil on Cuttings by Mechanical and Chemical Treatment

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Abstract

Disposal of drill cuttings contaminated with hydrocarbon-based drilling fluids is an area of significant concern for operators. Offshore, the US has introduced a 6.9% discharge limit for synthetic and 9.4% for ester contaminated cuttings into the Gulf of Mexico. These limits are based on Best Available Technology (BAT) and may be reduced if improved treatment technologies are available. Thermal desorption is one of the options considered for cleaning oil from cuttings in offshore operations, however footprint and HSE limitations make this technology unsuitable for offshore rigs.

By using a cuttings dryer or other mechanical means, residual oil content (ROC) can be reduced to 5% at the rig site but currently it is very difficult to reach lower ROC with traditional processes.

In this research study, chemical treatments have been investigated and used to enhance the efficiency of secondary oil recovery equipment (cuttings dryer) and to reduce the ROC. Effects of chemical concentration, physical parameters (such as contact time, mixing energy) were evaluated and chemical treatment, prior to mechanical separation, was found to be very effective to decrease residual oil on cuttings.

This paper presents the results of these studies on oil on cuttings reduction and the effect of various chemical treatments on the efficiency of secondary oil recovery equipment.

Introduction

In many parts of the world oil-based cuttings generated during the drilling process have to be treated prior to disposal, due to the legislation limit, and in some areas, prohibiting disposal. In the UK sector, the discharge limit is set at 1% ROC whereas in the Gulf of Mexico, a maximum of 6.9% ROC for synthetics and 9.4% ROC for esters is permitted based on the Best Available Technology (BAT). Cuttings re-injection (CRI), ‘skip and ship’, bulk slurry transfer, and pneumatic bulk transfer are some of the various solutions available for managing and disposing offshore drilling waste. Apart from CRI, all the methods require land-based waste treatment and there is a need for offshore cuttings treatment especially when CRI is not available. One of the main advantages of offshore treatment is the reduced cost and reduced logistical difficulties at the rig site. By treating the cuttings to a low ROC level, more oil-based fluid can be recovered and re-used thereby reducing the overall waste volume. Depending on the mud type, the location and the legislation, the treated cuttings can then be discharged.

Different methods have been investigated to try to reduce the level of oil on cuttings offshore such as thermal treatment[1] but limitations in terms of HSE issues and footprint mean that this technology is not really suitable for offshore rigs. Washing systems have also been tested but were not very successful as the amount of process waste byproducts generated and equipment is quite large.[2] Secondary oil recovery equipment or cuttings dryers have been developed and perform well with a typical average residual oil on cuttings of 5%.[3] At present, achieving lower ROC using only this technology is difficult.

The work of Oakley, *et al*.[4] has shown the influence of oil-based drilling fluid chemistry on oil retained on cuttings. Some of the key parameters included the use of strong wetting agents and the effect of plastic viscosity on the ROC. By using surfactants or thinners, the viscosity around the cuttings can be decreased enhancing the oil removal.

The results reported and discussed in this paper cover the effect of chemical treatment to enhance the secondary oil recovery equipment. A laboratory test has been developed to simulate the secondary oil recovery equipment. The effects of chemical concentration and physical parameters such as contact time and mixing energy were also investigated. This paper also describes the implementation of this technology in the field and presents some initial results.

Experimental Methods

Lab-Scale Cuttings Dryer

One of the first requirements during this study was to simulate the mechanical process *i.e.*, cuttings dryer. Two different types of cuttings dryers are available: vertical (conical basket) and horizontal (cylindrical basket) screens. For the vertical screen, the cuttings dryer is a vertical-axis centrifuge which works on the principle of applying accelerated G forces (conical basket) to the cuttings as they are transported across a mesh screen. The G forces vary from 98 G at the top of the screen to 352 G at the bottom of the screen. Depending on the formation type, cuttings wetness and feed rate, the ROC is typically around 5%. The other type of cuttings dryer uses a cylindrical screen that allows a constant G force to be applied uniformly over the entire screen area. The G Force can be varied from 100 to 600 G with the residence time varying from 0.5 to 7 seconds.

In this study, a vertical-screen cuttings dryer was simulated with a constant G Force applied through the screen. A modified Waring blender cup along with a speed controller was used to apply the desired G force. A cylindrical screen (5-cm diameter) was built using a 20-mesh screen. The equipment set-up is shown in Fig. 1. Using this configuration, the RPM and hence the G Force can be varied using a Waring blender speed controller.

The centrifugal acceleration experienced by the screen will depend on the rotational speed (RPM) and the radius (R, distance from rotating axis). The Relative Centrifugal Force or G-Force is defined as:

$$RCF = 1.118\,R\left(\frac{RPM}{1000}\right)^2 \tag{1}$$

where: RCF = Relative Centrifugal Force, (G)
R = Radius (mm)
RPM = Rotations per minute, the rotational speed of the screen

By varying the RPM, the G Force can de determined using the formula in Eq. 1. In order to simulate the field cuttings dryer, the RPM was set at 3000, which corresponds to 252 G.

In the field, the cuttings are continuously fed to the dryer. In the laboratory, a batch system was used and the cuttings were fed to the basket screen and then spun for a set time. This method was found more reliable and safer than a continuous feed.

Chemical application

Tests were run on a batch system using 50 g of cuttings for each test. The cuttings were placed in a 100-mL glass bottle and the chemical treatment applied at this stage if required. The contact time was varied (30 s, 1 min, 2 min or 5 min) depending on the test performed. All the chemical treatments were diluted in base oil and their concentration varied. The mixture (cuttings + chemical treatment) was fed into the basket screen and spun for a set time. The cuttings were then collected and tested for ROC.

ROC Determination

The residual oil content was determined using the standard method described in API RP 13B-2.[5] A 20-mL retort was used for the entire testing. When running a retort test, the main error factor observed was the reading of the water volume on the measuring cylinder. Standard deviation was calculated to determine the effect of ±0.1 mL on the ROC determination. The results are summarized in Table 1. From these tests, we can see that a 0.1-mL reading error will have a large impact on the ROC accuracy (± 0.54% w/w). In order to improve the accuracy of the test method, the collection vessel was changed to a 5-mL measuring cylinder, as the oil level in these tests was quite low and this helped minimize the reading error.

Repeatability tests were also done on the cuttings before chemical treatment in order to assess the test method accuracy. A standard deviation of ± 0.01 was found on the % ROC w/w (weight by weight) on dry cuttings and ± 0.02 on the % ROC w/w on wet cuttings (Fig. 2). The ROC level can be expressed in two forms: weight-by-weight on wet cuttings or weight-by-weight on dry cuttings. In this study, results were recorded as a percentage of weight-by-weight on wet cuttings as this nomenclature appears to be the most common within the industry.

Results

General

Cuttings generated by North Sea drilling operations were used for all these tests. Characterization of these cuttings is summarized in Table 2.

Tests were run on a batch system as per the method described above. The model cuttings dryer was then run for 15 s at 3000 rpm, which corresponds, to a realistic field operation. Initial tests with this field cuttings using the lab scale cuttings dryer at 3000 rpm for 15 s did drop the ROC from 8% down to 4% indicating a good representation of the field cuttings dryer.

All the chemical treatments were diluted in base oil. Initial tests were run with Base Oil 1 alone to determine the best concentration for reducing the ROC (Fig. 3). Adding Base Oil 1 to the cuttings decreases the ROC from 4% to 2.15% in the best case. Increasing the Base Oil 1 concentration above 20% v/v increases the ROC. A minimum amount of base fluid is needed to loosen the OBM surrounding the cuttings, but if the base oil concentration is too high, the ROC will start to increase again. The best concentration to improve the ROC appears to be 15% v/v Base oil 1 (5 mL with 50-g cuttings).

Effect of chemical treatment and chemical concentration

Different chemicals were tested to determine their ability to reduce the ROC (Fig. 4). The chemical concentration was set at 5% v/v in Base Oil 1 and left in contact for one minute with the cuttings and the mixture tested with the lab-scale cuttings dryer. Reduction in residual oil content was achieved with most of the chemicals (Fig. 4).

The effect of chemical concentration was studied with Chemical A (Fig. 5). Increasing the chemical concentration did not improve the ROC and indeed if too much chemical was added, the ROC increases compare to the base oil alone. A 5% v/v chemical treatment appears to be the most effective concentration of this chemical.

Effect of Contact Time

In the field, different chemical addition points are available throughout the solids-handling system. Depending on the addition point, the chemical treatment will be in contact with the cuttings for different lengths of time. Different contact times were tested from 30 s up to 5 min. A 30-s contact time corresponds to an addition just before the cuttings dryer feed whereas a higher contact time (up to 5 min) might be reached if the chemical application is done at the shaker and will also vary depending upon the distance between the shaker and the cuttings dryer feed. Tests were run with Base Oil 1 and Chemical A (Fig. 6). Increasing the contact time from one to five minutes does not decrease the ROC. The chemical needs to be in contact with the cuttings for one minute in order to work efficiently and reduce the viscosity around the cuttings. After one minute contact time, the ROC was stable (around 2.15%) and the cuttings did not seem to deteriorate with time.

Effect of Base Oil Viscosity

Preliminary tests have shown that ROC can be improved by adding base oil or base oil with surfactant, making up a chemical treatment. By adding the chemical treatment, the viscosity of the fluid around the cuttings can be reduced, facilitating the removal of the OBM layer. Six different base oils were tested (their properties are summarized in Table 3) and run through the lab-scale cuttings dryer (Fig. 7). Increasing base oil viscosity increases the ROC from 1.9% to 2.5%. The base oil viscosity should be kept as low as possible in order to improve ROC. The mud base fluid dictates which base oil will be used to improve the cuttings dryer efficiency. The fluid recovered from the process will be returned to the active mud system. Therefore any chemical treatment utilized should not have any detrimental effects on the mud system.

Implementation of this technology in the field

Based on the preliminary laboratory testing, a field trial was set-up on a South Texas land-based drilling rig. The objective of this field trial was to reproduce the laboratory results and to confirm the ability of chemical treatment to significantly reduce the ROC during full-scale field operations at actual cuttings generation rates.

Based on the laboratory study, the equipment was set-up (Fig. 8) where special considerations for the application of the chemical treatment were taken to minimize personnel exposure. As the cuttings are discharged from the shaker screens, they entered a screw conveyor and were conveyed to the cuttings dryer. The liquid effluent from the cuttings dryer was further processed with a centrifuge for additional fines removal. Both solids from the cuttings dryer and the centrifuge were collected in a screw conveyor before being discharge in a skip. The chemical can be applied at two different points: screw conveyor or shaker chute in order to assess the effect of contact time. A chemical pump was used to vary the application rate and determine this effect on the ROC.

The initial tests were run with Chemical B at two different concentrations 1 and 5% and the chemical was applied at the screw conveyor. A second base oil (Base Oil 2) was also tested. Samples were collected at different points as shown in Fig. 8:

- Cuttings from top scalping shaker (A)
- Cuttings dryer feed (B)
- Cuttings dryer discharge (C)
- Centrifuge discharge (D)
- Centrifuge effluent (E)

Results are summarized in Fig. 9. On this particular type of cuttings (soft shale), the cuttings dryer efficiency was quite good (around 55%) with a ROC of 4.9%. Pre-treatment on the screw conveyor with Base Oil 2 at different concentrations did not substantially improve the cuttings dryer performance although it did increase from 55% to 60%.

Pre-treatment with Chemical B improved the cuttings dryer efficiency quite drastically from the untreated base line (from 55% to 80%) with the best result using 5% Chemical B at 1.8 L/min. The ROC dropped from 4.9% to 2.9%. Increasing the Chemical B concentration from 1% to 5% did not substantially improve the cuttings dryer efficiency. Increasing the chemical application flow rate from 1 to 1.8 L/min did not seem to increase the cuttings dryer efficiency.

Centrifuge discharge samples were tested and the ROC determined by retort. ROC was between 9% to 12% on all the tests regardless of the chemical type and concentration. Chemical pre-treatment in the cuttings dryer did not seem to affect the final centrifuge discharge ROC. Most of the particles after chemical treatment in the cuttings dryer and the centrifuge effluent were below 5 to 7 μm (Table 4). Adding the chemical treatment to the cuttings dryer feed did not seem to affect the particle-size distribution (PSD). OBM samples were analyzed at the beginning and the end of the process and the PSD seems to be relatively consistent (Table 4). This indicates that the chemical treatment did not have any adverse effects on the mud system. No additional fines were created as a result of the chemical treatment

(% LGS constant) and no problems were reported when the recovered mud was re-used.

Discussion

The reduction of ROC offshore is an area of high interest for the operator as it will decrease the transportation cost and may allow cuttings discharge in some areas. While cuttings dryers reduce the ROC, this not always enough for cuttings discharge. The results reported in this study show that by using chemical treatment together with a cuttings dryer, the ROC can be decreased to low levels reducing the amount of drilling fluid lost when cuttings discharge is permitted. 1% to 5% v/v chemical treatment is required to achieve the best ROC reduction. The results also show that the chemical treatment had no adverse effect on the mud system.

The first field test has been successful showing the reduction in ROC when using Chemical B prior to a cuttings dryer. More testing is required to determine the best dosage, application rate and optimization of the process both technically and economically.

Conclusions

- The combination of chemical treatment and cuttings dryer reduced the ROC (residual oil content).
- A lab-scale cuttings dryer was built and tests indicated that the model is a good representation of the real thing.
- The effect of different chemical treatments was studied to minimize ROC and optimize treatment level.
- Chemical viscosity is an important parameter in reducing ROC. A minimum contact time between the cuttings and the chemical treatment is required to achieve the best reduction in ROC.
- A field test was performed and used to validate the laboratory results. ROC reduction was observed with chemical treatment and the cuttings dryer efficiency was improved. The chemical treatment had no adverse effect on the mud system
- More field tests will need to be performed in order to optimize the application rate and chemical dosage.

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Table 1 - Error Factor in Volume Readings from the Retort Analysis

Test #		- 0.1 mL V_{water} READ	V_{water} READ	+ 0.1 mL V_{water} Read	Standard Deviation
Test 96-1	% ROC w/w/wet cuttings	3.45	3.09	2.62	0.42
	% ROC w/w/dry cuttings	4.45	3.91	3.37	0.54
Test 96-2	% ROC w/w/wet cuttings	3.48	3.06	2.64	0.42
	% ROC w/w/dry cuttings	4.45	3.92	3.38	0.54
Test 96-3	% ROC w/w/wet cuttings	3.5	3.08	2.66	0.42
	% ROC w/w/dry cuttings	4.47	3.93	3.4	0.54

Table 2 - Cuttings Characterization

SG	1.8
CEC (meq/100g)	22.0
Oil Content (% w/w)	8.0
Reactive Clay (%)	28.0
Quartz (%)	44.0

Table 3 - Base Oil Properties

PRODUCT	TYPE	DENSITY	VISCOSITY CST AT 40°C
Base Oil 1	Mineral oil	0.82	2.45
Base Oil 2	Diesel	0.85	3 to 4
Base Oil 3	Mineral oil	0.82	1.73
Base Oil 4	Mineral oil	0.78	2
Base Oil 5	Enhanced mineral oil	0.814	3.5
Base Oil 6	Isomerized alpha olefin	0.776	3.6

Table 4 - OBM and Centrifuge Effluent PSD Analysis

#	CHEMICAL TREATMENT	D_{10}, μM	D_{50}, μM	D_{90}, μM	% LGS
OBM – Before chemical treatment	None	0.98	7.53	39.8	1.9
OBM – After chemical treatment	None	1.03	8.67	42.1	2.0
Centrifuge Effluent	None	0.6	2.38	6.56	
Centrifuge Effluent	Base Oil 2	0.65	2.27	4.9	
Centrifuge Effluent	1% Chemical B	0.6	2	4.37	
Centrifuge Effluent	5% Chemical B	0.62	2	4.5	
Centrifuge Effluent	5% Chemical B	0.73	2.19	4.61	

Fig. 1 – Lab-Scale Cuttings Dryer Set-Up.

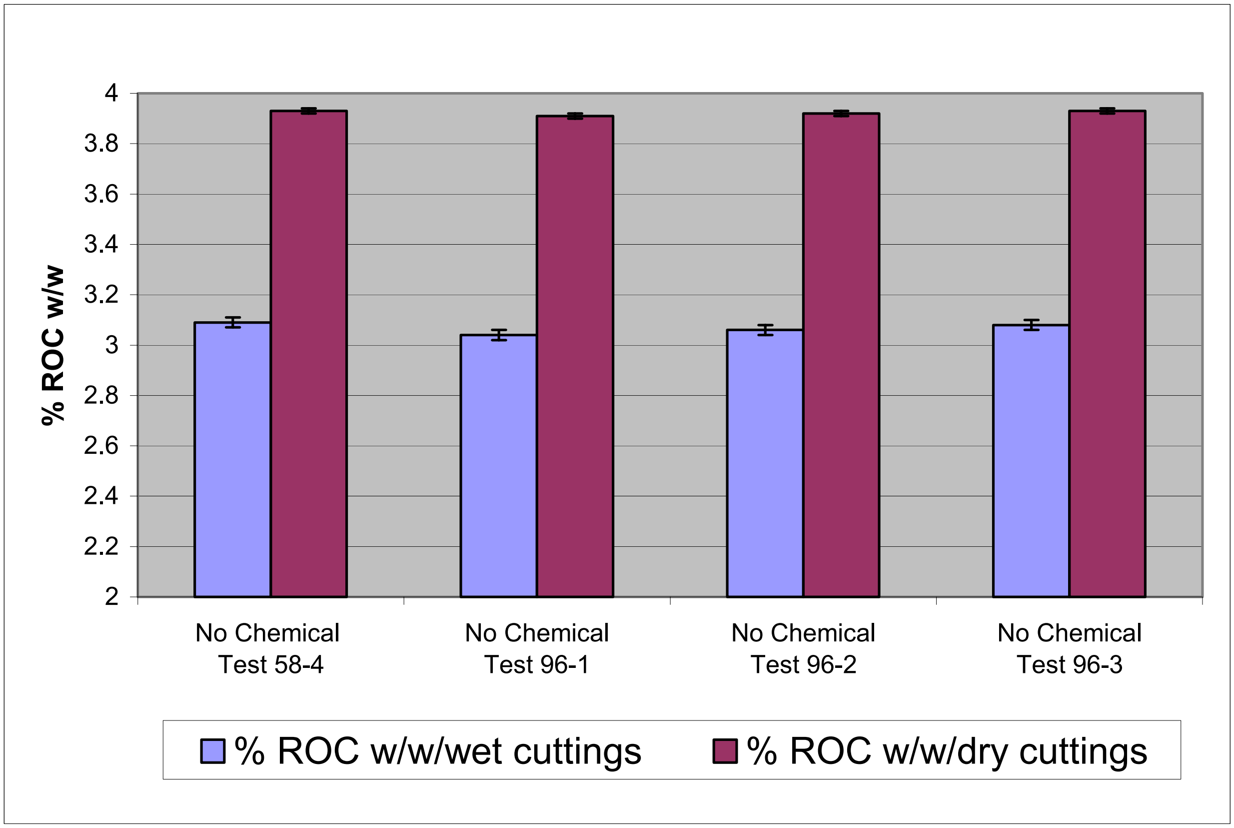

Fig. 2 – Test Method Accuracy: Repeatability Tests.

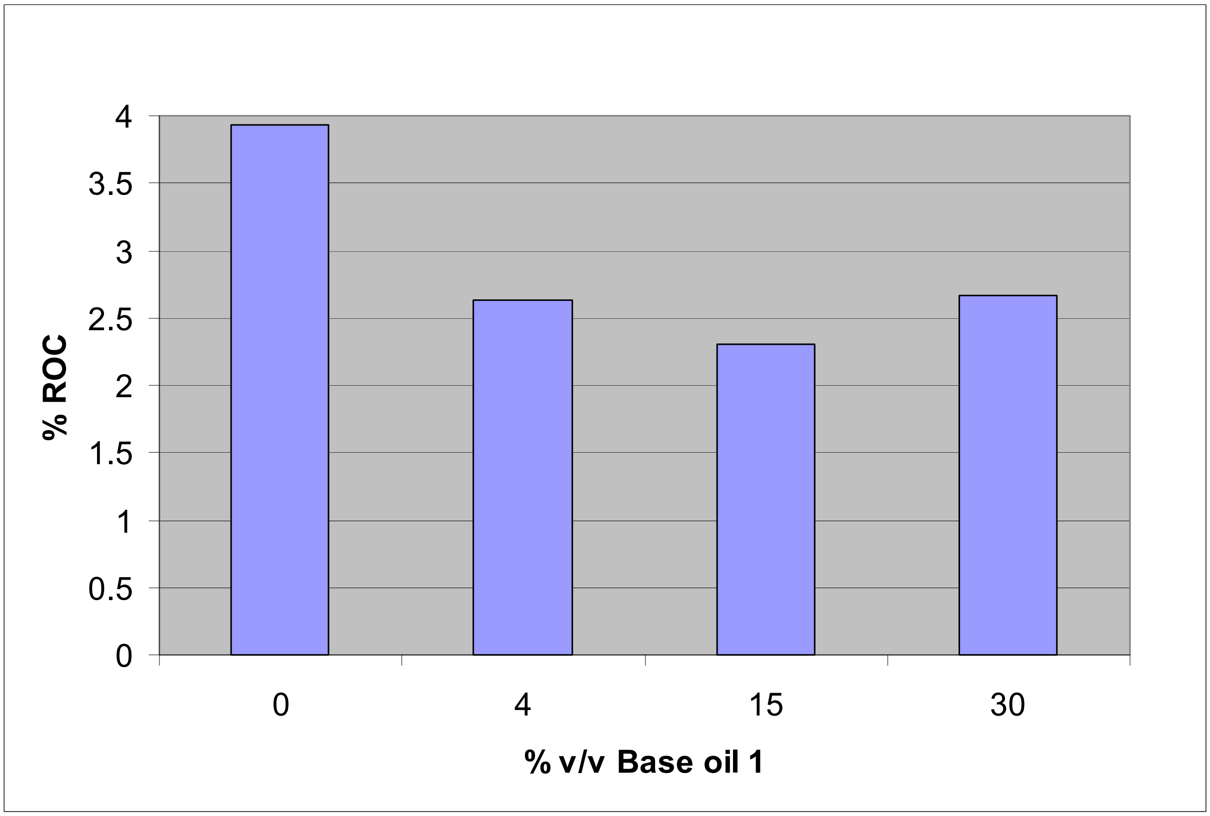

Fig. 3 – Effect of Base oil 1 concentration on ROC reduction.

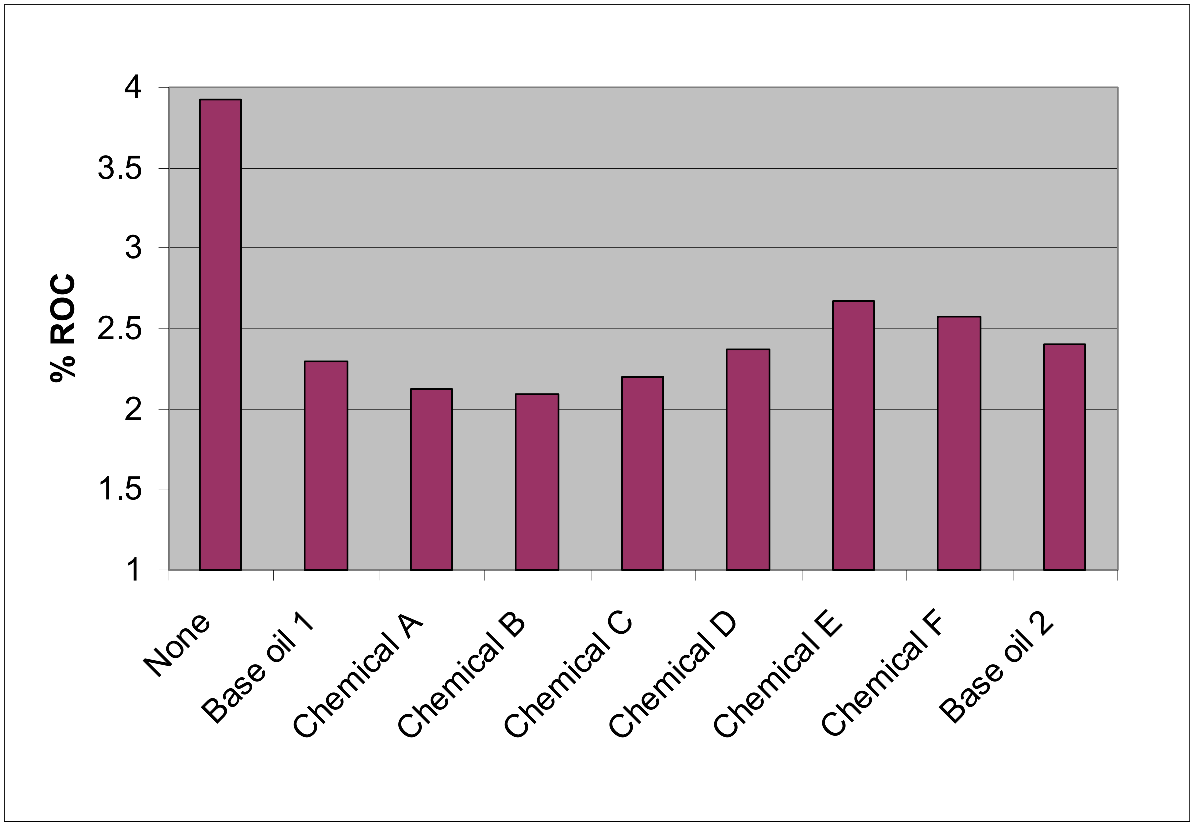

Fig. 4 – Effect of Chemical Treatment on ROC.

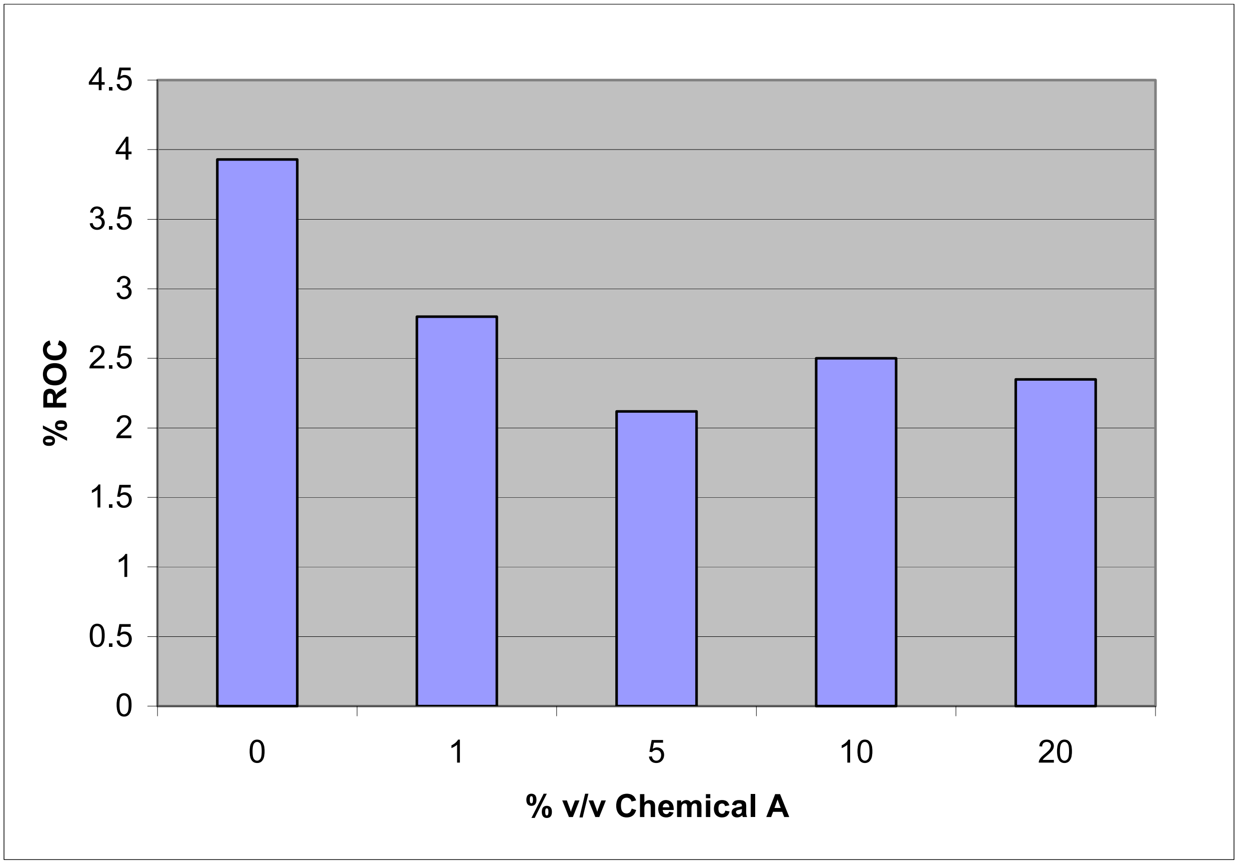

Fig. 5 – Effect of Chemical A concentration on ROC.

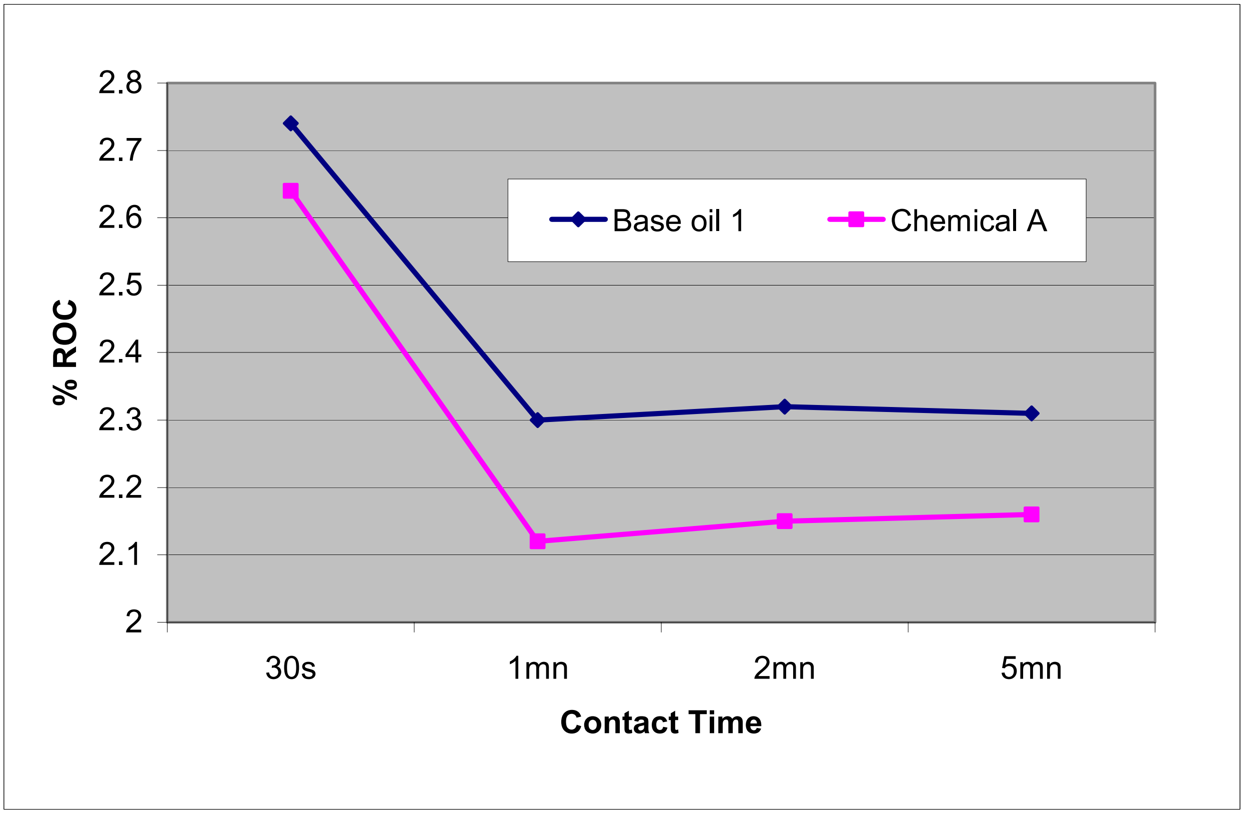

Fig. 6 – Effect of Chemical Contact Time on ROC.

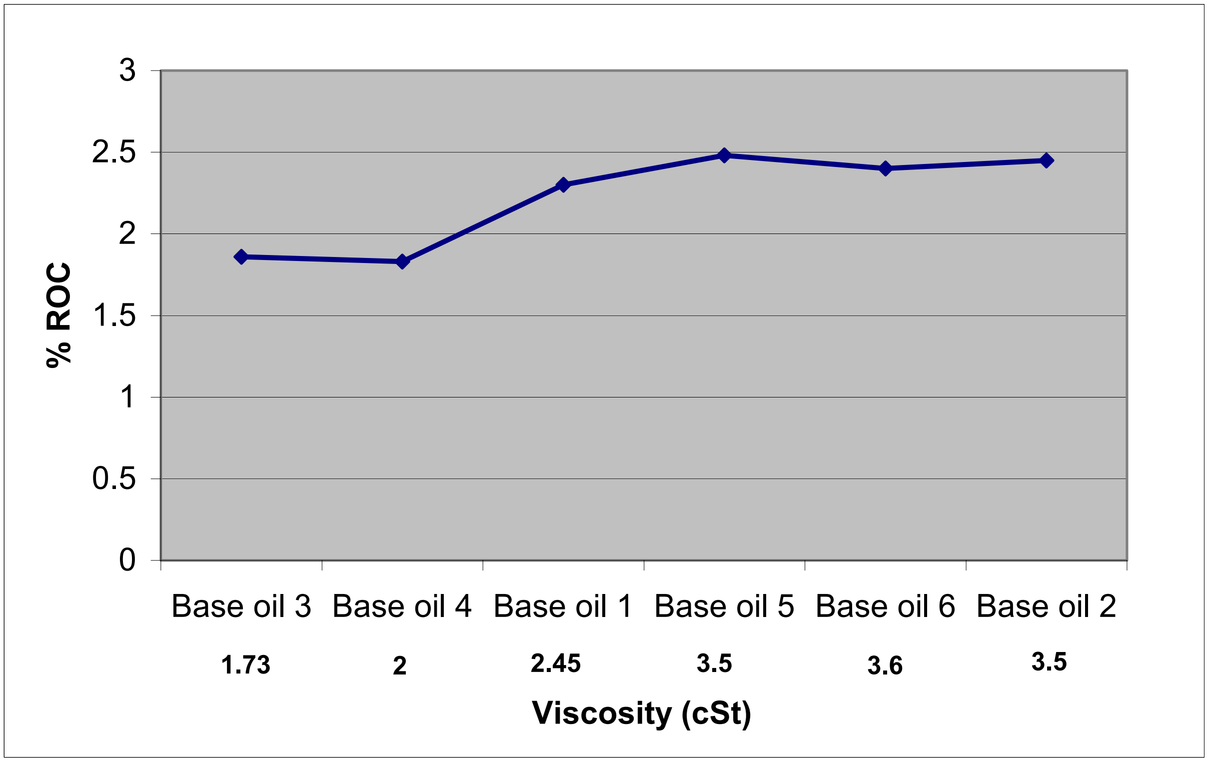

Fig. 7 – Effect of Base oil Viscosity on ROC.

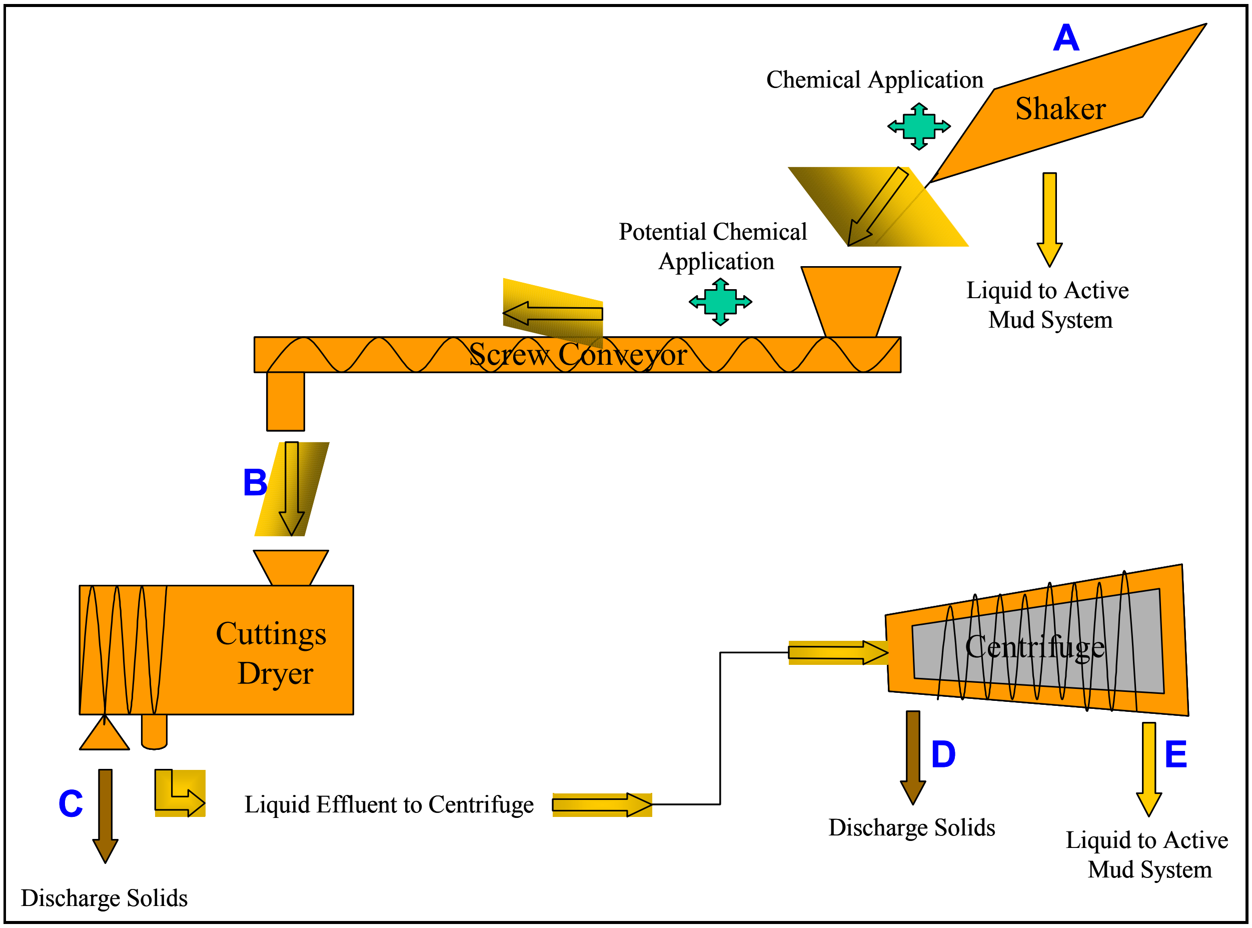

Fig. 8 – Field Test Equipment Set-up.

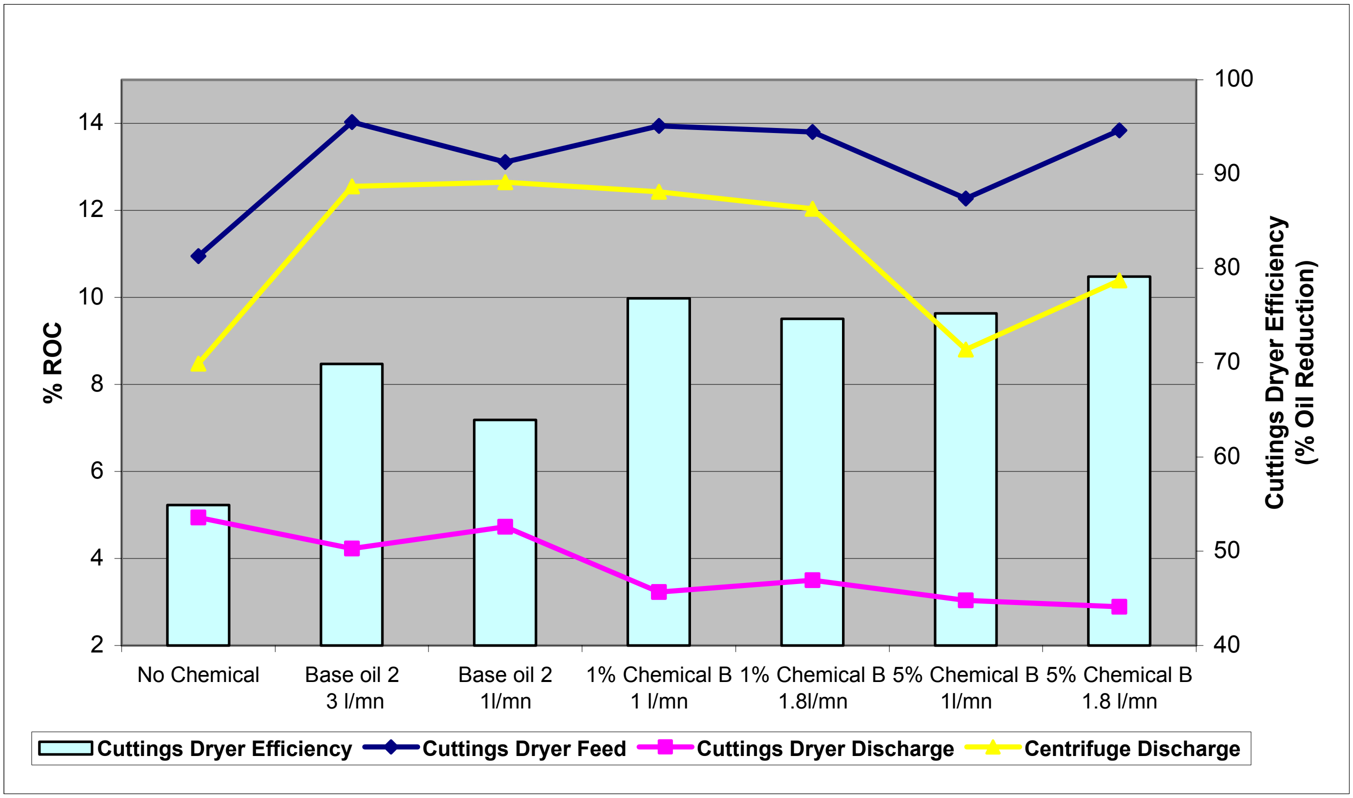

Fig. 9 – Field Trial Results: Effect of Chemical B on ROC.