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TÍTULO DO TRABALHO:

Designing a PHPA Mud & Comparing the Effect of Cement Contamination on a PHPA Mud and a Bentonite Mud

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Abstract

Water based drilling mud is result of mixing water with clay and other additives. Depending on quantity and type of additives or even presence of contaminants, the consistency and drilling performance of the mud may change. In this context, the current experiment was concerned with creating a PHPA Mud with compatible drilling properties of a Bentonite Mud. Through API Tests, such as Mud Weight, pH, Water Loss, Cake Thickness, Viscosity, Funnel Viscosity, Shear Strength, and 10-sec Gel Strength, the similarities and differences between PHPA and Bentonite water-based muds were analyzed. An optimum amount of bentonite to be added into the PHPA mud in order to reach those compatible drilling properties was found, and then the optimum PHPA and Bentonite muds were contaminated by 1% of Cement, and their physical properties were also analyzed. Thus, the primary focus of this report is to show the procedure used to reach the minimum bentonite concentration to attend the purpose, while the secondary focus is the analysis of cement contamination on those muds. After discussion, it was possible to conclude that the optimum PHPA Mud which attends the purpose has 12.5 ppb of Gel, and presents values of some physical properties close to those found when using only bentonite as mud additive. In addition, the effects of cement contamination is less significant on polymer systems (PHPA Mud) than on bentonite based mud systems. Thus, PHPA mud systems may be a feasible option to replace the use of bentonite mud systems when necessary.

Keywords: Cement Contamination, PHPA Mud, Bentonite.

Introduction

Drilling mud is result of mixing water with clay to reach desired consistency. In this context, bentonite, a sodium montmorillonite clay, is used as a base material for drilling fluids. It has low permeability, exceptional sealing capabilities, and it provides rheological properties and filtration control to WBM systems. In sand soils, for example, bentonite clay is mixed to the drilling water to increase the viscosity and keep the borehole from collapsing (Drill Manual, 2015). On the other hand, due to its cohesive structure, it may be difficult to remove bentonite mud from the borehole and aquifer. In this case, an option is to use synthetic muds or compounds such as PHPA, a long-chemical molecule, which interacts with minimal concentrations of bentonite to link particles together and improve rheology without increasing colloidal solids loading (Oilfield Glossary, 2015). Thus, a minimum solids fluid can be formulated to maximize the rate of penetration and provide a good hole cleaning capability.

Hi-tech Fuid Systems (2015) states that a PHPA system mud consists of a drilling fluid with partially hydrolyzed polyacrylamide as a functional additive. It provides shale stability, friction reduction, works as a viscosifier for water-base muds and extends bentonite clay in low-solids mud. Also, it seals microfractures and coat shale surfaces with a film retarding dispersion and disintegration.

Along with PHPA, the mud produced and analyzed in this study also contains a fluid loss control that acts as viscosifier made of modified polysaccharide, named Bio-Lose, and Caustic, the common name for sodium hydroxide. Caustic is used in most water-base muds to increase and maintain pH and alkalinity.

The cement contamination of the mud is common during the drilling, especially because of the cement plugs and drilling cement. The main source of this contamination is the drilling of green cement or adoption of poor placement procedures. Because of the nature of the cement, it releases ions of calcium (Ca^{+2}) into the mud, transforming the sodium montmorillonite (or bentonite) into calcium montmorillonite. It increases pH, causes flocculation of the bentonite clay and changes in rheological properties of the mud. It also increases cake thickness and fluid loss of bentonite based mud systems. In polymer systems, such as PHPA mud, the cement contamination increases the calcium content and the pH, resulting in precipitation of polymers and loss of control over the mud system (Wiper Trip, 2015).

In order to revert this process, the mud needs to be treated to precipitate the ions and restore the desirable characteristics of the mud. This treatment may be made with sodium bicarbonate, $NaHCO_3$, that will lead to a precipitation of an insoluble calcium carbonate and restore the properties of the mud.

Methodology

The main physical parameters discussed and tested in this experiment were MW, pH, Viscosity, Gel Strength, Yield Point, Water Loss, Cake Thickness, Funnel Viscosity, and Shear Strength of the produced muds. Based on all these parameters and calculation methods, this current work will focus on the procedures used to find the minimum bentonite concentration to reach compatible drilling properties between PHPA and Bentonite Muds, the criteria of comparison used, and the analysis of cement contamination on those muds. In this experiment, Bentonite, PHPA, Bio-lose, and Caustic were used as mud additives and Cement as mud contaminant.

The accomplishment of the first part of this experiment (Part I) was to design a PHPA mud with compatible drilling properties of a 18 ppb Bentonite mud. Thus, a bentonite mud of 3 lab bbl was produced with 1050mL of distilled water and 54 g of Bentonite. The distilled water was measured in a graduated cylinder, the Bentonite was taken from its container, measured in the common mass balance, and the mixture was stirred for few minutes using the blender. Tests of viscosity, yield point, gel strength, pH, funnel viscosity, shear strength, mud weight, water loss, and filter cake thickness were performed and recorded. This mud was called Mud A.

After that, 3 lab bbl of a new mud (Mud B) was produced with 1050 mL of distilled water, 0.5 ppb (or 1.5g) of PHPA, 0.1 ppb (or 0.3 g) of Bio-lose, and 0.1 ppb (or 0.3g) of Caustic. The concentration of Bentonite varied and, at each new concentration, those tests previously mentioned were performed. Four different concentrations of Bentonite were used: Mud B1 with 10 ppb (or 30g) of Gel, Mud B2 with 12.5 ppb (or 37.5g) of Gel, Mud B3 with 15 ppb (or 45g) of Gel, and Mud B4 with 20 ppb (or 60g) of Gel. Between these muds, Mud B2 gave results closer to those found with the Mud A, and then it was called “the Optimum PHPA Mud”.

The procedure adopted to minimize time of work and waste of products was to produce one sample of mud (Mud B) and gradually add bentonite to reach the new concentration desired and, at each new mud composition, the mixture was stirred for few minutes using the blender.

In the second part of the experiment (Part II) the samples of Mud A and B2 were prepared again with the same composition as used in the Part I, and contaminated by 1% of cement, that is, 12 g and 11 g of cement, respectively. After contamination, they were called Mud C and D. Tests of viscosity, yield point, gel strength, pH, funnel viscosity, mud weight, water loss, and filter cake thickness were also performed and recorded for both contaminated muds.

At each repetition, the sample of mud was changed and the equipment cleaned before new measurement. At the end of all experiments, the mud was discarded after mixed with wood dust in order to make it solid, and all equipment were cleaned and stored. All experiments follow API instructions and methodology of previous works (Gois, 2015).

Results and Discussion

The following table (Table 1) depicts the experimental results obtained from the above procedures.

Table 1 A. Mud Properties Recorded during Part I Procedures

Mud Sample		pH	MW	$^{\theta}$600	$^{\theta}$300	10-sec GS	AV	PV	YP
		[1]	[ppg]	[cP]	[cP]	[lb/100ft2]	[lb/100ft2]	[lb/100ft2]	[lb/100ft2]
A		**8.2**	**8.58**	**34,5**	**25,5**	**6**	**17.25**	**9**	**16.5**
B	B1	9.5	8.3	29	19	1	14.5	10	9
	B2	**9.4**	**8.5**	**64**	**40**	**4.9**	**32**	**24**	**16**
	B3	9.3	8.52	53	32	7.5	26.5	21	11
	B4	8.9	8.67	103	81	9	51.5	22	59
C		**10.7**	**8.8**	**57**	**33**	**1**	**28.5**	**24**	**9**
D		**10.9**	**8.5**	**23**	**15**	**3**	**11.5**	**8**	**7**

Table 1 B. Mud Properties Recorded during Part I Procedures

Mud Sample		Water Loss, mL			Cake Thickness	Shear S.	Funnel V.
		2.5 min	5.0 min	7.5 min	@7.5 min	[lbs/100ft2]	[sec/qrt]
A		**3.5**	**4.7**	**6.0**	**1/32''**	**5.2**	**60**
B	B1	-	-	-	-	0	-
	B2	**3.0**	**4.0**	**4.8**	**4/32''**	**4.5**	**58**
	B3	-	-	-	-	8	-
	B4	-	-	-	-	60	-
C		**38**	**56.5**	**68**	**10/32''**	**-**	**-**
D		**7**	**10.5**	**13.3**	**2/32''**	**-**	**57**

The main purpose of this work is to explain the criteria of comparison used to find the minimum bentonite concentration that reaches compatible drilling properties between PHPA and Bentonite Muds. This comparison was based on physical parameters, such as mud weight, apparent and plastic viscosity, yield point, initial gel strength, shear strength and funnel viscosity. The pH was also tested. However, due to presence of caustic in the Mud B, it was not possible to reach values of pH of 8.2, which was found for the bentonite mud.

Those properties and API tests were chosen as criteria of comparison between muds because they are the base of drilling performance. Drilling fluids must be mixed with additives to attend specific functions: to bring soil cuttings up from the bottom of the hole to the surface, suspend and drop them out as the fluid flows through the settling pit, to prevent formation damage, to control kicks, formation pressure and migration of fluids into formation, to transmit hydraulic energy, cool and lubricate bit, drilling assembly and tools, and so on. All these desired results are obtained by properly designing the mud pits, controlling rheology, weight and filtration of drilling fluids, avoiding chances of corrosion, checking the thickness of the mud periodically, and removing some of the accumulated cuttings from the settling pit. Thus, all tests performed in this study give us an overview of how the mud would behave when drilling, and allow us to compare different types of mud by their drilling performance.

Figure 1 consists of a graph with different curves of physical mud measurements vs concentration of bentonite. Through this graph, it is possible to find accurately the concentration of bentonite to attend the purpose of designing a PHPA mud with specific characteristics and compare this value with the amount found experimentally. The optimum concentration is represented by a little "x".

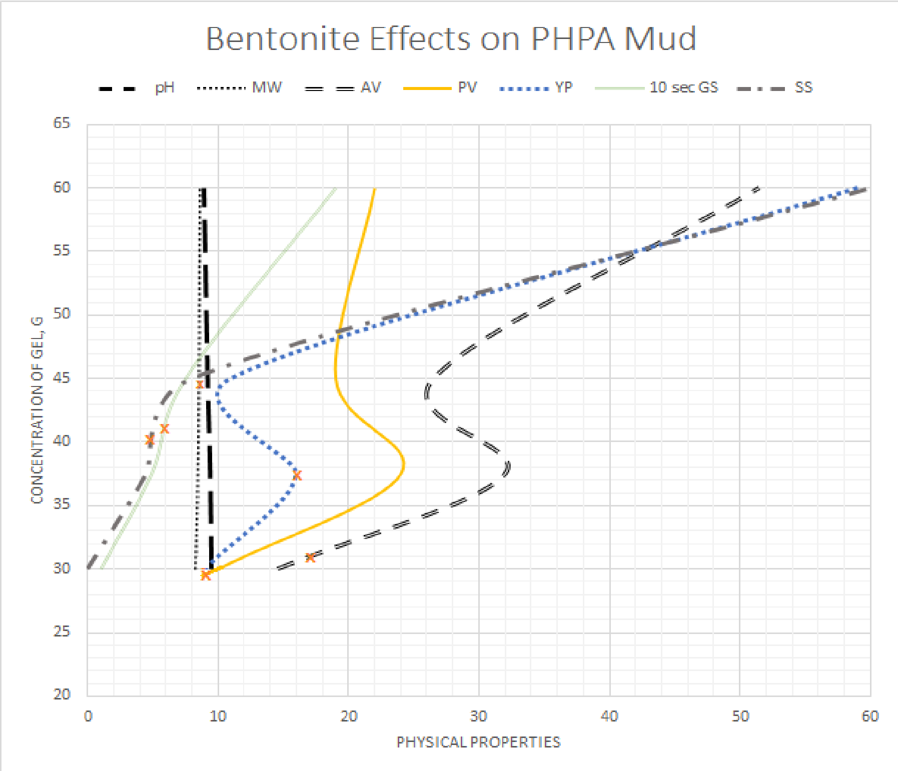

Figure 1. Curve of Physical Properties Measurements vs Concentration of Gel;

By analysis of Figure 1, there are two important observations. At first, there is no concentration of Bentonite in the PHPA Mud that matches all results found using the mud with 18 ppb of bentonite only. As the figure shows, the "X", which represents the optimum concentration of Gel, varies its position at each different property analyzed. Thus, the only alternative is to choose the mean point of those optimum points found for each parameter, that is, **37.5g or 12.5 ppb of Gel**. Fortunately, it was exactly the value estimated during the experiment as the optimum and minimum concentration of bentonite to attend the purpose. Thus, B2 is the optimum PHPA Mud with characteristics as closer as possible of those found using the mud with 18 ppb of bentonite. The second important observation is the presence of curves with "S" format, which is an unexpected result. Since the only difference between mud samples is the concentration of bentonite that is linearly changing, the curve tendency should be also linear. This disagreement shows the experiments may be not properly conducted. In order to provide more accurate conclusions, it would be better to repeat these experiments.

Even though under possible errors, it is possible to see by Table 1 analysis that Mud B2 and Mud A have very close values of Funnel Viscosity, Yield Point, Mud Weight, Initial Gel and Shear Strength, and Water Loss. Thus, functions as consistency, capacity of suspending particles, formation control, pumping force necessary to restart the circulation of mud, and quantity of fluid lost to the formation, respectively, are also similar for those muds.

After discussing the primary focus, this section will now approach the secondary focus of this study, that is, the analysis of 1% of cement contamination on muds A and B2 that will be called Mud C and D after changes due to contamination.

Through Table 1 analysis, it is clear the effects of cement contamination on bentonite based mud systems and polymer systems work by different ways. In bentonite mud systems, for example, 1% of cement was responsible for increasing all physical properties tested but Yield Point. The filter cake thickness, which increased **from 1/32" to 10/32**", the consistency of the mud (that could not be tested by FV due to its high thickness), and water loss were the parameters most significantly affected.

On the other hand, the polymer system represented by the PHPA mud was affected in a different way by cement contamination. In this case, 1% of cement decreased the rheological properties (AV, PV, YP, and 10-sec GS) and increased pH. Parameters such as Mud weight, cake thickness, funnel viscosity and water loss had little or no changes in their values. Figure 2 depicts changes in quantity of water lost during the API filtration test for muds A, B2, C and D. When those different curves are compared, it shows how the PHPA mud is less susceptible to cement contamination changes than the bentonite based mud.

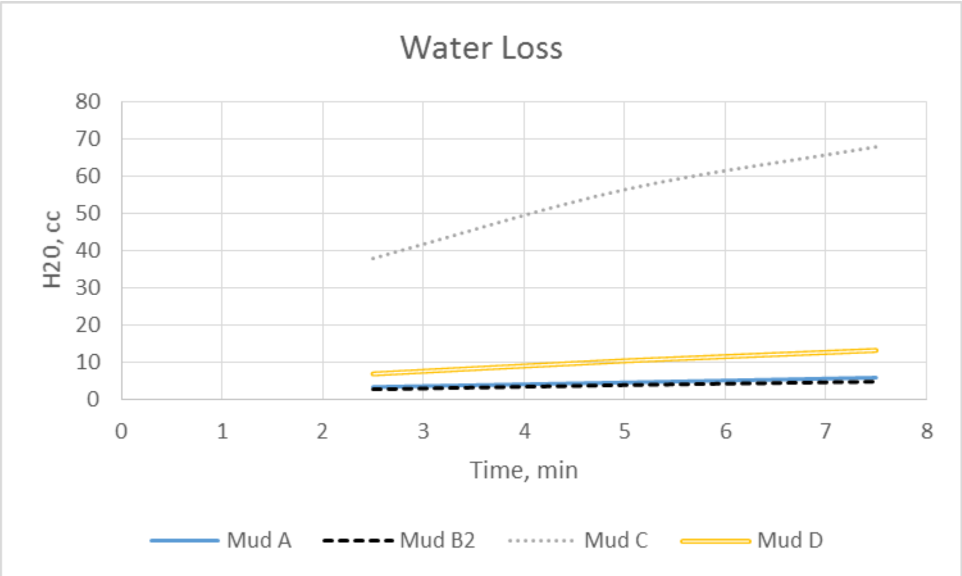

Figure 2. Water Loss Measurements for Bentonite and PHPA muds contaminated and non-contaminated by cement.

Changes that are more significant happen to the bentonite mud system because of the nature of the cement that releases ions of calcium and transforms bentonite into calcium montmorillonite, resulting in flocculation of the bentonite clay and changes in rheological properties of the mud (Bentonite Baroid, 2008). Since the PHPA has a smaller amount of bentonite, it is also less affected. From these results, a clear conclusion is that polymer system muds, such as the optimum PHPA Mud (Mud B2) produced, may be a feasible option to replace the use of bentonite mud systems, especially when drilling green cement or adopting poor placement procedures. Its drilling performance is close to the expected for bentonite based muds, and the advantage is its lower susceptibility to cement contamination. Before its use, however, it is necessary to pay attention on pH values to avoid unacceptable range of alkalinity, and analyze economic issues.

Conclusions

This experiment was meant, as primary focus, to show the procedure and criteria used to find the minimum bentonite concentration to reach compatible drilling properties between Bentonite and PHPA muds. As secondary purpose, the analysis of cement contamination on those muds was also performed. The procedure for the first part of the lab consisted of producing two water-based mud samples: one with 18 ppb of bentonite, and other with PHPA, Bio-Lose, Caustic and different quantities of bentonite. Mud tests were performed for each different mud sample to analyze the similarities and differences between PHPA and Bentonite water-based muds, and the minimum concentration of bentonite in the PHPA mud that reaches the purpose was found. In the second part of the lab, the optimum PHPA and Bentonite muds were contaminated by 1% of Cement, and their physical properties were also analyzed. Viscosity, yield point, initial gel strength, shear strength, pH, water loss, cake thickness, mud weight, and Funnel Viscosity were the mud physical properties evaluated in these experiments. After analysis, it was possible to conclude that there is no concentration of Bentonite in the PHPA Mud that matches all results found using the mud with 18 ppb of bentonite only. The closest optimum point found, however, is 37.5g or 12.5 ppb of Gel, which agrees with the value estimated for Mud B2, also called optimum PHPA Mud. Even though curves with “S” format were not expected, Mud B2 and Mud A still have very similar values of Funnel Viscosity, Yield Point, Mud Weight, Initial Gel, Shear Strength, and Water Loss. Other important conclusion is the effects of cement contamination on bentonite based mud systems and polymer systems work in different ways, and the PHPA mud is less susceptible to cement contamination changes. Thus, PHPA mud systems may be a feasible option to replace the use of bentonite mud systems, especially when drilling green cement. It is necessary, however, to pay attention on pH values to avoid unacceptable range of alkalinity, and analyze economic issues before its use.

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