



## The Use of an Abrasion Reducer in Successful Field Trial of Hematite Weighting Agent In West Venezuela

Mario A Ramirez, Juan Pablo Luzardo, Baker Hughes INTEQ Drilling Fluids; Freddy Quiroga, Francisco Ramirez, PDVSA

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### Abstract

A new hematite weighting material has been introduced by Petroleos de Venezuela (PDVSA) and a hematite supplier<sup>1</sup>. A series of six field trials were conducted in east and west Venezuela demonstrating the benefits of the new weighting agent. The trials encountered several problems during pilot production and testing. The most severe were down-hole tools failure, experienced during a pilot test to validate abrasion/erosion laboratory results and the weight material performance. These results indicated that additional development work was necessary for the hematite to have application in eastern Venezuela.

PDVSA-INTEVEP carried out a testing program to reduce fluid-related erosion and abrasion in subsequent field trials. The final drilling fluid design is based upon previous experience and laboratory testing. The testing indicated that a finer hematite was needed to minimize wear with the D90 value as the primary selection criteria for quality control. The investigation also indicated that an additive developed in conjunction with the fluids contractor would reduce the abrasion and erosion characteristics of hematite weighted oil-based mud under high density and shear flow rate conditions.

A detailed plan was put into place to evaluate abrasion and erosion during the drilling operation. The field trial utilized oil-based mud with a maximum density of 15.8 lb/gal and flow rates in excess of 500 gpm. At least 4 rig parts and down-hole tools were measured during this field test. After this detailed field trial, the surface equipment and down-hole tools showed no major wear. The abrasion results proved to be lower than those achieved with the laboratory formulation. The measured pump pressures were lower than expected and no excessive wear was identified in the mud pumps' liners. Moreover, the fluid abrasion reducer showed stability at elevated temperatures with its addition to the drilling fluid properties. The field trial was performed during a sidetrack, providing good abrasion and drilling fluid performance in comparison to the original hole, which used barite weight material.

The paper presents the abrasion results in the laboratory of a field mud formulation combined with data

related to downhole tools before and after the initial field trial. The additive proved to be effective not only to manage hematite fluid abrasion and erosion, but also to improve the oil base mud's filtration and rheological properties.

### Introduction

Flow induced abrasion was found to be a considerable problem in field tests using Ilmenite as a weighting material. These field test observations were in general confirmed by laboratory experiments. The abrasiveness was however, highly dependant on the particle size distribution of the hematite. Experiments by Bloomberg clearly showed that the abrasiveness can be reduced in API barite by removing the large particles<sup>2</sup>. The same has been shown to be valid for the hematite weighting material.

The abrasion resulting from a fluid is dependant on many factors, such as shape, concentration, and hardness of these particles. As a fluid is used and circulated, some attrition is expected.<sup>3</sup>

On the basis of Blomberg's studies, the problem of hardness of alternative weight materials can be resolved by processing the particle size to no more than 3% wt larger than 45 microns, compared with API barite, which has 3% by wt larger than 75 microns ( $\mu$ ).<sup>4</sup>

The new hematite product was developed by Petroleos de Venezuela (PDVSA). An initial series of six field trials were conducted in east and west Venezuela, demonstrating the benefits of the new weighting agent. A subsequent series of trials were planned to evaluate the abrasion/erosion effects of hematite on downhole tools. As shown in Figure 1, these prospects had varying degrees of risk, should the hematite result in excessive abrasion. The importance of this project led to a review of the past field trials and to a resolve to overcome any problems, thus enabling the product to be fully introduced to field operations.

The causes of the failure of the first field trial were poor communication between the operator, the drilling Fluids company and the drilling and evaluation (D&E) company, a lack of common goals, and the need for protocol for the field trial.

After reviewing the learning from the previous trials, it was decided to assemble a task force combining the resources of the operator and the Drilling Fluids and D&E companies, to identify common expectations, review benchmarks and set realistic goals. Figure 2 indicates the variety of density and flow rates that could be used as benchmarks. The planning phase took in excess of three months. This phase included extensive protocol discussion and technical meetings for tool and fluid design. The outcome was a workshop to publish agreed upon protocol and clear goals. A business review was the deliverable to close the learning cycle.

It was agreed by the hematite “plus” team that operational success should be the main criterion for the overall field trial success. This was decided based upon several factors:

- There had been a MWD failure on the previous field trial.
- Wellbore instability problems were observed during the original well that resulted in the well being abandoned.
- The use of 15.8 lb/gal oil-based mud (OBM) on the trial well as compared with 11.0 lb/gal OBM on the first trial could cause greater abrasion.
- Pump pressures could exceed 4,000 psi, possibly compromising hydraulics and hole cleaning.

Figure 3 and Figure 4 provide a summary of the drilling design selected for field trial.

### The Planning Phase

The task force was composed of representatives from the Drilling Fluids company in Houston and Venezuela and the operator hematite team (Fig. 5). The activities planned and developed from January to April 2002 included:

- Meeting between the Drilling Fluids company and the operator to plan the overall strategy and presentation of the same to the operator E&P operations.
- Participating in an operator operations meeting to present the general plan to field personnel.
- Reviews and discussions at meetings with service companies assigned to the field trial.
- Routine Drilling Fluids and D&E meetings to identify common goals.
- Drilling Fluids service company and the operator Drilling Fluids groups discussions to agree to the final OBM formulation for the field trial.
- Design and review of the field trial protocol, involving more than eight revisions.

During this process the Drilling Fluids company functioned as a link between operator’s operations and research groups. The Drilling Fluids company participated in the operator E&P operations meetings during this process.

The Drilling Fluids company and the operator agreed

upon the following drilling fluids design after extensive laboratory testing:

- A new OBM would be built and used to eliminate the effect of drill solids, especially sand.
- Calcium Carbonate in a concentration of 60 lb/bbl would be used as a bridging agent.
- The addition of 5 lb/bbl Polymeric Additive (PA) as an abrasion reducer. This recommendation was based upon laboratory work at the operator’s research laboratory.
- The hematite to be used would be quality controlled to have a grind size with a D90 of 31 microns and referred to as “hematite plus”.

A workshop was held in Ciudad Ojeda, West Venezuela. This workshop was designed to ensure that all groups that were involved in the field trial understood the importance of the tests.

- The workshop was attended by 48 people, including personnel from D&E and the Drilling Fluids service company, the operator’s research and E&P, including reservoir personnel, the solids control company, the drilling contractor and HS&E personnel.
- The meeting was chaired jointly by the Drilling Fluids and operator’s research company.
- The test protocol, which was approved by all concerned, was distributed to the office based and wellsite personnel.
- The roles and responsibilities during the trial were reviewed and agreed upon.
- The common goals were reviewed and agreed upon.

The meeting was judged to be a total success. Potential problems were identified and procedures put in place to avoid trouble.

### Field Trial Guidelines

The following activities were put in place, as a result of the workshop:

- All wellsite personnel attended to HS&E training conducted by the operator, covering aspects of hematite usage.
- A pre-spud meeting was held on location.
- The main issues discussed during the workshop were presented at the wellsite.

The following field trial guidelines were also established during the workshop:

- The downhole tools should achieve at least 80 hours with no failures for the trial to be declared a success.
- The maximum circulating time should be 120 hours.
- The sand content to be controlled between 0.75 to 0.25% by vol.
- The operations should be engineered to minimize fluids Non Productive Time (NPT) related to wellbore instability.

- The mud pump liner changes during the trial should be minimized.

### Laboratory Testing

Extensive laboratory testing program was conducted at both the Drilling Fluids' and the operator's research facilities during the planning phase. It was decided to perform the following additional evaluations during the field trial:

- Obtain information during the drilling operations to validate the laboratory results using field laboratory data.
- Monitor the activity and track the differences between expected and actual fluid performance.
- Real time adjustments would be made to the fluid, as dictated by performance during the trial.
- Fann 70, abrasion testing, PSD, API tests and lubricity testing would be run on a daily basis.

Table 1 shows laboratory test results of the fluid formulation. The effect of polymer additive on abrasion is shown in Figure 6.

### Field Trial Results

#### Field Trial Operations

- The section was successfully completed and the casing was set and cemented as planned.
- There was no wellbore instability problems observed.
- The pump pressure was maintained between 3,500 and 3,700 psi without hole cleaning problems.

#### Field Trial Goals

- The total circulation time to drill the interval was 99 hours. The time was limited by the total bit revolution limit of 500K revolutions.
- There were no MWD or motor failures. The MWD was in excellent condition after 99 hours.
- The maintenance of the tools after the trial showed no major abrasion as depicted in Figures 7 and 8.
- It was not necessary to make any mud pump liner changes.
- There was no fluids related NPT during the trial.

#### Field Trial Drilling Fluids Performance

- The mixing plant and rig site facilities were inspected prior to the trial to ensure no downtime during the mixing process.
- Hematite quality was defined in the protocol to have a D90 particle size of  $30\mu \pm 3\mu$ . The D90 value averaged  $31.61\mu$  as determined by a Mastersizer 550.
- The base fluid was transferred to the wellsite and the mud density was increased to 15.8 lb/gal using 5,400 sacks of Hematite. The final volume was 1,497 bbl.

- A concentration of 60 lb/bbl of fine calcium carbonate was added to the 100% OBM to improve mud sealing properties, as per the protocol.
- The final coefficient of lubricity @ 200° F in the field was 0.145, compared to a value of 0.178 in the laboratory with the same fluid formulation.
- The abrasion test value, using API 13I-Modified, on the laboratory fluid was 0.2125 mg/min. The maximum value recorded was 0.11 mg/min using the freshly formulated fluid. The abrasion test value during the drilling field test was 0.025 mg/min.
- The drilling fluid properties remained stable during the field trial, as shown in Figures 9 and 10.

### Post Trial Workshop

A workshop which included 33 people was held to present the results of the field trial and close the learning cycle.

- An overview of the process to achieve the goals of the field trial was undertaken at this meeting.
- The test results generated from measurements of the mud pumps, the drilling fluid and the downhole tools was reviewed.
- The operator HS&E group presented a video on HS&E issues related to future hematite usage.

### Conclusions

- The optimized particle size distribution eliminated the excess abrasion and erosion that had been experienced previously.
- The polymeric additive used for controlling abrasion worked as expected with the hematite.
- The field performance of the polymeric additive validated the lab testing procedures.
- The total circulating time for Downhole tools was 24% higher than the minimum required as per the goal set by the team. No major abrasion problems were observed during tool inspections which included measurements of key components, dictated by field trial protocols combined with photographic documentation.
- The abrasion test value of field mud obtained by using API 13I modified test was approximately 50% of the value obtained during lab testing.

### Acknowledgments

The authors thank the many people that contributed for the success of this field trial including Baker Hughes INTEQ and PDVSA.

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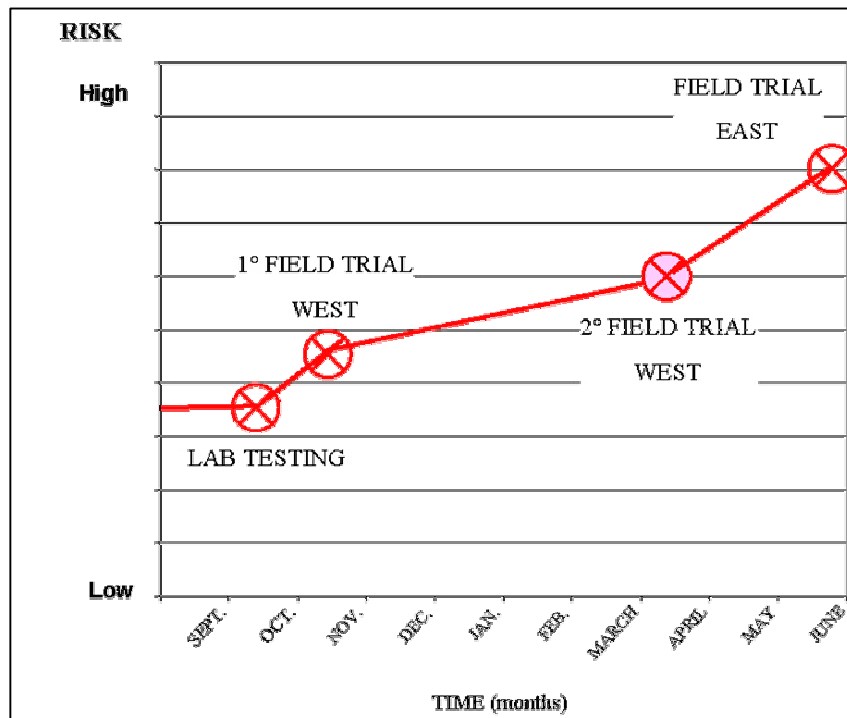


Figure 1. Risk Assessment for field trials with new hematite

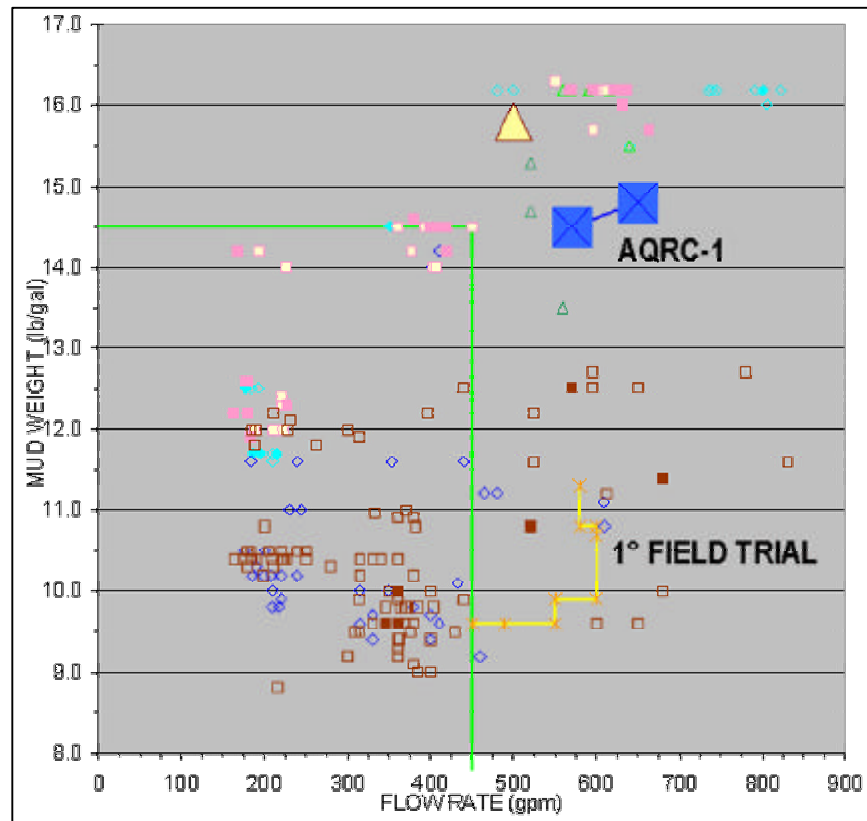


Figure 2. Benchmarking of hematite field trials

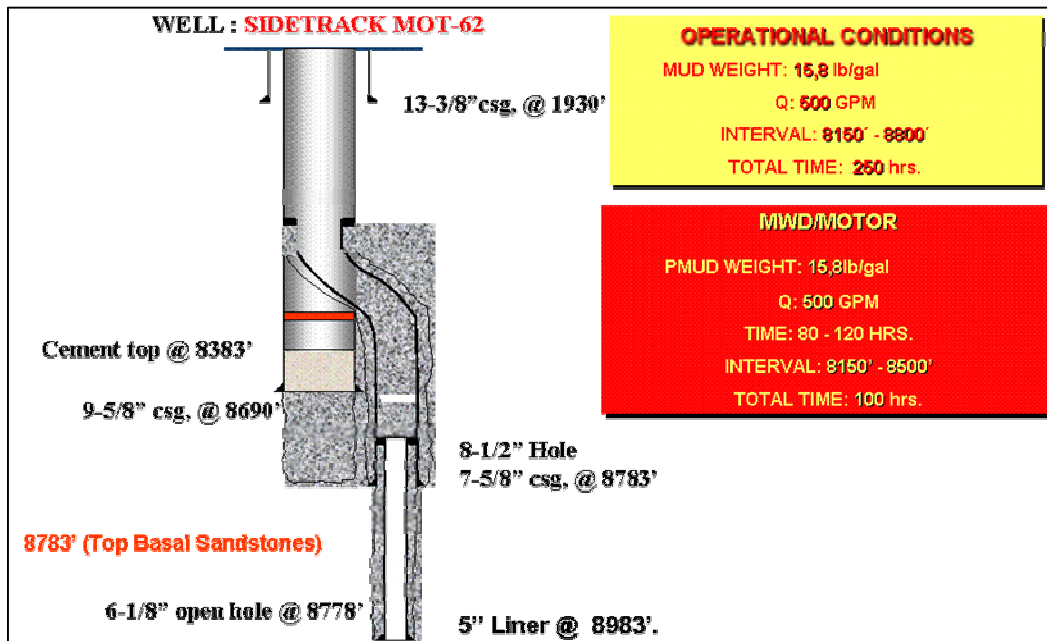


Figure 3. Well schematics

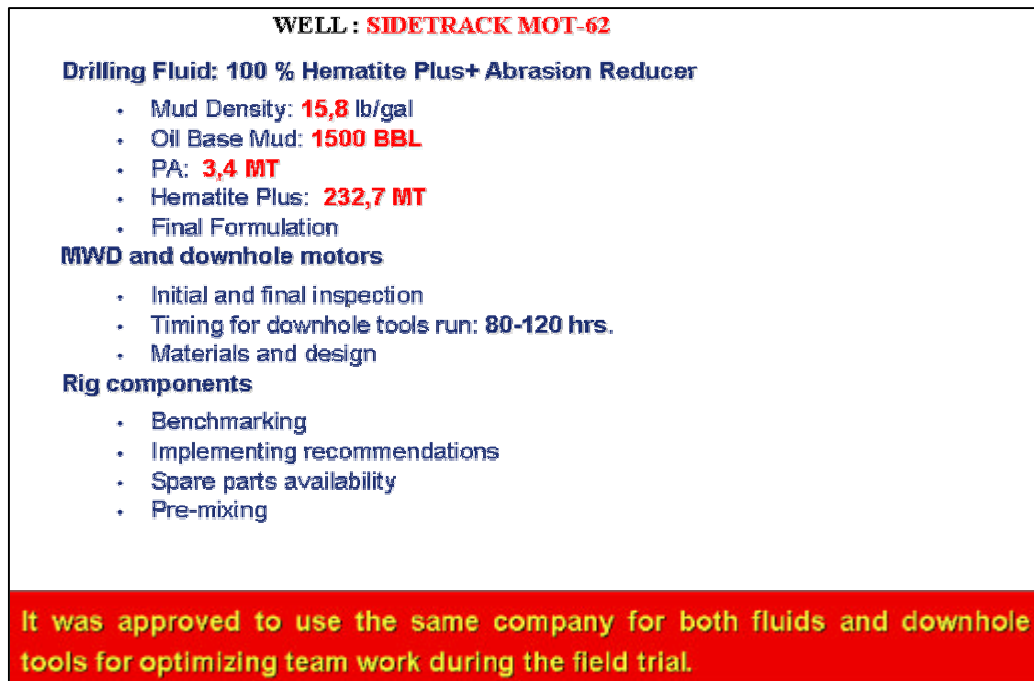


Figure 4. Operational conditions

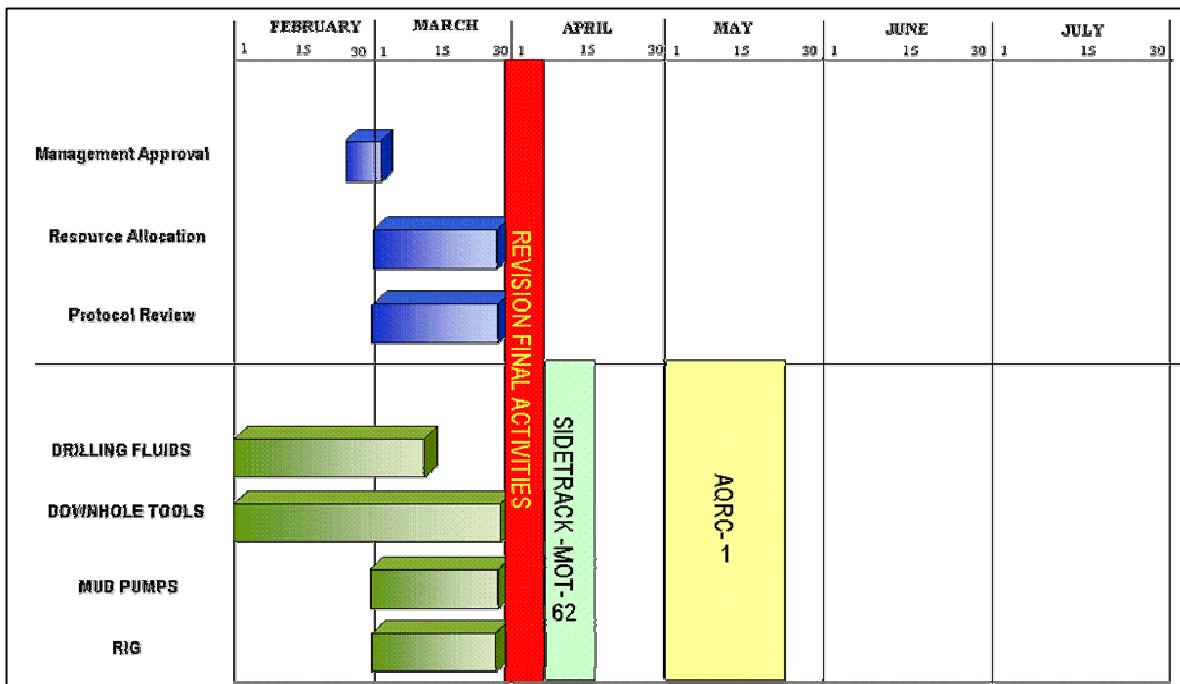


Figure 5. Planning stages for the field trial

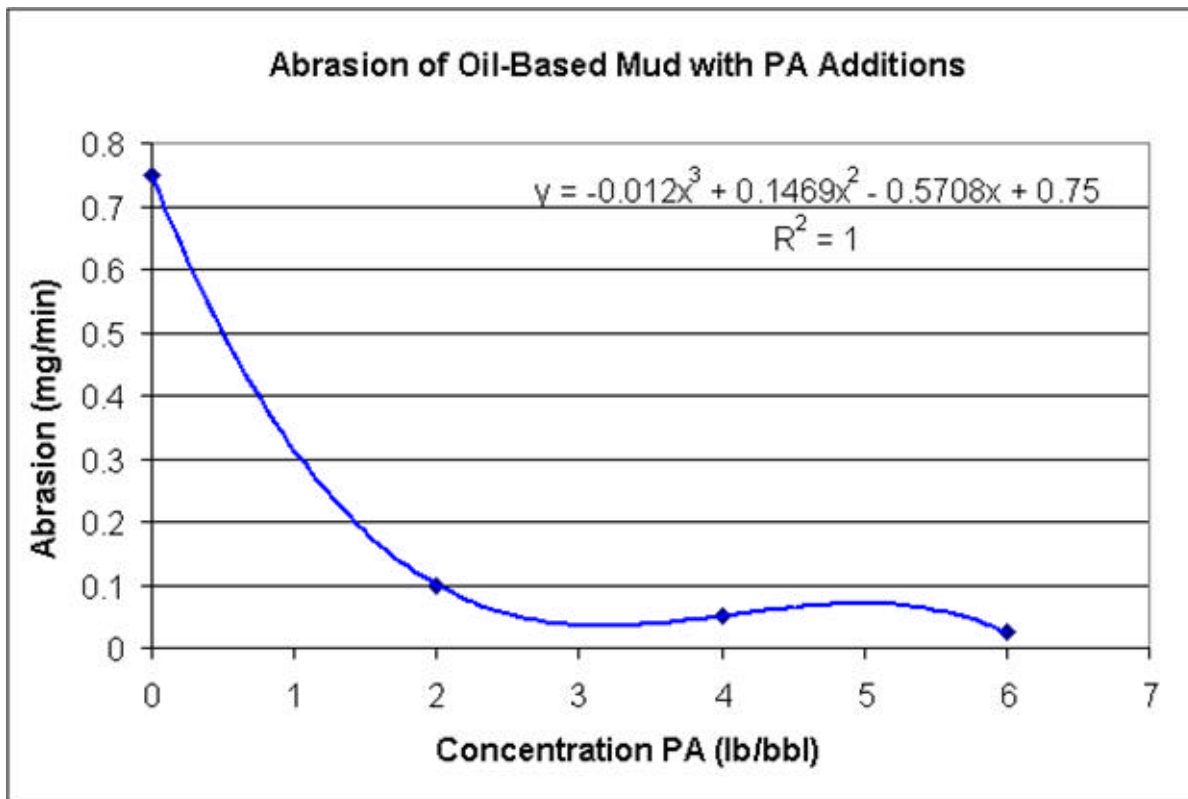


Figure 6. Effect of polymer additive on abrasion



**Figure 7. Bit after the field trial**



**Figure 8. Cleaned bit after the field trial**

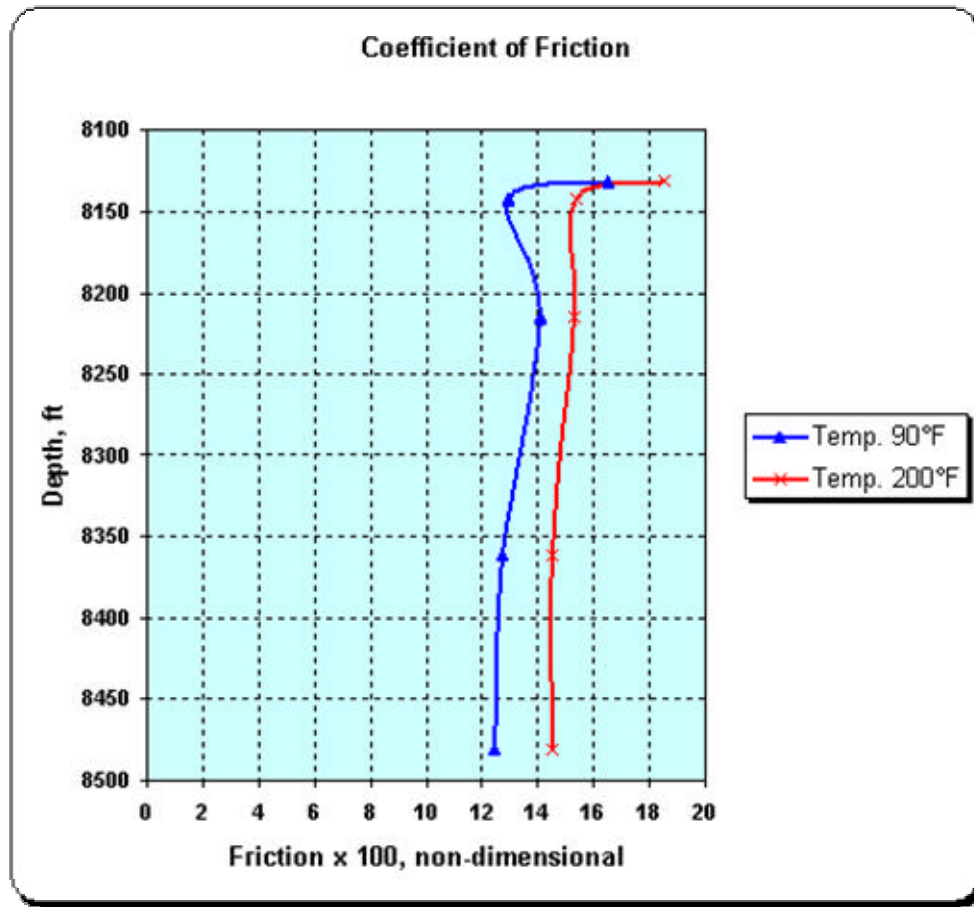


Figure 9. Lubricity performance

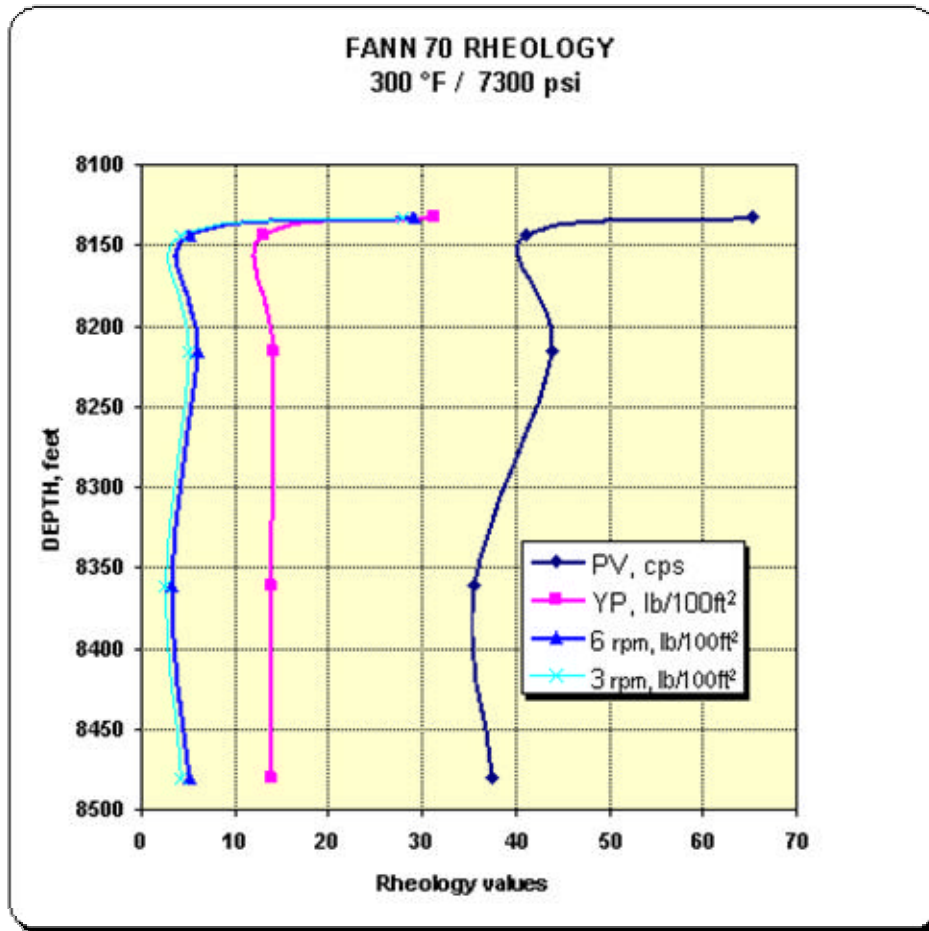


Fig 10. Fann 70 Viscosity during the field trial

Properties	Units	Base		#1		#2		#3	
		A	D	A	D	A	D	A	D
Density	lb <sub>m</sub> /gal	15.8		15.8		15.8		15.8	
PV	cP	103	116	125	64	86	94	87	-
Yp	lb <sub>f</sub> /100ft <sup>2</sup>	33	44	24	27	40	34	42	-
Gel 10"/10'	lb <sub>f</sub> /100ft <sup>2</sup>	10/23	13/45	10/18	8/19	19/38	18/32	23/45	37/68
6/3 readings	lb <sub>f</sub> /100ft <sup>2</sup>	16/11	19/14	15/11	14/10	18/16	22/19	21/18	50/42
HPHT	cc/30 min.	3.4	2.2	-	2.4	3.2	3	3	2.8
Sólids	%	27	27	27	27	26	-	27	-
Water	%	3	3	2	2	2	-	2	-
Oil	%	70	70	71	71	72	-	71	-
ES	Volts	2000+	2000+	2000+	2000+	1344		2000	
<b>Sealing Test /PPA a 250°F, 2000 pss &amp; Aloxite disk 400 mD</b>									
Initial Filtrate	mL		1.6		0.5		2		2
Total filtrate	mL		4.2		1.1		5		4.4
<b>Abrasion Test : modified API-13I</b>									
Abrasion	mg/min.				0.2125				

**Table 1. Lab testing results of formulated fluid.**

Property	Initial
Plastic Viscosity-Fann 35	59
Yield Point- Fann 35	20
Plastic Viscosity- Fann 70	65.3 @ 300 F - 7.300 psi
Yield Point- Fann 70	31.2
D90μ	226
D50 μ	82
D10 μ	8.5
LGS (lb/bbl)	47.3
PPT	5.4
Lubricity coefficient @ 200 F	0.185
Modified abrasion test mg/min	0.05

**Table 2. Initial Fluid Properties field mud**