



Drilling Slop Water Reclamation

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Abstract

Rigorous environmental regulations shifting toward zero-discharge have focused attention on drilling wastes. Drilling with both oil-based muds (OBM) and synthetic-based muds (SBM) generates waste streams, often referred to as "slop mud" or "slop water." Hydrocarbon contamination renders these slops ineligible for overboard discharge. The unusable mud is typically sent for disposal or reconditioning. For operators, large volumes of slop mud result in enormous disposal expenses and represent a potentially significant environmental issue.

In addition to good fluid design and solids-control equipment that help reduce the amount of waste generated, current separation processes can treat slop mud waste streams by breaking the weakly emulsified water phase and recovering the OBM/SBM so the mud can be reused without the need for expensive reconditioning. The process also reduces the amount of generated waste. Mud and water are pumped into separated holding tanks, with the recovered water treated (flocculation and filtration with bag filters) and discharged. Flocculated/filtered solids can be sent for standard industrial disposal.

This paper describes an advanced treatment system designed to treat slop mud and clean/polish recovered water to make it dischargeable without further treatment. The system includes a chemical technology that decreases the time required for phase separation and increases the quantity of water recovered. The system has a unique design that maximizes the efficient removal of the recovered water after phase separation has occurred, thereby increasing the oil/water ratio of the recovered mud and reducing solids loading in the recovered water. The new system includes techniques and equipment in addition to bag filters to clean/polish the recovered water so as to increase the lifespan of the filter bags, reduce frequency of filter bag disposal and meet stringent environmental regulations, which are not possible with other separation processes.

Introduction

"Slop water" or "Slop mud" are among the significant waste streams from exploration and development activities. Slop water or Slop mud is a waste stream

which is produced when an oil/synthetic/diesel-based drilling fluid becomes contaminated with water. These waste streams are byproducts of cleaning the drill floor, shaker room, pump room and other areas where spillage and interfaces during displacement occur. Contamination can also take place during boat-cleaning operations, pit cleaning and other similar operations. With the understanding that different rig configurations and operating practices greatly influence the produced slop volume, it is safe to say that an average of 500 bbl of slop (or contaminated water) is produced on a daily basis during normal drilling activities.

After contamination the drilling fluid may contain 50-90% loosely emulsified water and 10-50% non-aqueous drilling fluid. This affects the properties of the drilling fluid by lowering the oil-water ratio (OWR), increasing viscosity, decreasing emulsion stability and ultimately forming an unusable drilling fluid. Due to the hydrocarbons present in the oil/synthetic/diesel-based drilling fluids, this waste stream is not suitable for overboard discharge, so it is typically sent for disposal or reconditioning. For operators, these volumes add up to huge disposal expenses and represent a potentially expensive environmental issue.

In addition to good fluid design and solids-control equipment to help reduce the amount of waste generated, current separation processes exist to treat slop water/mud waste streams by breaking the weakly emulsified water phase and recovering the OBM/SBM, while at the same time reducing the amount of waste generated. Currently, these slop wastes are pumped into treatment tanks where appropriate chemicals (demulsifiers) are added to separate the water from the drilling fluid. The demulsifier treatment concentration ranges from 2-4% by volume. The primary goal of this form of slop separation is to break only the weakly emulsified water phase and recover the oil/synthetic/diesel-based drilling fluid. The objective is to leave the OBM/SBM intact, so the mud can be reused with minimal reconditioning. The separation process lasts from 8 – 24 hours.

Once separation has occurred, the separated constituents (drilling fluid and water) are transferred to separate holding/treatment vessels. The recovered water is treated (flocculation and filtration) to local

discharge standards, if possible. If it cannot be discharged, it must be reused.

Opportunities for improvement were noted in several areas within this process. The results reported and discussed in this paper cover the effect of novel chemical treatments and mechanical design enhancements incorporated to improve the process efficiency.

Research and Development

A research and development commitment was formed to examine the potential for improving the existing slop-separation and water-polishing technologies. The following were identified as key improvement areas:

- **Separation Time:** A shorter separation time could radically increase the quantity of slop processed
- **Phase Separation Efficiency:** Increase in the phase separation efficiency would improve the drilling fluid OWR
- **Surfactant Concentration:** Reducing the concentration of the water-soluble surfactant consumed would likewise reduce the organics in the recovered water and ease the downstream polishing of the water to meet discharge criteria
- **Surfactant Sensitivity to Shear:** Too much shear can cause the separated water to re-emulsify back into the slop. A more effective surfactant/mixing technology would reduce the likelihood of re-emulsification.
- **Optimization of Filtration Process:** Current water-treatment practices necessitate frequent changing of filter cartridges which is expensive, labor intensive and time consuming.

Laboratory Scale Experiments

Surfactant Screening

Several water-soluble surfactants at different concentrations were tested for their effectiveness in separating contaminant water from a selection of different slop muds. Oil-soluble surfactants were not investigated as they are more likely to be retained in the drilling fluid and affect the properties and environmental performance of the drilling fluid. Laboratory-built slops were prepared by mixing different types of field muds with synthetic sea water, at 1:1 ratio by volume. These laboratory-built slops were used to screen the performance of a wide range of demulsifying chemicals before the most effective are tested on actual slop samples from the field. The surfactants were compared against each other to separate water from mud in terms of recovered efficiency, rate of separation and clarity of recovered water. The time and volume of water collected were measured.

Effect of Shear (Jar Mixer Test)

It was noted that some of the chemicals are more sensitive to over-mixing and if too much shear is applied, any separated water may be re-emulsified back into the slop. To determine the most effective mixing regime for optimum water recovery, each surfactant identified through the preliminary surfactant testing was tested at 2% v/v at various mixing speeds over different periods of time, using a jar mixer.

Effect of Raking for Enhanced Water Separation

It was observed in some slop samples, the treatment with surfactant resulted in water separation but the water was unable to rise to the surface for decantation. A raking mechanism was employed at this stage to help release any entrained water that may be trapped within the mud phase. The rake is turned at a very low speed through the mud creating low-pressure zones which allow any trapped pockets of water to coalesce and escape upwards (Figure 1).

Effect of Temperature

The effect of temperature on water separation from slops was investigated using 0.75% v/v surfactant A. Slop samples were tested at 20°C and 4°C. In most cases decreased temperature brought with it decreases in both the amount of water recovered and the rate of the reaction. The amount of water recovered at 4°C was approximately 22% less than that recovered at 20°C. Thus, the OWR of the recovered mud is lower at lower temperatures and is detrimental to the properties of the recovered mud.

The best results were repeated using the fabricated laboratory-scale model (80:1) of the actual slop treatment plant (Figure 2). This was done in order to simulate the process and confirm the repeatability of the Jar Mixer tests.

Implementation in the Field

Based on the preliminary laboratory-scale testing, a pilot-scale unit delivering a 10-gal/min flow rate was designed (Figure 3). It consists of two modules:

- Separation Module
- Water-Treatment Module

Separation Module

The objective of this module is to separate the slop into mud and water and recover the non-aqueous drilling fluid. The slop is pumped into the separation tank with a built-in blade mixer and rake mechanism. A dosing pump is used to add a demulsifying surfactant into the tank via injection ports around the side wall of the tank. This allows the homogeneous dispersion of the surfactant into the slop mud. The surfactant is mixed into the slop for two minutes to allow for separation, and then left to gravity settle over an appropriate period of time. This is

approximately fifteen minutes or less depending upon the surfactant used. The raking mechanism can be applied at this stage to enhance the water recovery (Figure 4). After settling and raking, the water is ready to be pumped out via the discharge valves located on the side of the tank. Before the water can be removed, the interface between the mud and the water must be determined. This interface is determined by a ball float. The ball sinks through the water phase and floats on the surface of the recovered mud below. The level of the interface is determined electronically and displayed on a multi-view screen as inches of fluid from the bottom of the tank.

Water-Treatment Module

Water that is removed from the Separation Module is not suitable for discharge and must undergo further treatment. This is achieved by the Water-Treatment Module, comprising the clarifier unit, pH-control unit, chemical treatment unit, dissolved air flotation (DAF) unit and filtration unit.

Clarifier Unit

The separated water flows through the cone-shaped coalescing tank and is directed through the cone baffles with hundreds of square feet of lipophilic coalescing media. Mechanically emulsified oil particles rise from the water to the lipophilic media, and float to the surface. Once on the surface the oil is skimmed off for disposal. Fine silt and particulates from the wastewater stream settle at the base of the coalescing tank. With the opening of a single valve, the solids are dropped into a bag filter into the solids-separation chamber for disposal.

pH-control Unit

The water from the clarifier is fed directly into the pH unit for adjusting the pH prior to chemical treatment. For optimum chemical treatment with coagulant and flocculant, the water must have a pH of 6.0 – 9.0. The pH of the water is measured by a pH probe in the tank and, accordingly, the PID controller kicks in the acid or caustic pumps till the desired pH range is achieved.

Chemical Treatment Unit

The treated water from the pH unit is injected inline with a coagulant and a flocculant before being fed to the aging tank. The chemical treatment of the water removes the smaller droplets of oil and solids that the coalescing tank could not remove. These smaller particles need to be coalesced or agglomerated into larger particles before they can be effectively removed from the water. Agglomeration and/or coalescence of the droplets are dependent on their surface charge density, the physio-chemical properties of the interfacial film surrounding the droplets, and the composition of the aqueous phase. The first two features may be modified using coagulants and flocculants. The small oil droplets

in the recovered water are stabilized by native surface-active species, which typically result in a negative surface charge on the oil droplets. The addition of either organic or inorganic coagulants may be used to neutralize this stabilizing charge, thereby allowing the droplets to come into close contact and promoting aggregation and coalescence. Additionally, high-molecular-weight polyelectrolytes may be used to flocculate the oil droplets. Thus, even if the oil droplets do not coalesce, they are sufficiently aggregated to improve their separation from the aqueous phase in subsequent separation techniques, in this case using, dissolved air flotation.

The type of treatment, order of addition, and timing the sequence of additions will vary with the specific batch of separated water and type of surfactant previously used. A small laboratory-scale test should be carried out on the sample of the separated water to determine the optimum treatment.

The chemically treated water is pumped into the aging tank where the residence time is allowed for the formation of flocs to take place. The water from the aging tank is then fed under gravity to the DAF unit to prevent the flocs from being destroyed during transit.

Dissolved Air Flotation Unit

Dissolved air flotation is the process of removing the suspended solids, oil and other contaminants via air bubble flotation. The process involves dissolving air into water under pressure. When this air/water mixture is injected into the waste stream, the pressure is released and the air comes out of solution, producing bubbles, which attach themselves to contaminant material in the waste water. This increases the buoyancy of the contaminated material and floats it to the water surface. This material is skimmed off the surface of the water into a scum collection chamber and the clean water flows into the end chamber.

Filtration Unit

The DAF processed water is passed through the multi-media filter which contains a special media blend that filters out particles larger than 25 microns. The second and third in series are the organo-clay and activated carbon filters to remove both free oil and dissolved hydrocarbons.

Conclusions

Incorporation of these optimization steps reduces the solids as well as the oil and grease loading on the filters, thereby increasing their life and reducing the filter-replacement frequency and disposal. The introduction of these elements has decreased the oil and grease (O&G) an average of five times during the performed field trials (e.g. 643 ppm to 167 ppm) before the water enters the filters. The overall process advantages are:

- Decreased phase separation time - 10 to 15 minutes per batch (Figure 5)
- Decreased surfactant usage (0.75% by volume)
- Increased filter life, thereby decreasing the cartridge replacement and disposal costs
- Decreased footprint as a result of compact plant design
- Improved OWR properties of the recovered drilling fluids (Figure 6)
- Enabled recovered water to meet environmental requirements

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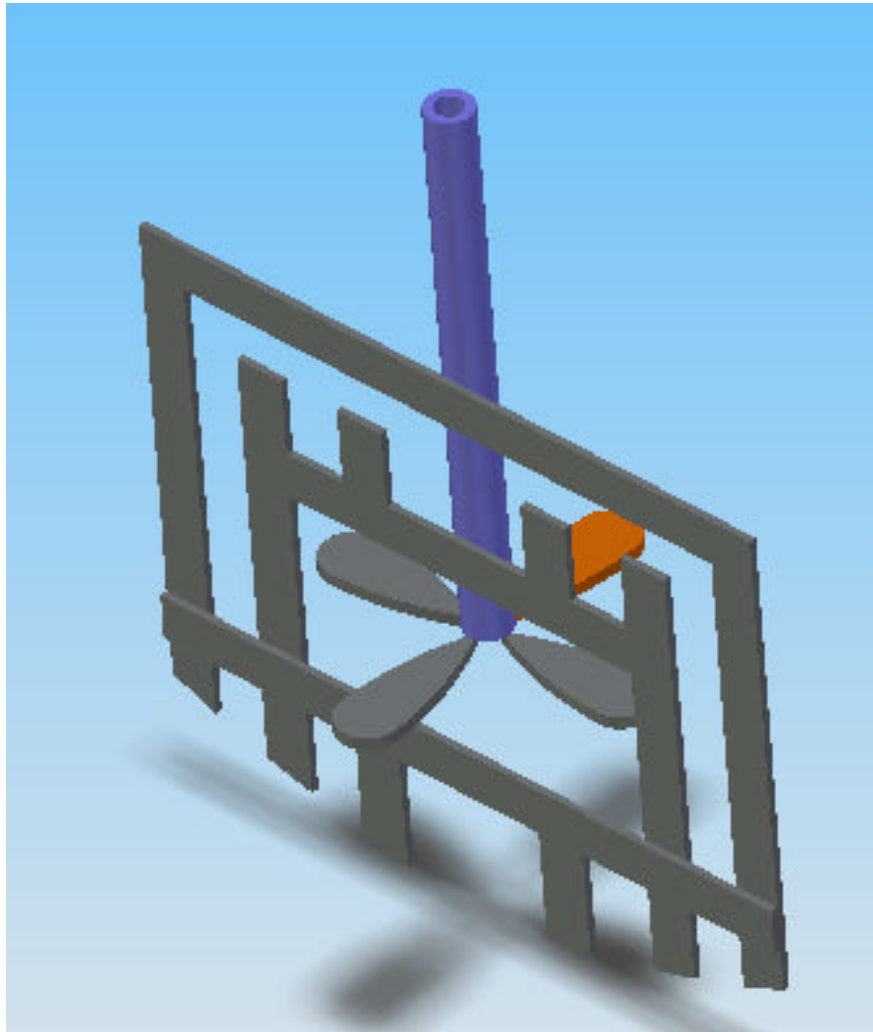


Figure 1 – Rake-and-agitator system model for the separation module.

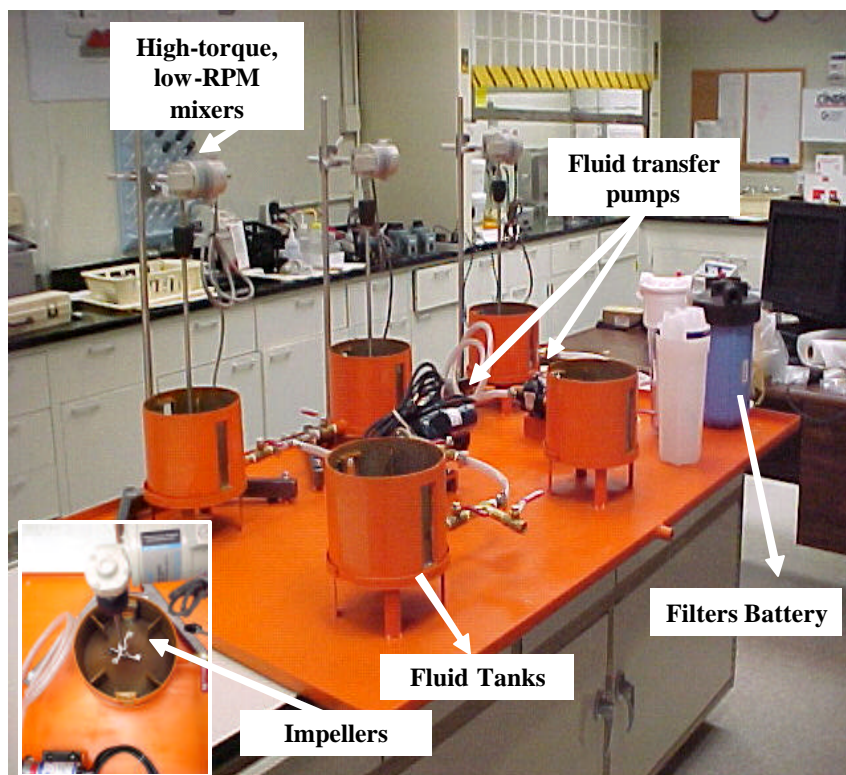


Figure 2 – Laboratory-scale model of the slop treatment plant.



Figure 3 – Pilot-scale unit delivering a 10-gal/min water-treatment flow rate .



Figure 4 – Slop-separation module.

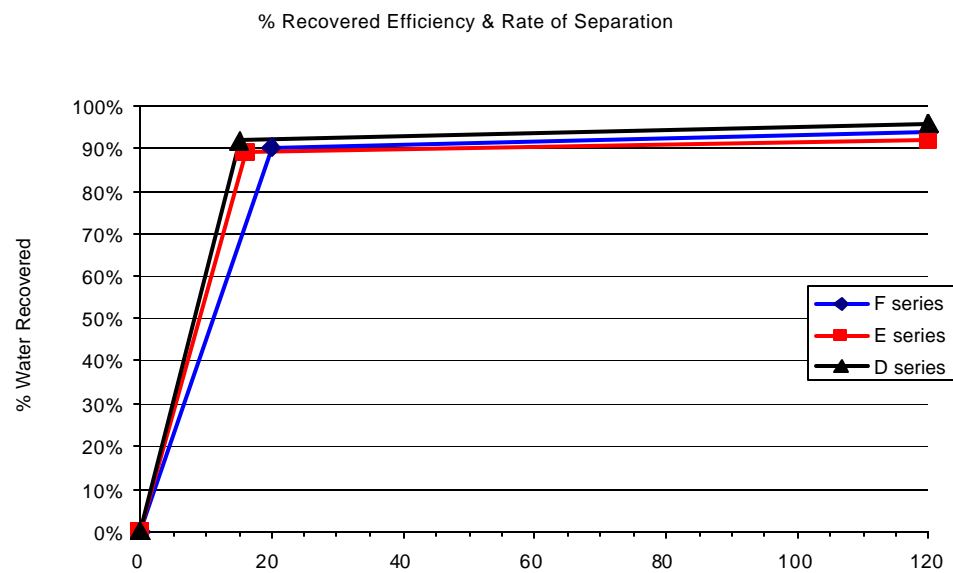


Figure 5 – Separation efficiency versus time (X-axis).

SAMPLE	F1 Base Mud	F3 50/50 Slop Mud	F5 Recovered Mud
Surfactant Name			A
% Surfactant			0.75% vol.
Retort Analysis			
% Water	20	58.5	20
% Oil	56.5	28.5	54.5
% Solids	23.5	13	25.5
O/W Ratio	74/26	33/67	73/27
SG	1.59		1.44
Rheology			
600rpm	70		45
300rpm	41		27
200rpm	30		17
100rpm	19		11
6rpm	7		3
3rpm	5		2
PV	29		18
YP	12		9
10s gel	9		4
10min gel	19		9
ES	211		423

Figure 6 – Original and recovered non-aqueous drilling fluid properties (after slop separation and water extraction).