

Hybrid Separation Technology Improves Solids Removal Capabilities for Non-Aqueous Drilling Fluid Systems

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Abstract

As drilling fluids are used, ultra-fine low-gravity solids (LGS) accumulate and can negatively affect fluid performance. Previously, no effective, field-proven technology solutions have existed to remove ultra-fine LGS; dilution has been typically used to address this issue, which escalates costs and results in excess volumes of fluid.

In addition, the treatment, handling, and transport of oil-contaminated drill cuttings, centrifuge underflow, and other waste streams can have a major effect on operator costs and risk exposure. Efficiently separating hydrocarbons from drill cuttings can help to dramatically reduce disposal volumes and the toxicity of remaining wastes while enabling the recovery or reuse of fluids. Technology alternatives capable of delivering dry, separated solids can be too complex and cost prohibitive for many land operations and cannot effectively process drilling fluids.

The recently developed and deployed hybrid separation technology uses low heat in a high-vacuum environment to produce pre-mix quality drilling fluids and dry separated solids, while recovering up to 99.5% of the fluid. When processing drilling fluids or drill cuttings, the residual oil content on the separated solids is less than 1% total petroleum hydrocarbons (TPH). The technology can be used at the rig site, waste pit, or centralized facility to recover valuable base fluids and reduce disposal volumes.

The paper explores the initial field applications of the hybrid separation technology. Focus will be placed on how hybrid separation changes the current technology landscape by expanding capabilities for solids removal and waste treatment.

Introduction

The North American shale revolution introduced a new set of drilling practices targeting unconventional resource characteristics. Operators now routinely drill lateral wells ranging from 7,000 to 18,000 ft. The capability to extend the lateral to the two- and three-mile length results from three critical factors: 1) improved rig capabilities that deliver more horsepower and higher pump rates; 2) sophisticated rotary steerable systems (RSS) that help drillers maintain “sweet spot” trajectories; and 3) non-aqueous fluid (NAF) that provides inhibition, lubricity, and generally superior rates of penetration (ROP).

These improvements have made it possible to drill much faster. In 2012, operators in the Marcellus shale averaged 1,350 ft/day; in 2018, the average is 3,400 ft/day.¹ The entire lateral is often drilled in three or four days. In the Eagle Ford shale, where daily footage can reach 4,000 ft/day, a combination of high weight on bit (WOB), high rotary speed (RPM), high total flow area (TFA) on bit nozzles, and high-powered mud pumps literally blasts the lateral to total depth (TD).

Although fast drilling clearly minimizes rig days and well construction costs, it also creates a new set of challenges related to drilling fluid management. The well-known principle that a clean fluid drills faster than a solids-laden fluid is being tested by these aggressive drilling practices. Mechanical force now delivers high ROPs. Conventional solids control equipment (e.g., shakers, screens, centrifuges) cannot always keep pace with the solids loading generated while drilling a long lateral through shale in a short period of time. A high concentration of low gravity solids (LGS) in the drilling fluid cannot be avoided, even though it contributes to high equivalent circulating density (ECD) and increases the risk of downhole losses.

Typical solids control equipment packages are often not capable of handling the full pump rate with these aggressive drilling rates. To manage the full pump rate requires scaling up the equipment package at the rig site, which is typically not feasible as a result of space, power limitations, and costs.

Rather than slow the drilling rate, operators tolerate LGS concentrations far above the 6% by volume value that was once the industry target. An informal field survey conducted by a major service company yielded data concerning LGS content in the shale plays, as shown in Table 1.

Shale Reservoir	Average LGS Content % by Volume
Haynesville	10
Eagle Ford	18
Delaware / Midland	10
Bakken	10
Marcellus	12
Utica	10-12
Montney	8

Table 1. LGS content in shale plays.

At the end of each well, the operator has 2,000 to 3,000 bbl of NAF that can be heavily contaminated with solids. If the

fluid system has been used over several wells, the NAF can potentially be contaminated with ultra-fine and colloidal solids that are detrimental to the mud properties. The NAF can be reused from well to well, but a solids removal operation must occur before the next job begins. The two most common methods of addressing this situation are centrifuging and dilution.

Drilling Fluid Reconditioning Methods

When the well reaches TD, the active NAF system can be displaced and returned to the stockpoint for reconditioning. In the most ideal circumstances, running it through a series of centrifuges can reduce LGS as low as 5%. However, if the fluid contains a high percentage of ultrafine or colloidal sized solids, then the effect on LGS removal is significantly compromised. Relying only on centrifuging depends on the size of the solids retained in the NAF. Although the overall LGS concentration can be decreased, the colloidal solids that cannot be removed have the most damaging effect on drilling fluid performance.

When there is little time between wells, newly mixed NAF can be sent to the rig while the contaminated mud is being processed. A standard diesel-based fluid costs approximately \$120/bbl. There are costs associated with bringing new fluid to location and reconditioning the returned fluid. As more wells are drilled, the volume of NAF generated during the project increases. Storage capacity can become an issue, and the excess volumes can pose an environmental liability if not properly managed.

Centrifuging alone does not typically achieve the targeted LGS. Dilution is also often used to control LGS. Using dilution alone is arguably the most expensive approach to managing solids contamination. The combination of the two methods is a long standing industry practice.

The following example demonstrates why dilution alone is not the best approach. Assuming 5% LGS is the desired state, each barrel of solids entrained in the system will require 19 bbl of dilution fluid. As shown in Figure 1, the original 2,000-bbl active system containing 10% LGS becomes a 4,000-bbl system when diluting back to a 5% LGS value. The higher the initial LGS concentration, the higher the dilution volume required.

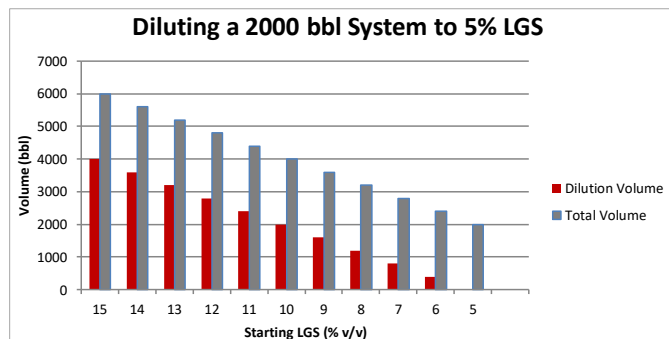


Figure 1. The higher the initial LGS concentration, the higher the dilution volume required.

Although shale play operators may be less particular about the LGS levels in their active mud system while drilling, they may want to begin each new well with a lower concentration. For example, one major operator returned fluid with 20% LGS by volume. Based on the 2,000-bbl example and a realistic target of 8% LGS for the reconditioned system, the total NAF volume generated by dilution will be 5,000 bbl. That is far more than needed for the upcoming well, so mud storage can become an issue. Acres of frac tanks holding the excess volumes of NAF are now common near these areas of high activity.

Dilution means adding base oil (usually diesel for onshore wells) and all additives required to build and maintain desired fluid properties. An Eagle Ford well drilled with NAF in October 2018 reached TD at 18,022 ft measured depth (MD). According to the mud reports, the amount of diesel used for dilution to maintain desired solids concentration cost \$14,000 per day, with a cumulative cost of \$76,567. In this case, dilution made up almost half of the total mud cost.

Dilution does not remove fine solids, which will be recirculated and further degraded during each drilling operation. Ultimately, the NAF becomes a spent fluid: another waste stream requiring disposal.

A Better Option: High Quality Pre-Mix NAF

A new method for fluid reconditioning of NAF produces a clean fluid, ready for use in the active system when the operator displaces to NAF in the lower wellbore. This NAF pre-mix field-tested system can remove colloidal and ultra-fine LGS, so that the refreshed low-solids NAF will contribute to even faster ROPs. The residual oil content on the separated solids is less than 1% TPH (Figure 2).

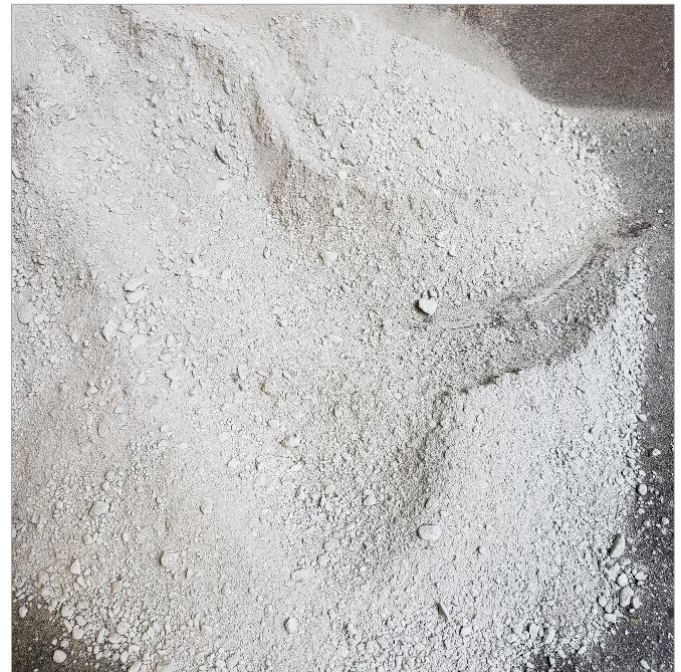


Figure 2. Dry solids output from low-heat, high-vacuum process.

To achieve these results, this process uses low heat in a high-vacuum environment to produce pre-mix quality drilling fluid and dry separated solids, while recovering up to 99.5 % of the fluid. The NAF is sent to the unit where the on-board pump continuously transfers the material to the thermal extraction barrels.

The NAF is conveyed, mixed, and heated to volatilize the hydrocarbons and water in the feed material under a negative pressure environment. The treated solids and newly formed vapors are separated out and recovered. The solids are removed from the system and discharged into bins for haul off. The vapors are condensed in a closed loop system. A heat exchanger removes heat for optimized performance of the evacuation/condensing device. The condensed fluid is a low density pre-mix drilling fluid that can be added back into the active mud system.

Effectively removing ultra-fine LGS, which was not previously possible, eliminates the need for dilution and improves the ability to recover drilling fluids so they can drill more wells with less fluid volumes.

The processing unit is a single compact, mobile system configured on a 53-ft trailer, suitable for operation at the rigsite, a centralized treatment facility, or a liquid mud plant where reconditioning often occurs (Figure 3).



Figure 3. Example layout of solids removal unit at the rigsite.

The unit can be mobilized to the proposed site quickly. Installation requires less than two hours. The initial start-up can be completed in four hours; after the unit is operational, only a 90-min “warm-up” is needed after an overnight shutdown. The power requirement is comparatively low at 400 kW. Table 2 summarizes the general specifications.

	Single Separation Mode	Dual Separation Mode
Processing capacity	80-100 bbl/day	160-200 bbl/day
Fluid recovery efficiency	>99%	>99%
Residual oil on solids	<1% wt TPH	<1% wt TPH
Running load	265 kW	500 kW
Voltage	480 VAC	480 VAC
Certification	cULus	cULus
Feed mix tank capacity	6.3 bbl	13 bbl
Dimensions	Single self-contained trailer Length: 53 ft Width: 8.6 ft Height 13 ft 2 in	Single self-contained trailer with support skid Length: 53 ft Width: 8.6 ft Height 13 ft 2 in
Weight	67,000 lb	70,000 lb
Control system	Fully automatic programmable logic controller (PLC) with dual 14-in HMI screen	

Table 2. Technical specifications.

Unlike other thermal treatment methods that apply high temperatures to remove mud and/or oil from cuttings, the new technology works at a much lower temperature (approximately 50 to 60 °C /120 to 140 °F) that prevents thermal cracking of the base oil used in the drilling fluid, as shown in the gas chromatography-mass spectrometry (GC-MS) analysis performed during the field trial (Figure 4).

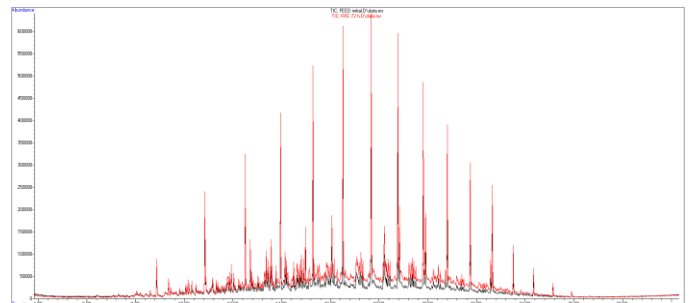


Figure 4. GC-MS results demonstrate base oil is not damaged by low-heat process.

The operational boiling point is lower, and both the external phase (oil) and internal phase (water) are retained in the effluent. The throughput rate is variable, depending on the oil/water ratio (OWR) of the fluid to be treated. For example, because water has a higher heat capacity than diesel, a diesel-based fluid with an OWR of 70/30 (or higher oil content) will process faster than a 65/35 OWR fluid.

The process results in a significant density reduction that makes the treated fluid particularly well-suited for conditioning an existing NAF system without resorting to pure diesel dilution and increased chemical additions. Figure 5 shows the results achieved by processing an 11.9 ppg NAF.

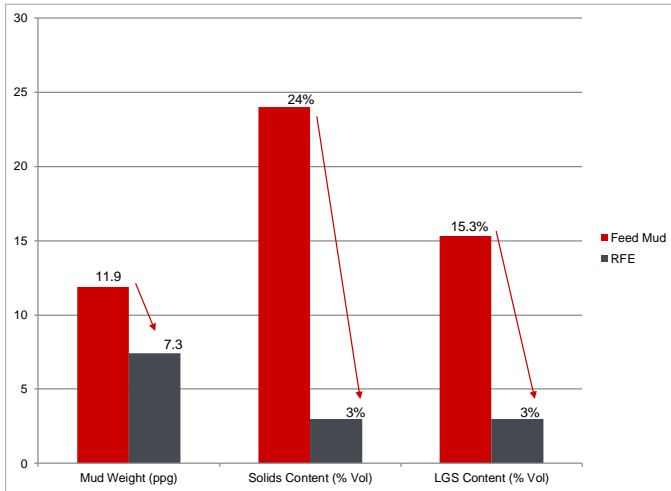


Figure 5. Reduced density and LGS concentration achieved with low-heat, high-vacuum process. OWR of feed mud 77.6/22.4 vs. OWR recovered fluid 77.3/22.7.

Field tests confirm that the results shown here are typical of the solids removal process, and can be achieved at the rigsite or in any onshore treatment facility. For example, 2,000 bbl processed through this hybrid separation technology can result in approximately 1,500 bbl of recovered fluid, with approximately the same OWR as the feed, and approximately 220 MT of solids removed.

The low-density pre-mix NAF provides operators with an economical option for maintaining reasonable NAF volumes without the storage issues associated with relying on high-volume, high-cost diesel dilution. The unit can be operated at the rigsite for processing while drilling, or serve equally well

for end-of-well fluid clean-up jobs, delivering lower solids than can be achieved with centrifuging and preserving the NAF performance characteristics that make it the preferred fluid for long shale play laterals.

Conclusions

- Current unconventional resources require drilling long laterals (up to 18,000 ft, in some areas) at extremely high ROPs, leaving little or no time for removing solids entrained in the NAF systems.
- Because NAF systems are typically reused from well to well, the concentration of damaging LGS can reach 18 to 20% or more.
- As the mud is reused over several wells, the LGS degrade further into ultra-fine and colloidal solids that cannot effectively be removed with conventional solids control equipment (e.g., centrifuge).
- The new low-heat, high-vacuum solids removal system provides a highly mobile method for treating the active mud system at the rigsite or for treating returned mud at the end of each well in a timely manner.
- Solids are efficiently removed with the low-heat, high-vacuum unit; this is achieved with low power requirements, as compared to other high-temperature thermal methods.
- The unit itself has a small footprint, roughly 53 × 9 ft, and integrates well into existing rig or facility layouts.

References

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