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## EVALUATION OF THE INFLUENCE OF THE VISCOSIFIER ON THE PROPERTIES OF SYNTHETIC DRILLING FLUIDS

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**Abstract.** *Due to environmental organizations pressure, synthetic drilling fluids, known as the fluids new generation, and their formulas are being studied to become less aggressive to the environment where they are employed. Between the products used to make this fluid, there is the emulsifier, usually of toxic composition. Therefore, it is sought to replace it for a less aggressive or harmful to the environment. This research had as objective to evaluate the viscosifier content influence on the properties of synthetic fluids made with natural emulsifier. For this, 60/40 oil/water fluids were formulated, varying the content of the viscosifying additive, 2 and 3 grams. The fluids were evaluated through their rheological and filtration parameters and electrical stability. The results, in general, showed values within the specified by norm and the increase of organophilic clay content altered minimally the parameters, but it was still possible to observe an increase in the rheological parameters and also in the electrical stability, due to the secondary character as emulsifier of the clay.*

**Keywords:** *synthetic drilling fluids, viscosifier, natural emulsifier.*

### 1. INTRODUCTION

As technology advances, there are also growing concerns about the environment, and this is no different in the Oil Industry, which tries to extract the natural resource with the least possible disturbances to the surroundings. Therefore, research is required to make the entire drilling process suitable, as in the case of drilling fluid to be used, due to great concern about the environmental damages caused by its disposal.

Drilling fluids, or drilling muds, according to Thomas et al. (2001), are complex mixtures of solids, liquids, chemicals and sometimes even gases. These may assume, from the chemical point of view, aspects of suspension, colloidal dispersion or emulsion, depending on the physical state of the components. As stated by Machado (2002), from a physical point of view, these fluids assume behavior of non-Newtonian fluids, so that the relationship between the shear rate and the rate of deformation is not constant.

Whatever drilling fluid is chosen for the desired operation, it must have general characteristics such as, according to Thomas et al. (2001): to be chemically stable; keep the walls of the well mechanically and chemically stable; facilitating the separation of cuttings on the surface; keep solids in suspension when you are at rest; be inert in relation to damage to producing rocks; to make use of any treatment, physical or chemical; be pumpable; present a low degree of corrosion and abrasion in relation to the drilling column and other equipment of the circulation system; to facilitate the geological interpretation of the material removed from the well; and present cost compatible with the operation. These features are essential for optimized drilling in terms of time, cost and safety.

Regarding the influence of the type of fluid, regardless of the formulation used, they must have certain functions, such as: cleaning the bottom of the drill bit and transporting gravel to the surface; exert hydrostatic pressure on the formations so as to avoid the influx of undesirable fluids and stabilize the walls of the well; cool and lubricate the drill string and drill bit; transmit hydraulic power to drilling tools; relieve the weight of the drilling column by means of flotation; and minimize environmental impacts (THOMAS et al., 2001 and SANTOS, 2012).

In each oilfield, and for each specific well, there are different physical and lithological conditions that require a specific composition of the fluid that meets the requirements of the drilling process. Of the various drilling fluid compositions available for drilling oil wells, the most notable are synthetic ones. This type of fluid is currently

considered to have the best performance and is used in preference to the oil-based because of its lower aggressiveness, and to new challenges where water-based fluid is not recommended, such as wells that cross salt zones and formations of reactive shales. The synthetic fluid, considered as the image of the new generation of drilling fluids, has a high cost, but due to its specifications, this has been a viable alternative for the use in the conditions already mentioned, due to the current horizons of drilling.

The term "synthetic mud" refers to fluids whose continuous phase is composed of one or more fluids produced by a specific chemical reaction and not by processes of physical separation of the crude oil (fractionation and distillation) or breakdown (catalytic cracking) of petroleum fractions (OFFSHORE PETROLEUM BOARD, 1998).

Caenn et al. (2011) points that synthetic fluids have advantages in their performance when compared to aqueous based fluids, the main ones being: the low compatibility indicated for reactive formations, greater thermal and structural stability, better lubrication, lower corrosion rates and greater ease of reuse.

Considering the above, some studies have sought to determine the toxic levels of the fluid and propose changes in the synthetic base used in the drilling fluid and/or in the formula used to make it. In this formulation, there are different additives used, for example the emulsifier, which has the function of maintaining the stability of the water-in-oil emulsion, and organophilic clay, which has the viscosifying function, i.e. imparting greater viscosity to the fluid.

Emulsifying agents play a key role in the stabilization of emulsions, as Oliveira et al. (2004), reducing the interfacial tension between the oil and the water present in the emulsions. However, these compounds cannot reduce the interfacial tension to the point of totally reducing the free surface energy caused by the increase of the interfacial area. In this way, the emulsions are thermodynamically unstable systems and, in the technological development, it is tried to use means that can delay for as long as possible the separation of the phases.

Currently, the commercially available emulsifier is produced from amides and imidazolinones, which are toxic compounds. Therefore, it is sought to manufacture an emulsifier less harmful to the environment, as in the case of a natural compound based on vegetable oils. These include soybean oil, which in its manufacturing process has as a by-product sludge with the same characteristics of the composition of the oil itself, that is, high content of fatty acids, very favorable to the use for the production of emulsifier, besides having reduced economic value and high quantity in the industry.

As for the second focus additive of this work, organophilic clays were introduced into the drilling fluids in the 50s of the last century, acting as controllers of the system rheology. These are produced, in general, from the cation exchange reaction of a hydrophilic clay with quaternary amine or ammonium salts. Organophilic clays when dispersed in the oleophilic medium promote an increase in the viscosity of the blend to which it has been incorporated. This increase contributes, in drilling fluids, to a greater capacity to carry solids, a necessary function to use this product (Sousa et al., 2011).

In this study, the type of emulsifier was changed, using a natural one based on food grade vegetable oils, as well as the clay content, both changes were made with the purpose of evaluating the interaction between the two additives, aiming at a fluid less aggressive to the environment and still results in well performance.

This work aims to evaluate the influence of the viscosifier content on the properties of the synthetic fluids prepared with natural emulsifier.

## 2. EXPERIMENTAL PROCEDURE

Four different formulations, in duplicate, of 60/40 synthetic oil / water ratio drilling fluids were studied and these are found in Tab. 1.

Two emulsifiers, one natural and one commercial, were used. The natural emulsifier (EBO) used was produced from the soya by-product of the soybean oil industry, has a high content of fatty acids and has the appearance of a grease with high viscosity. For comparison of the results, a commercial emulsifier for the production of fluids was used as reference. This emulsifier is Liomul, a product synthesized from amides and imidazolines, widely used in the industry. Thus, in Tab. 1, the fluids F1 and F2 correspond to the fluids with natural emulsifier and the fluids F1P and F2P correspond to the fluids with commercial emulsifier.

Table 1: Formulations of 60/40 drilling fluids studied.

Components	F1	F1P	F2	F2P
n-paraffin (mL)	199,5	199,5	199,5	199,5
Hydrated lyme (g)	2,5	2,5	2,5	2,5
Emulsifier (g)	10,0	10,0	10,0	10,0
Hydrated lyme (g)	2,5	2,5	2,5	2,5
Brine (mL)	136,5	136,5	136,5	136,5
Filtration reducer (g)	1,0	1,0	1,0	1,0
Organophylic clay (g)	2,0	2,0	3,0	3,0
Baritine (g)	sq*	sq*	sq*	sq*

\*sq: Sufficient quantity to reach mud weight of 10 lb/gal.

The fluids were prepared by adding the additives under stirring on high speed mechanical stirrers of the Hamilton Beach brand at low speed of 13,000 rpm and subsequent addition of a certain additive was increased speed to 17,000 rpm. The stirring time until addition of the next component is shown in Tab. 2.

Table 2: Stirring time of the components of the fluids.

Components	Stirring time (min)
n-paraffin	-
Hydrated lyme	10
Emulsifier	5
Hydrated lyme	10
Brine	5
Filtration reducer	5
Organophylic clay	10
Baritine	10

After preparation of the fluids, they were tested in three moments: 1 ° before addition of baritine, 2 ° after addition of baritine and 3 ° after thermal aging.

The addition of baritine is the process known as densification, which serves to raise the specific mass of the synthetic fluid to the commonly used, which is 10 lb/gal.

The thermal aging has the purpose of simulating the working conditions of bottom of well, process in which the fluids were thermally aged in Roller Oven of the mark Fann, model 705ES, by 16 hours, to 200 ° F.

The rheological properties were obtained through the use of a Fann 359 model viscometer together with a thermal cup at a temperature of 65.6 ° C (150 ° F). The values of apparent viscosity (AV), plastic viscosity (PV), yield point (YP) and gel strength (GF) were calculated using the data obtained in the viscometer readings according to EP-1EP-00011-A (PETROBRAS, 2011).

The electrical stability was obtained using the thermal cup at a temperature of 65.6 ° C (150 ° F) and the Fann Electric Stability Meter, model 23D. Five measurements were taken and the value adopted as the final result was a statistical mean among the measurements made, taking out the lowest and the highest value among them.

The HPHT filtration property was made using the Fann brand HPHT filter press. This test was performed at a temperature of 93.3 ° C (200 ° F) and at a pressure of 500 psi, and the volume of filtrate was collected in a graduated cylinder. This collected volume is multiplied by two so that the result is closer to the reality found in the field, and this value together with the percentage of water measured in the filtrate are adopted as the test results.

The evaluation of the synthetic drilling fluids was made from these parameters obtained by the cited tests and compared to each other.

### 3. RESULTS AND DISCUSSION

The averages of the results obtained from the tests made in the formulated fluids are shown in Figs. 1 to 3 and Tab. 3, where Fig. 1 presents the results of the rheological parameters of the synthetic fluids studied.

According to the American Petroleum Institute (1979), the apparent viscosity is the viscosity of the fluid when measured at a given shear rate. In the model adopted for Bighamian drilling fluids, the apparent viscosity can be calculated from the value measured on a rotational viscometer at 600 rpm (rotations per minute).

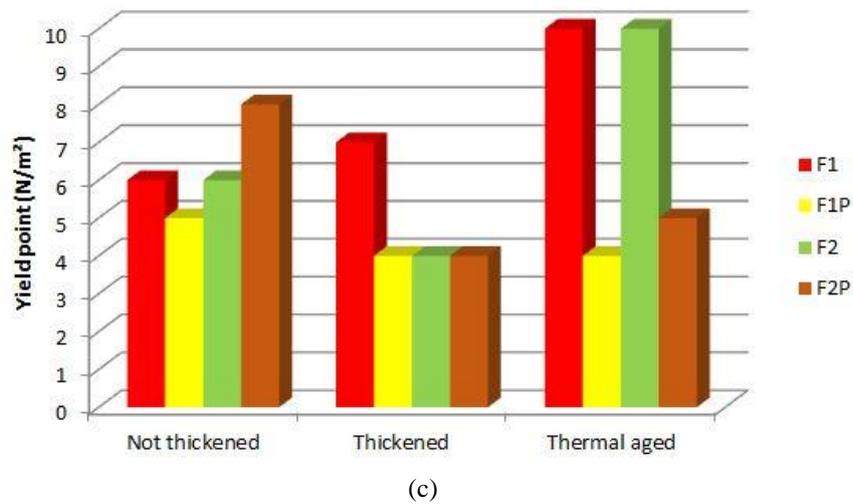
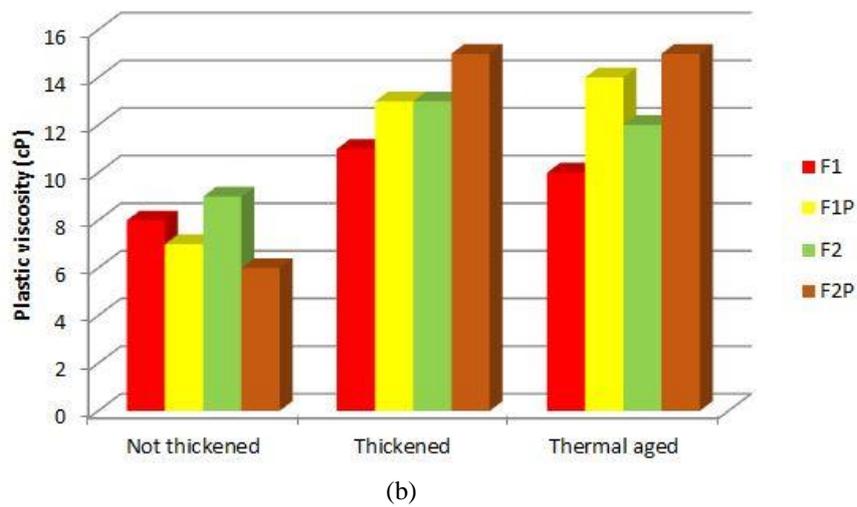
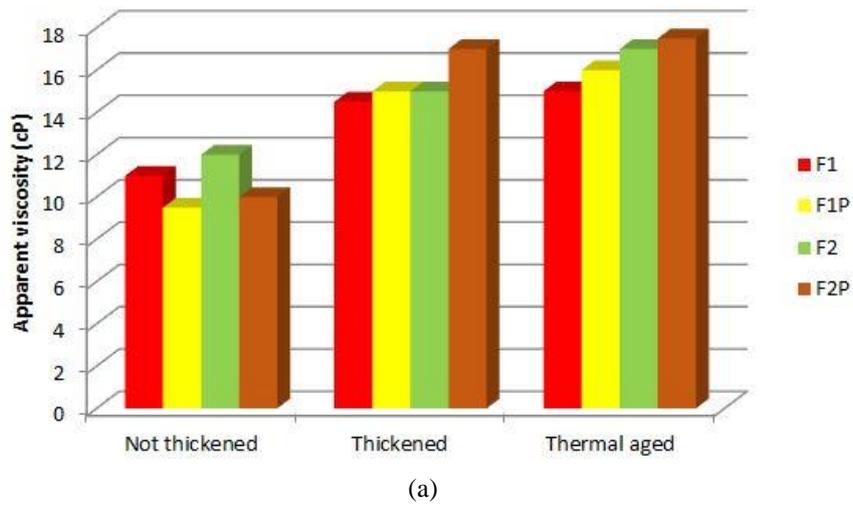
Moreira et al. (2007) cites Machado (2002), which complements the idea presented above by stating that this measure can be made in the Viscometer Fann 35A, used in the experiments, and that this AV value is related to the load loss that occurs during the circulation of drilling fluid, which will be larger the higher the L600 value.

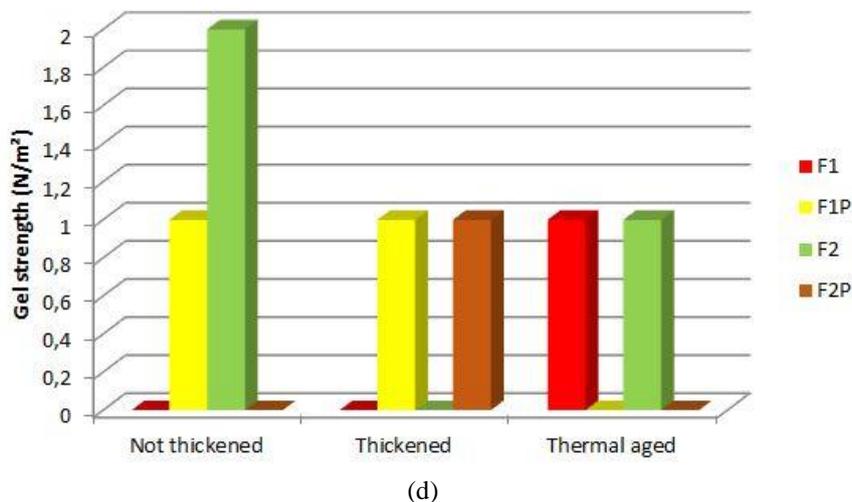
It is possible to observe, for all the fluids, an increase of AV with the addition of baritine. Although this additive is classified as a thickening agent, the particles thereof when dispersed in the fluid improves the interaction of the present additives contributing to increase of AV. There is also an increase in AV with the thermal aging treatment of fluids, this is due to the high temperature and constant bearing that promote a greater dispersion of the additives and, consequently, a greater interaction between them, thus increasing such property.

An apparent viscosity increase can be observed when the amount of organophilic clay increases from 2 to 3 grams, which is in accordance with the viscosifying character of this additive.

It is observed that the fluids with the EBO emulsifier present higher values of AV before the densification when compared to the standard fluids, it can be said that this emulsifier adds a higher viscosity to the fluid when there is no presence of the thickener. However, when adding the baritine to the synthetic fluid, the values of AV obtained for the studied fluids were higher in that the commercial emulsifier Liomul was used, this can occur due to a greater interaction of this emulsifier with the hydrophilic (polar) and hydrophobic (apolar) parts, increasing the dispersion of the water droplets and thus increasing the dispersion also of the baritine particles. Nevertheless, the values found did not vary significantly between the fluids with the different emulsifiers.

Such AV values within commercial standards for natural emulsifying fluids translate into a good ability to draw solids during drilling as desired for drilling fluids.





(d)  
Figure 1. Rheological parameters of the studied fluids, being: (a) apparent viscosity, (b) plastic viscosity, (c) yield point and (d) gel strength.

According to Silva (2003), the plastic viscosity is a measure of the internal resistance of a fluid to its own movement. It can be used as an indication of the concentration and interaction of solids in the fluid. The higher the solids content, the higher the plastic viscosity. For any solids concentration, the plastic viscosity will increase as the particle size decreases. The main reason to explain this phenomenon is the increase of the surface area of the solids as a consequence of the diminution of their size.

As for the steps of the experiment, there is only an appreciable variation, an increase of the PV with the addition of baritine, due to the increase in the solids concentration in the fluid.

It is observed an increase of the plastic viscosity with the increase of the organophilic clay amount, phenomenon usually occurred according to Silva (2014). Machado (2002) describes this behavior and states that the increase in plastic viscosity comes from the friction between the dispersed solid particles and the dispersant liquid molecules. The friction between these particles can be derived from the solids concentrations, the size and shape of the solids present in the fluid, as well as the viscosity of the fluid phase.

It is observed that the studied fluids, for the most part, presented the same behavior for the values found of PV compared to those of AV when comparing the different emulsifiers, possibly with the same causes for such tendencies.

In this case, the values of PV within the standards, as well as the VA, result in the desirable capacity to drive the gravels formed by the perforation.

According to Silva (2003), the yield point represents the effort required to start a moving fluid. It is an indicator of the forces of attraction between the particles when the drilling fluid is in motion. According to Caenn et al. (2011), in practice, the YP is used to evaluate the performance of the drilling fluids, indicating the need for some maintenance treatment when it presents difficulties to the displacement. The YP is sensitive to the electrochemical environment, as it indicates the force of attraction between the particles, and therefore indicates the need for a chemical treatment when necessary.

Although Silva (2003) affirms that addition of solids, breaking of solids into smaller pieces, introduction of contaminants, inadequate chemical treatment and instability at temperature may increase the flow limit, this parameter did not present a clear pattern in the analyzed fluids.

When comparing the fluids with EBO and Liomul, it is possible to observe that, in the majority of the results, lower values of YP were found for the commercial emulsifier. It occurs probably because of a better affinity of this emulsifier with the other additives of the fluids.

Results of balanced YP, that is, within the desired values as found, lead to ease of return of the circulation in the well and cleaning efficiency of this well.

According to Silva (2003), the gel strength of a fluid is a measure of the tension required to initiate the movement of a fluid at rest. These measurements are usually known as the initial gel strength (10 seconds stopping) and the final gel strength (ten minutes stopping). High gel strength can result in the difficulty of lowering electrical or similar tooling tools, loss of drilling fluid when the tool is lowered into the well and gas and fluid inlets, the latter two occurring due to the high pressure exerted by the tool and, consequently, by the fluid that eventually fractures the rock.

It is observed in the results of this research that the majority of the values found is of a gel strength equal to zero, which characterizes a flat gel. According to Hyne (2014), this phenomenon, flat gel, is desirable for drilling fluids and common in base oil fluids and inverted emulsion, since they are used at great depths, in which gel strength does not become important, since the fluid column is very extensive and if the fluid gels, the force required to start the flow would have to be very high, compromising the well.

When comparing the results obtained for fluids with both emulsifiers, GS does not vary with the additive used.

In general, an increase in rheological parameters (AV and PV) was observed when increasing the organophilic clay content from 2 to 3 grams, which is in accordance with the viscosifying character of this additive.

The results of electrical stability are shown in Fig. 2.

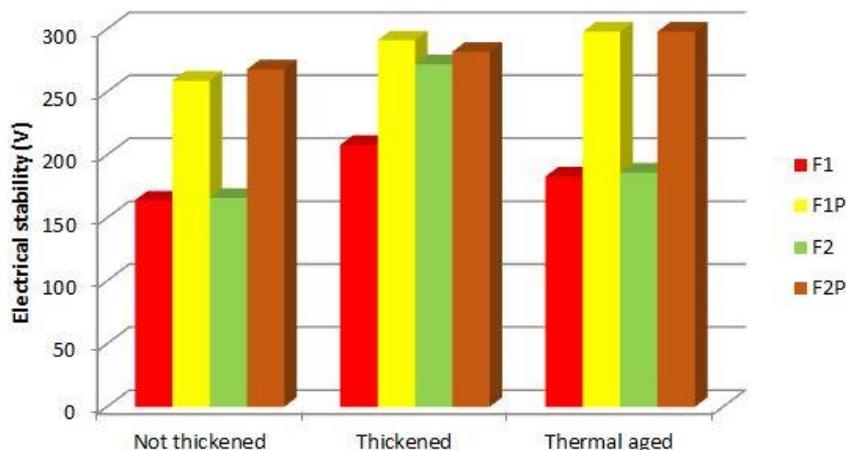


Figure 2. Electrical stability of studied fluids.

According to Perez (2008), the electrical stability parameter is the measure of the voltage required to initiate an electric current flow and is indicative of how strongly the water is emulsified in an organic base. Higher values indicate a stronger emulsion and, therefore, a more stable fluid.

As for the steps of the experiment, it is possible to observe a considerable increase in the parameter values after the addition of baritine, which can be explained by the secondary action of baritine as an emulsifier. The baritine, organophilic clays and the finely divided perforated solids themselves will help to stabilize the emulsion, since conveniently oil-wetted they will be absorbed at the interface between the water droplets and the continuous phase. After the treatment of thermal aging, in most cases, a decrease of ES values occurred. However, these still remain larger than the first ones obtained prior to the addition of baritine. This may occur due to the greater dispersion of the particles of the additive in the emulsion, minimizing the high concentration of the micelle interfaces.

As for the different formulations of the fluids, the increase in the amount of organophilic clay presented an increase in the electrical stability, which can be explained by the same mentioned reason of the addition of baritine.

It is observed better values of electrical stability for the fluids with Liomul commercial emulsifier, which means that it has a greater capacity of stabilization of the emulsion in relation to EBO. Nevertheless, the fluids with natural emulsifier presented values close to those required by the standards.

Electrical stability results within the desired range show a stabilized emulsion, with fewer tendencies to coalescence of the emulsified particles and thus phase separation, which results in a certainty that the water will not invade or react with the formation.

As for the filtration of fluids, this test is commonly performed only at the 3rd moment, i.e. after thermal aging, and the results of filtrate volume and percentage of water, signaled by H<sub>2</sub>O, are shown in Tab. 3.

Table 3. Results of filtration of studied fluids.

Fluids	FV	
	3° (mL)	H <sub>2</sub> O (%)
F1	5,7	0,0
F1 <sub>P</sub>	4,5	0,0
F2	5,8	0,0
F2 <sub>P</sub>	6,5	0,0

The evaluation of the volume coming from the filtration process results in one of the most important parameters for the study of an emulsifier, since this one directly evaluates the stability of the emulsion, because the more stable the less volume of filtrate and water in it will result from this emulsion. According to Moreira et al. (2007), the value of FV is directly related to the volume of fluid that invades the formation, under certain conditions of temperature and pressure.

As for the fluid formulation, the organophilic clay content showed no appreciable interaction with this parameter, showing only a minor increase with the increase of the additive amount.

It is possible to observe that most of the values found for the studied fluids vary minimally, so these fluids present results very close to this parameter.

And lastly, it was possible to observe that the values found vary between 4 and 7 ml and has a percentage of water in filtrate of 0%, values that are within the specifications of the PETROBRAS standard EP-1EP-00011-A (PETROBRAS, 2011).

The results obtained in this parameter were highly promising, these results in a good stability of the emulsions, which hinders the separation of the phases during the use of the fluid.

#### 4. CONCLUSIONS

From the results observed in this study with different formulations of synthetic drilling fluids using the natural emulsifier or not, it is possible to conclude that: i) fluids with standard emulsifier and natural emulsifier showed the same tendencies with variation of viscosifier content, ii) the rheological parameters increased with the addition of organophilic clay, iii) the gel force measured classifies the fluid as a flat gel, iv) the increase in electrical stability with the addition in the amount of organophilic clay is due to the fact that although this additive is not primarily emulsifying, it ends up contributing to the stability of the emulsion, e v) all values of the parameters measured are within the standards imposed by Petrobras for the evaluation of an viscosifier to be used for synthetic drilling fluids.

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