

## The History of Flat Rheology Drilling Fluids

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### Abstract

One of the most significant developments during the past twenty plus years for drilling fluids was that of Flat Rheology Oil-Based Muds (FROBM). A FROBM is a non-aqueous drilling fluid that displays a flat rheology profile (including low-end rheology, yield point (YP) and 10-minute gel strength) that is not significantly affected by temperature and pressure. These fluids, although initially developed for drill deepwater wells in the Gulf of Mexico, have impacted other areas globally in their utility in efficiency of drilling performance.

The intent of this paper is to document the significant elements in the history of the development and application of Flat Rheology Invert Muds (FROBM). Additionally, this paper will provide new light and focus on the status of FROBM and emphasize the new-found benefits that these systems provide. In doing so, the development, technologies, and features of FROBMs will be reviewed and discussed as well as their limitations.

### Introduction

The development of FROBM gives meaning to the saying “necessity is the mother of invention”. The oilfield necessity was the advent and rapid acceleration of Deepwater drilling (BP Deep Horizon Oil Spill Commission Staff writer, 2011). In the 1990s, an enabling technology for Deepwater drilling for the Gulf of Mexico (GoM) was the introduction of synthetic-based muds (SBMs) (Wood *et al.*, 1998). Due to both the environmental and the technical benefits of these fluids, they were quickly becoming the choice over other non-aqueous fluids (regulatory) and water-based drilling fluids (performance) (Friedheim, 1994). With the introduction of the Second-Generation Synthetic Fluids (Friedheim *et al.*, 1996; Wood *et al.*, 1998) the use of these newer synthetic base fluids for Deepwater drilling increased due to the reduced overall viscosity, improved environmental profile and lower cost structure (Burrows *et al.*, 2001).

By the end of the 1990s, a few drawbacks for SBMs use in Deepwater centered around their viscosity and its impact on wellbore stability. The wellbore stability issues often resulted in downhole losses of whole mud while drilling, running casing, and cementing (Zamora *et al.* 2000).

Three factors heightened the impact of these wellbore instability/lost circulation issues:

- Increased rig cost (at the time rig costs varied from \$150K to \$200K per day now this price is approaching \$500K/day) (Adomaitus, 2022).
- Increased waiting time from logistical side for supply boats (60-120 miles offshore; depending on weather conditions, it could take a minimum of 8-16 hours or as much as up to several days), thus increasing non-productive time (NPT).
- Cost of expensive synthetic fluid being lost downhole (at that time synthetic fluids were ranging from \$200-\$300/bbl. With losses several hundred to several thousand barrels, cost could range from \$250 - \$500K for lost drilling fluid alone).

Numerous ancillary fluids technologies were introduced to address this issue including wellbore strengthening technologies (Aston *et al.*, 2004; DuPriest, 2005; Tehrani *et al.*, 2007; van Oort *et al.*, 2011) and micronized weight material (Oakley, 2006; Bolivar *et al.*, 2007; Fimreite *et al.*, 2004) to mention two.

Only the FROBM technology entailed a complete drilling fluid system. Additionally, several of the technologies above could and were used in conjunction with FROBM. When this occurred, a more effective solution was realized for reducing losses on more complex wells.

The common elements for all Deepwater wells are the water depth is significantly deep (always above 1000 ft now) and the temperatures near the mud line are very low (typically less than 45° F, 7.2° C). In Deepwater wells, the drilling window becomes abnormally narrow with increasing water depth due to a lower overburden pressure. Adding to the narrow drilling window, the very cold-water temperatures near the mudline in Deepwater also contribute to downhole losses by cooling down the drilling fluid and thus significantly increasing fluid rheology, which in turn impacts equivalent circulating density (ECD). This is especially the case for long static periods of the fluid such as during connections, tripping, running, and cementing casing. Therefore, breaking circulation often led to ECD surges and thus lost whole mud.

Furthermore, the increasing complexity and tortuosity of Deepwater wells contributed to downhole losses by promoting greater a propensity for dynamic barite sag of the fluid and greater requirement for proper hole cleaning. These drilling situations can also increase ECDs and increase the chance of exceeding the fracture limit and thus induce downhole losses.

These demands on the fluids contributed the need to develop a properly designed and engineered invert (non-aqueous) fluid for drilling these Deepwater wells – thus the birth of Flat Rheology Oil-Based Mud (FROBM).

## Genesis

There is some controversy as to which service company developed with the “first” true FROBM as well as which operator was the first to implement these fluids in the GOM. There, however, is no controversy that at the beginning there were only two players -- M-I SWACO and BAROID. They developed systems in the 2001-2002 timeframe, while Baker Hughes didn’t introduce their version until sometime between 2005-2007 (Mullen *et al.*, 2005; Rojas *et al.*, 2007). Others followed later (Kratzer, 2020; Schlemmer *et al.*, 2010).

This section focuses on the fluids and history of those two service companies.

BAROID claims the position of being first to develop a FROBM in that they announced the ACCOLADE system at the OTC (Offshore Technology Conference) in May 2002 (Halliburton Staff, 2002). In this press release and the previous paper published by Burrows (Burrows *et al.*, 2001), the term “flat” was barely mentioned. In the Halliburton press release and OTC announcement (virtually identical) the term “flat” was never mentioned. These articles did, however, point out a few pertinent details which came into play for FROBM technologies such as:

- “Excellent rheological performance in the colder temperatures of the Deepwater environment”
- “The new system significantly improved rheology control, lower equivalent circulating density, and provided a greater margin of wellbore stability.”
- This appears to be the first mention of “clay-free”.
- The official release did mention “fragile gels” twice.

In the Burrows SPE paper (Burrows *et al.*, 2001) the term “flat” is mentioned three times and in each case refers to the gel structure being “flat”. This primarily focus was on a new low-viscosity ester (PETROFREE LV), which displayed about 25% less kinematic viscosity (KV) than the original PETROFREE ester.

In June 2002, BAROID reported in World Oil (McFadyen, *et al.* 2002) success of their new synthetic-based mud (ACCOLADE system) featuring a “clay-free” and stable cold-temperature viscosities resulting in lower ECDs and less losses. A more detailed account of this new synthetic was presented at the 2004 IADC/SPE Conference (Burrows *et al.*, 2004). The conclusions and key points were as given above.

M-I SWACO started work on their FROBM in the spring of 2002. While BAROID had been aligned with BP on the development of their ACCOLADE system, M-I SWACO was aligned with Shell. In the fall of 2002, M-I SWACO completed their development and application testing. In early spring 2003, their first field trial was with Shell. The results proved quite

successful.

The issues that M-I SWACO focused on included ECD management, rate of penetration, and hole cleaning performance. From the field trail, the M-I SWACO FROBM (later marketed as RHELIANT) demonstrated significant improvement in hole cleaning performance, which contributed to higher rates of penetration, while exhibiting lower ECD values in the narrower drilling-margin intervals. This field trial was quickly documented in May of 2003 (Power *et al.*, 2003), and the benefits were fully expanded upon in two Shell papers in 2004 (van Oort *et al.*, 2004; Lee *et al.*, 2004).

From a patent perspective the two major service companies dominated this area (BAROID Patents; M-I SWACO Patents). Later, others populated the area with similar ones (Other Patents), but many have since been abandoned.

## Definition

The definition of a FROBM seems relatively straight forward. A FROBM is a non-aqueous drilling fluid that displays a flat rheology profile (e.g., low-end rheology (6 & 3 rpm), yield point (YP) and 10-minute gel strength) that is not significantly affected by temperature and pressure.

Ultimately, FROBM should achieve the desired balance of fluid rheology for ECD requirements of drilling narrow margin windows (van Oort *et al.*, 2004) without sacrificing performance issues of hole cleaning, barite sag, cutting suspension as well as the wellbore and system stability. These elements of a FROBM were illustrated quite well by Dr. Eric van Oort in 2004 (van Oort *et al.*, 2004) by Figure 1.

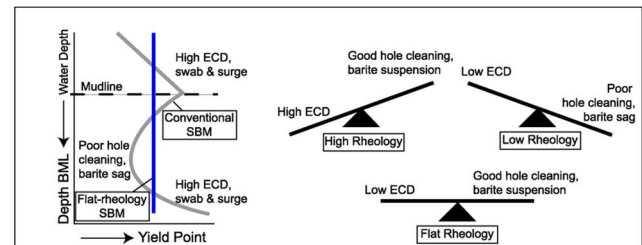


Figure 1 – Depiction of FROBM basic concepts of temperature independent rheology versus that of a conventional fluid (left) and the requirement of balanced properties to address drilling requirements (right) (van Oort, 2004).

## History

Looking at the first reported comparison (Lee *et al.*, 2004) of the “flatness” of a FROBM versus a conventional synthetic-based mud, you see two effects (Figure 2). One sees that the cold temperature (below 100° F; 38° C) YP and 6 rpm reading drop substantially (Chart A vs Chart B). While the higher temperatures (above 100° F; 38° C) rheology increases slightly (Chart B vs Chart A). This effect essentially “flattens” out the rheology profile in the FROBM (Chart B, Figure 2). BAROID emphasized “high flat gels” as one of their criteria (Burrows *et al.*, 2004) for these new FROBM.

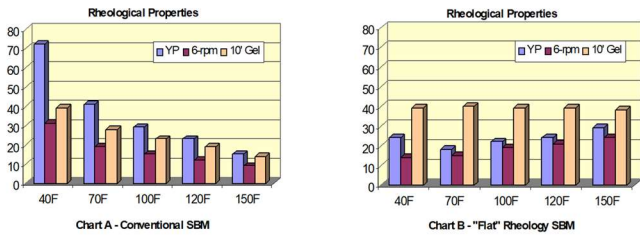


Figure 2 – Two charts A & B compare Rheological Properties (YP, 6 rpm and 10-minute Gel Strength) for conventional Synthetic-Based Mud (SBM) to that of a Flat Rheology SBM over the temperature range of 40° F (4.4° C) to 150° F (65.6° C) (Lee et al. 2004).

Both M-I SWACO and BAROID publicly promoted similar attributes for their FROBMs (Table 1). Although the emphasis and approaches differed, the results were the same: less mud losses, reduced barite sag, and better hole cleaning. There also were subtle but important similarities between the two that were never highlighted.

Table 1 – Features promoted by two major service companies that offered FROBM in 2004	
M-I SWACO RHELIANT (Lee, et.al. 2004)	BAROID ACCOLADE (later ENCORE) (Burrows, et. al. 2004)
Flat Rheology Profile (independent of temperature & pressure)	Stable Rheological Profile
Fragile & non-Progressive Gels	Fragile & non-Progressive Gels
Low Organophilic Clay Content (2-4 ppb)	No Organophilic Clay
Lower ECDs	Lower ECDs
Better Hole Cleaning	Better Hole Cleaning
Reduced Incident of Barite Sag	Reduced to No Incidence of Barite Sag
Less Induced Mud Losses	Less Induced Mud Losses
Environmentally Compliant (GoM)	Environmentally Compliant (GoM)

One subtlety which is seen in both is found in Figures 2 and 3 (BAROID Staff, 2004). Figure 3 shows the Tau Zero at different depths representing different temperatures and pressures. Tau Zero (“0”) is the fluid’s yield stress at zero shear rate (0 rpm) or the torque required to just start a system moving from rest. Tau Zero is selected for measurement because low shear rates remove inertial effects from the measurement and thus arguably a truer measure of yield stress than measurements taken at other points. The data shows both a relative flatness in Tau Zero and a slight increase with increasing pressure (water depth). This same trend is also reflected in Figure 2 Chart B with temperature in both the Yield Point and 6 rpm readings.

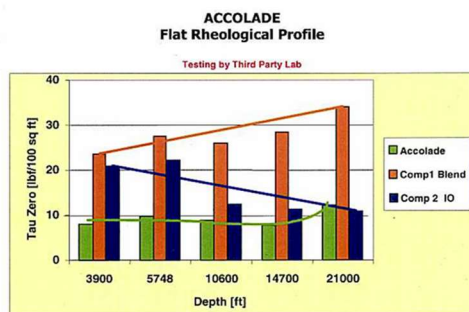


Figure 3 – Tau Zero data for Baroid’s Accolade (Baroid Staff, 2004) across a wide temperature range typical of GOM Deepwater drilling (38° F – 225° F).

This increase in viscosity at higher temperatures and pressures is extremely important for the downhole fluid behavior and benefits in dealing with barite sag, hole cleaning, and downhole losses (van Oort *et al.*, 2004). This was eventually identified as an important aspect of a later BAROID system (BaraECD™).

Figure 4 (left graph) illustrates the behavior of BAROID’s clay-free BaraECD™ system to two conventional clay containing invert emulsion fluids (IEFs) (Rødsjø *et al.*, 2013). The two conventional systems showed similar trends in which decreasing shear rates resulted in decreasing shear stress. The viscosity equilibrated rapidly to one shear stress value (the two green lines). The Clay-free system initially showed a corresponding drop in shear stress upon reducing shear rates, but a different effect was also observed. Starting immediately instead of the viscosity equilibrating to a constant value, a slight increase was observed over time. This effect was more pronounced at the lower shear rates (i.e., 0.5 rpm and 0.3 rpm).

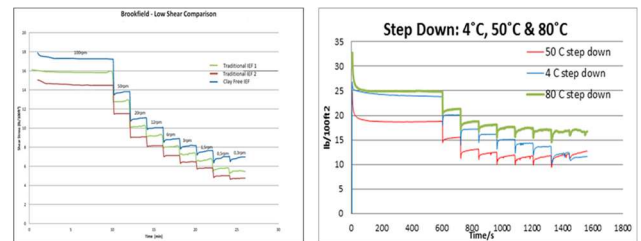


Figure 4 – Two Brookfield viscometer tests illustrating the tendency for 1) viscosity to begin to build at low shear rates in these new FROBM (left figure) (Rødsjø et al., 2013) and the effect to be amplified at moderate to higher temperatures (right figure) (Knox, 2015).

This effect indicates some type of “interaction” of chemistries especially at these lower shear rates. This type of low-shear viscosity could aid in both barite and cuttings suspension when pumping slow. Furthermore, addition evidence indicated (Rødsjø *et al.*, 2013) rapid but fragile gel formation resulted from this interaction too.

The right-side of Figure 4 illustrates another step-down test at three different temperatures (4° C (39° F), 50° C (122° F) and 80° C (176° F)) again on BAROID’s BARAECD ((Knox, 2015). This graph shows the same effect at the lower shear rates as the one on the left, but it also illustrates two other nuances. Firstly, the increases in viscosity at lower shear rates are affected by temperature. The higher the temperature, the higher the increase in viscosity at the low shear rates (e.g., 0.5 rpm and 0.3 rpm). Also seen is a “dip” at the middle shear temperature (50° C). This “dip” indicates that there is a component or interaction that is activated at a certain temperature. Once this activation occurs, overall viscosity then increases again.

The key point here is that this effect is realized at higher temperatures thus applicable to all wells. The downhole benefit of this rheological and thixotropic effect is that it will aid in hole cleaning, preventing barite sag while maintaining a constant ECD (through its flat rheology profile). This effect will be discussed again in this paper.

FROBMs were also designed to provide a good strong but fragile gel structure. Higher gel strengths of course aid in cutting suspension and mitigation of barite sag. The issue with

higher gel strengths, however, is that when pumping resumes after a static period, the force necessary to break these gels will determine the corresponding surge pressure. Minimizing this pressure will obviously reduce the propensity for loss circulation of whole drilling fluid. This is exactly what was observed in the field (van Oort *et al.*, 2004). –

*“A common occurrence with FR-SBM (aka., FROBM) is that strings are cemented with full or at least partial returns, whereas on offset wells cemented in SBM no returns during cementing were observed. Although gels are in general maintained at higher values in FR-SBM (aka., FROBM), breaking those gels actually appears to be easier, resulting in lower surge pressures and frictional pressure losses in the annulus to be cemented.”*

Obviously, sufficient gel strengths are required for cutting suspension and reducing static barite sag. BAROID also promoted high gel strengths (Burrows *et al.*, 2004; Rødsjø *et al.*, 2013; Burrows *et al.*, 2008) as well as the concept of a “fragile gel” (BAROID Patents “a”). M-I SWACO also recognized this benefit (Lee *et al.*, 2004).

### **The ISSUE of CLAY**

The one area that BAROID and M-I SWACO publicly disagreed was that of organophilic clays (OCs). BAROID actively promoted and still does that one key element of a FROBM is eliminating the organophilic clay from the formulation (Burrows *et al.*, 2004). Claimed benefits included reduced whole mud losses, lower ECDs and high, flat gel strengths that break with minimal initiation pressure (Burrows *et al.*, 2004).

All these benefits were observed with both service companies’ systems. The issue of barite sag also was disputed. From extensive studies into dynamic as well as static barite sag M-I SWACO observed that in the absence of all OCs, barite sag was very difficult to prevent (Lee *et al.*, 2004). Regardless of low shear viscosity and other rheological parameters if totally dependent on polymeric or non-OC or oligomer modifiers, barite sag continued to be a problem. They also demonstrated that the presence or absence of OCs has very little consequences of the basic rheological aspects of FROBM (Lee *et al.*, 2004). Their absence apparently contributes to the gel behavior more than the overall rheology and when one depends on OCs primarily for viscosity (concentrations 5-8 ppb), the cold temperature profile and temperature effect on rheology is impacted adversely. It is for this reason that M-I SWACO lowered their total OC loading to 1-3 ppb in their system (Lee *et al.*, 2004).

More recent iterations of FROBM saw some newer chemistries introduced to mitigate sag and add to overall system rheology stability. This chemistry was based on glycol derivatives (Davis *et al.*, 2016). These products are used in the newer generation of FROBM. More recently, totally new chemistry has emerged which a polar hydrophobe is used to provide low shear improvements without impacting the high shear viscosity (Miller *et al.*, 2009). These products are unique but not much has been published on their performance. All

current FROBM rely on some form of active solids.

### **Benefits of FROBMs:**

The benefits and performance enhancements of the FROBM were immediately realized after their introduction. The documented operational benefits are listed below along with references to papers that support and expand upon them.

- Better cuttings transport and hole cleaning (Burrows *et al.*, 2004; van Oort *et al.*, 2004).
  - No incidences of pack-offs (van Oort *et al.*, 2004)
- Higher average ROP (Lee *et al.*, 2004)
- Reduction of ECD (Burrows *et al.*, 2004; van Oort *et al.*, 2004; Burrows *et al.*, 2008)
  - Reduced surge and circulation initiation pressures (Rojas *et al.*, 2007).
- Mitigation of barite sag (Burrows *et al.*, 2004; Lee *et al.*, 2004)
- Minimal whole mud losses (Burrows *et al.*, 2004; van Oort *et al.*, 2004)
  - While drilling (Burrows *et al.*, 2004; van Oort *et al.*, 2004)
  - Running casing and cementing (Burrows *et al.*, 2004; van Oort *et al.*, 2004)

The major driver for the development and introduction of these systems was mitigating or eliminating downhole losses, but it quickly became evident that this new technology delivered other benefits. Several factors contributed to the success in reducing these mud losses. Reduction of ECDs, better hole cleaning, eliminating pack-off incidents, fluid properties that contribute to the reduced surge and swab pressures, and a mitigation of barite sag, all resulting from a combination of constant fluid rheology and flat and fragile gel strengths.

The value that FROBM exhibited in drilling overflow to benefits for operational efficiency (OE). Some of these include eliminating the necessity to pump pills for hole cleaning (better hole cleaning), facilitating the ability to run casing at consistent and faster rate (lower surge and swab pressures), avoiding down time due to additional circulating time (lack of pack-off), increased ROP and stable fluid properties (less downtime for mud treatment). Furthermore, with the lower ECDs and thus reduced propensity for losses, NPT is reduced by avoiding the frequency of resolving hole problems or waiting on additional resources to do so. The benefits to both OE and reducing NPT justified using FROBM in other areas than Deepwater (Rødsjø *et al.*, 2013; Sindi *et al.*, 2022; Osorio *et al.*, 2022).

### **Next Generation FROBM:**

There have been numerous improvements by all companies in their FROBM offering during the past 20 years. M-I SWACO improved upon RHELIANT by revamping it two times, BAROID continued with a clay-free and a fragile gel approach but with modifications to base fluid and products,

Baker-Hughes (BH) termed their system a Constant Rheology Synthetic Based Mud (CR-SBM) (Rojas *et al.*, 2007), and Scomi referred to theirs as a Flat-Rheology (FR) mud system but qualified their definition (Schlemmer *et al.*, 2010). Newpark basically used all these terms to describe their KRONOS fluid – Flat Rheology, consistent rheology and Low-ECD mud (Kratzer, 2020; NEWPARK website 2024). All companies focus on lower ECDs while drilling and reducing pressure spikes when breaking circulation after static periods.

This section focuses on the improvements made by the two major service companies.

## BAROID

BAROID quickly moved from an ester/olefin blend to a straight olefin system. The ester base fluid used in the original PETROFREE was relatively viscous (5.0 – 6.0 cSt @ 40° F) and increased drastically at lower temperatures. To address this PETROFREE LV was introduced which utilized a thinner (3.5 – 4.5 cSt @ 40° F) ester. When BAROID introduced ACCOLADE, the base fluid was a blend (approximately 50/50) of ester and IO1618. In late 2004, they introduced a very similar system called ENCORE with basically a base fluid change to internal olefin (IO). Like other service companies, BAROID applied their technology learning of inverts to other based fluids such as paraffins and LTMOs (Maghrabi *et al.*, 2010).

ENCORE used primarily the same products that ACCOLADE had used, except a new product TAU-MOD was introduced. TAU-MOD provides low shear viscosity and suspension. BAROID began to emphasize the aspect of the ultra-low shear performance of their fluid (Figure 4) along with the fragile gel structure (Rødsjø *et al.*, 2013). These elements were well suited to minimize losses in narrow margin drilling environments that were due to induced losses especially when tripping, running casing and cementing. TAU-MOD in conjunction with RHEMOD L worked well to promote both the low-shear and gel properties in their fluids. BAROID also has incorporated a micronized weight material (Carbajal *et al.*, 2009) to enhance their newly created BaraECD (Halliburton Staff, 2014) for drilling narrow margin wells. Therefore, although they still avoided organophilic clay, the use of TAU-MOD (a sepiolite) became critical to the suspension ability and rheology profile of BaraECD (Halliburton Staff, 2012; Drilling Contractor Staff writer, 2014).

## M-I SWACO

M-I SWACO made several adjustments to their original RHELIANT system to improve its utility and ease of use. M-I SWACO utilized five different products for rheology, including two different organophilic clays and two different polymeric viscosifiers and a rheology modifier. Furthermore, thermal stability of the rheology profile above 275° F was an issue. Another issue with the original RHELIANT was the gel structure. Figure 2 shows they exhibited a “flat” profile, but the gel strengths were still relatively high (Figure 2, Chart B) in comparison to the conventional system (Figure 2, Chart A). Although RHELIANT promoted flat and fragile gels, they

became higher and not as flat once contamination occurred with drill solids (Figure 5, Chart A).

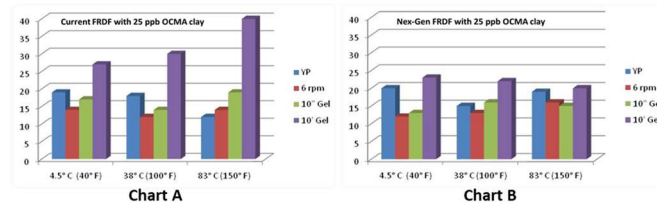


Figure 5 – Comparison of YP, 6 rpm and gel strengths between RHELIANT and RHELIANT PLUS FROBM contaminated with 25 ppb OCMA clay (Young *et al.*, 2012).

In 2011, M-I SWACO introduced RHELIANT PLUS (Drilling Contractor Staff writer, 2014; Young *et al.*, 2012; Friedheim *et al.*, 2011) which addressed all these concerns including the issue with the gel strengths (Figure 5, Chart B).

Although the new system addressed the issues that existed with RHELIANT, it required a greater degree of shear to activate the various chemistries. Since shear varies from drilling operation to drilling operation, M-I SWACO again redesigned the system and made another step change in their FROBM offering.

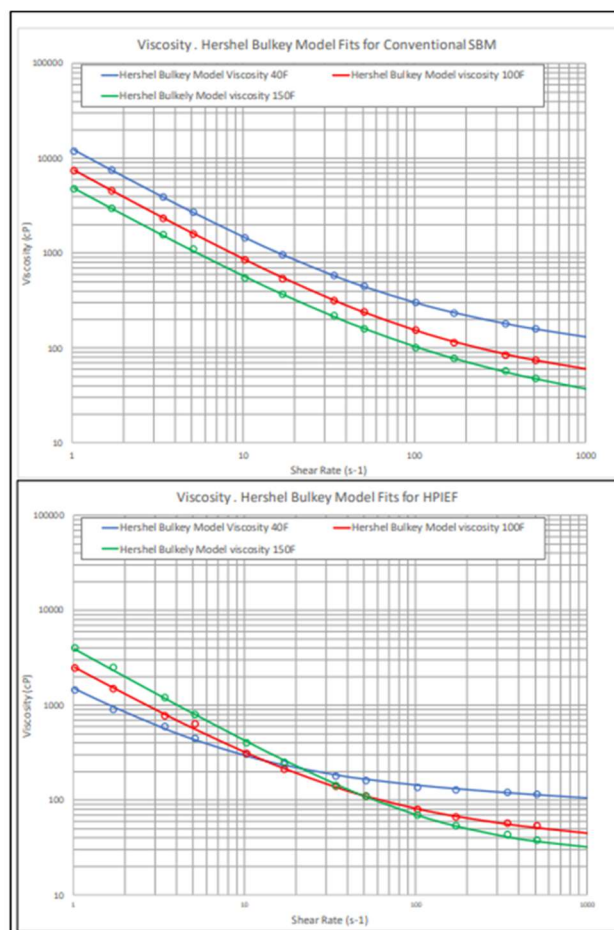


Figure 6 – Comparison of rheology profiles between a conventional mud (top chart) and M-I SWACO's RHEGUARD (bottom chart) FROBMs at 3 different temperatures illustrating the “reverse rheological effect” (Vickers *et al.*, 2020b).

The most recent evolution of M-I SWACO's FROBM began in Norway in 2014 and by the time that system was commercialized in 2018, it had been completely redesigned as compared to the previous two FROBM systems. The development parameters focused on thermal stability (up to 350° F), barite suspension (minimum barite sag), good hole cleaning and a flat rheology with lower gel structure than its predecessor (Vickers *et al.*, 2020a&b). This was accomplished by the development of a new emulsifier and wetting agent, a new rheological modifier (Khrarov *et al.*, 2020), and a new suspension agent and with the addition of micronized barite. The result was a more stable fluid, that displayed a lower but flat profile that displayed thixotropic behavior not yet seen (a reverse rheological effect) (Vickers *et al.*, 2020b). This "reverse rheological effect" is shown in Figure 6.

The top graph is a conventional fluid while the bottom graph (labeled HPIEF (High Performance Invert Emulsion Fluid)) is the new M-I SWACO system – RHEGUARD. It is evident that the new FROBM shows lower cold- temperature viscosity, but the higher temperature viscosity is not responding as typically seen. The higher temperature rheology increases at the lower shear rates thus providing additional suspension and hole cleaning properties. This has been observed in the field. Another benefit that was realized was the stability of the fluid after lengthy static periods of logging and tripping. This feature was something that helps operations avoid NPT due to barite sag or other phenomena related to poor suspension. Ultimately, this system has proven quite effective in difficult extended reach and narrow margin wells (Vickers *et al.*, 2020a&b).

### Mid-East Experience

Recently Sindi reported the benefits of FROBM to their operations (Sindi *et al.*, 2022; Osorio *et al.*, 2022). Essentially most of the benefits seen were the same as those for the application in Deepwater drilling, including improved hole cleaning and minimization of ECD, both contributing to a significant improvement in ROP.

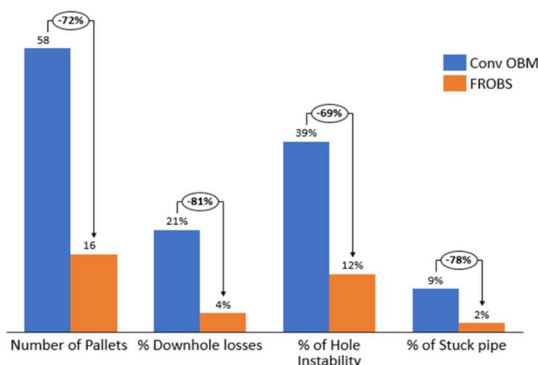


Figure 7 – Logistic and NPT improvements accredited to the FROBM as compared to the conventional OBM reported by Sindi in a recent application in the Kingdom (Sindi *et al.*, 2022).

The overall benefits, however, are illustration in Figure 7 (Sindi *et al.*, 2022). Here both drilling and logistical benefits are reported which not only contributed to lower NPT but

increased operational efficiency (OE). In this paper, Sindi identified is broader reaching benefits of the FROBM which even extend to topical sustainability goals as quoted below:

*“FROBS (aka FROBM) also reduced CO2 emissions with less logistical requirements due to lower chemical uses and lesser waste generation. This was a new sustainable technology solution that can be replicated at other locations to have a cost-effective and environmentally friendly alternative to current nonaqueous solutions.”*

In this case, the cooperation of operations, technical and support groups worked together to maximize benefits and value that the FROBM can bring.

### Conclusions

For over 20 years, FROBM have been making an impact on drilling with non-aqueous fluids. Although developed primarily for the Deepwater market, they have found great utility in other drilling applications. Research and development continue with the focus on downhole behavior and properties that will provide the greatest impact and benefit to lowering non-productive time (NPT) and increasing operational efficiency (OE). There is no doubt that the initial element of lowering cold-temperature viscosity has been set aside to focus on downhole behavior where these systems show benefits.

### Acknowledgments

There were a few industry contributors who did not work for any of the major service companies, but for major operators and played significant roles in the overall design and implementation of these systems. Dr. Eric van Oort of Shell was an important contributor to the development (van Oort *et al.*, 2004; Lee *et al.*, 2004) and introduction in the GoM, primarily working with M-I SWACO. Also, Juan Carlos Rojas, who was at BP at the time, worked with both BAROID and BHI (Rojas *et al.*, 2007). Both gentlemen helped develop, validate, and promote FROBMs by identifying the benefits of them within their own companies and to the industry.

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