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An Experimental Study on Usage of Hollow Glass Spheres (HGS) for Reducing Mud Density in Geothermal Drilling

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ABSTRACT

Drilling fluid is a fluid mixture that is used in oil, gas and geothermal drilling operations. Generating hydrostatic pressure, carrying cuttings to the surface and maintaining wellbore stability is essential for drilling fluid with its other important functions. For low pressure reservoirs, hydrostatic pressure of the drilling fluid should be low. To achieve that, mud density should be lowered. However, use of drilling fluids with higher density than required may fracture the formation and could cause partial or complete loss of drilling fluid into the formation that may cause serious problems. To obtain lower mud densities, methods such as air/dust drilling can be used or oil based muds can be preferred. But for environmental reasons and cost issues, HGS are a serious alternative. This study aims to find proper HGS type with a convenient composition in a water based mud.

In this study, hollow glass spheres (HGS) are used to obtain a density as low as 6.88 ppg which is much lower than the water density (8.33ppg). HGS are selected based on their pressure resistance and improved mud properties such as fluid loss, rheology, filter cake quality, pH and gelation. After selecting the proper HGS type, laboratory tests are conducted with different water based fluid systems such as KCl-Polymer mud, Polymer based mud and Flo-Pro with different concentrations of HGS. Polymer based mud with HGS at rating of 5000 psia showed the best performance in filter cake properties and carrying capacity. It is also tested at higher temperatures for geothermal wells and seen that HGS added lightweight drilling fluid also works well at higher temperatures. Polymer optimization for the selected drilling fluid with selected hollow glass spheres is conducted and particle size analysis is also in the content of this study.

1. INTRODUCTION

Drilling low pressure reservoirs have always been a difficulty for drilling industry. Low pressured reservoirs with low permeability and depleted zones are hard to drill in terms of technical difficulties and higher costs. The necessity for lightweight drilling fluids emerges for that reason. Drilling low pressure reservoirs with low permeabilities and depleted wells require lower density drilling fluids. Mud densities higher than stated limits could cause partial or total losses of the drilling fluid, increase in drilling costs due to extended drilling time, fracturing the formation and possible formation damage.

Having mud weights lower than pure water (Specific Gravity: 8.33 ppg) may be achieved in limited ways. Air/dust drilling and of Oil Based Mud (OBM) drilling are two possible options. Adding Hollow Glass Spheres (HGS) to the drilling fluid is a new concept in petroleum industry but a serious alternative for achieving low densities. HGS is used as a density reducing agent in drilling fluids to have lighter mud weights. The material is stable, incompressible and virtually insoluble in water or oil. It has a high strength to weight ratio which derives survivals in high pressure downhole conditions. HGS's density differs from 0.38 g/cc to 0.42 g/cc depending on its pressure resistance and its particle size changes between 15 µm to 135 µm. These are unicellular hollow spheres that have a composition of Pyrex-like soda-lime-borosilicate glass. The practice of using HGS to reduce the density of drilling fluids has become more important due to increasing demand for 'hydrostatic pressure management' with high performance low density fluids.

In this study, performances of water based muds at a density of 6.88 ppg with different hollow glass spheres are evaluated in terms of fluid loss, filter cake quality, pH, gelation and rheological properties. Mud densities as low as 6.88 ppg are achieved in different water based muds. Since maximum pressure to be encountered in the well is expected to be lower than 5000 psi, HGS5000 (5000psi) and HGS8000X (8000psi) are tested with KCl/Polymer, Polymer based and Flo-Pro muds with different HGS concentrations to reduce mud density to target density. After selecting the proper HGS type with the proper water based mud; optimization for polymers, bridging materials and PHPA are conducted in terms of drilling fluid properties. After selecting the WBM and HGS, the composition is also tested for high temperatures. Tests are conducted after 16 hours hot-roll for geothermal wells. Particle size analysis of the HGS: Dry and wet sieve analyses are conducted. For applications in the field, its storage and mixing methods are also studied.

2. EXPERIMENTAL PROCEDURE

The chemicals that the drilling fluids have are prepared following API Spec 13A with Precisa Electronic Balance. Each chemical is added to distilled water in 1± 0.1 minute and mixed for 3±0.1 minutes with Multi Mixer to ensure homogenity. Multi Mixer works at a rate of 11500±500 rpm (Model 9B with 9B29X impellers, API Spec 13A**).** After preparing the base fluid, mud density is measured in each composition. To decrease the mud density to 6.88 ppg, 3M- excel sheet which is the product of 3M Company is used for HGS5000 and HGS 8000X. It calculates the amount of HGS should be added to base fluid to achieve desired density by formulating base fluids' and HGSs' density.

After preparing the base fluid, Hollow Glass Spheres (HGS) are added to the drilling fluid. Since HGS are light and flyer materials, they do not mix with the drilling fluid by Multi Mixer as figured in Figure 3. Firstly, HGS is added to the drilling fluid and mixed with a spatula until the mixture become homogenous. After that, the mixture is mixed with Multi Mixer for five minutes. After preparing the hollow glass sphere added based light weight drilling fluid, physical and chemical tests are conducted.

2.1 Mud Density Measurement

Mud density is measured with mud balance according to API RP 13B-1 / ISO 10414-1 Mud Weight (Density). Before measuring it, air in the chamber is removed carefully.

2.2 Rheological Properties & Gel Strengths

Rheological properties are measured with Fann Viscometer according to API RP 13B1 Direct Indicating Viscometer. Measurements are carried out at 120ºF. Mud is heated on Fann Viscometer Cup. Plastic viscosity (PV) and yield point (YP) values are calculated. After recording rheologies, samples are stirred for 15 seconds at 600rpm and motor is shut for 10 seconds and 3 rpm readings are recorded. This value is called 10 second gel strength. And also the readings for 10 minute gel strengths are also recorded with the same procedure only waited for 10 minutes instead of 10 seconds.

2.3 Fluid Loss & Filter Cake Analysis

Fluid loss and filter cake analyses are conducted following API RP 13B-1/ISO 10414-1, Low-Temperature/Low-Pressure Test. Fluid loss is measured by applying 100 psi pressure to the drilling fluid for 30 minutes. After removing the mud from the cell and cleaning the filter cake, interpretations about the thickness, quality and permeability is conducted.

2.4 pH Measurement

The pH of a solution is a measure of its hydrogen ion concentration and is measured directly from the mud with a pH meter according to API RP 13B-1.

2.5 Particle Size Analysis

Particle size analyses are performed with Ro-Tap Sieve Shaker. Both dry sieve analysis and wet sieve analysis are conducted according to ASTM STP 447-B.

2.6 Conditioning

Conditioning is carried out with conditioning cells and roller oven. The samples are kept in roller oven for 16 hours and tested afterwards for high temperature measurements.

3. RESULTS

To achieve the target mud density of 6.88 ppg, two types of Hollow Glass Spheres (HGS) are tested with different types of water based drilling fluids. HGS5000 and HGS 8000X are tested with three types of water based muds. Elimination method is used in these laboratory tests, firstly water based mud is selected, afterwards proper HGS type is determined and optimization is done on the selected drilling fluid.

3.1 Selection of Water Based Mud (WBM)

Three types of water based muds are tested. 6.88 ppg mud density is achieved with different types of muds and different types of hollow glass spheres in every composition. Calcium carbonate which is one of the most commonly used bridging agent in non-damaging drilling fluids since it dissolves in hydrochloric acid is tested in each WBM. Calcium carbonate used in these tests is fine size calcium carbonate.

- Flo-Pro
- KCl/Polymer
- Polymer Based

<u>3.1.1 Flo-Pro</u>

Flo-pro which is the drill-in fluid of M-I Swaco Company has two different compositions. One composition is with the bridging agent calcium carbonate ($CaCO_3$) and one that does not. Flo-Pro is tested with 2 different combinations to achieve a 6.88 ppg mud density. Volumes of the HGS added are calculated with respect to 3M-HGS excel sheet. The amounts of HGS added differ because of different $CaCO_3$ concentrations. Since $CaCO_3$ is a bridging and weighting agent, the fluid with $CaCO_3$ has a density higher than the one without $CaCO_3$. Rheological properties of flo-pro drilling fluids are high, but the parameters of the compositions which have 15 ppb $CaCO_3$ is higher than the other compositions. Yield points are above the limits. Viscosities of both drilling fluids are high. Optimum pH range of Flo-Pro mud is lower than conventional water based muds. Addition of hollow glass spheres (HGS) decreases pH slightly in both drilling fluids. Fluid losses of flo-pro drilling fluids are above 100 cc and both filter cakes are weak and thick. Plastic viscosity (PV) and yield point (YP) values are also higher in both HGS compositions than the base fluids. HGS8000X behaved as a solid material when mixed with $CaCO_3$. Gel strengths of flo-pro drilling fluids are not so aggressive and easy to break.

<u>3.1.2 KCl/Polymer Mud</u>

In this section; 5% KCl concentration which is equal to 18.1 ppb KCl concentration is examined with HGS5000 and HGS8000X. 5% KCl/Polymer mud have tested in 2 different compositions. One composition is with the bridging agent Calcium carbonate ($CaCO_3$) and one that does not. Calcium carbonate used in these tests is fine size calcium carbonate. In every combination, mud densities close to 6.88 ppg are achieved. In the composition with HGS5000; fluid loss decreased compared to its base fluid due to the fact that hollow glass spheres behave as a bridging agent and reduce fluid loss. For the composition with HGS5000 without

$CaCO_3$; fluid loss increases compared to its base fluid. Fluid loss of the combination with HGS8000X is 47 cc and has a very thick and weak filter cake. Combination with HGS8000X without $CaCO_3$'s fluid loss is 12.4 cc and higher than the Base Fluid-2. Both fluid losses are above acceptable limits for a drilling fluid. Rheological properties of the composition with HGS5000 are reasonable. But for the composition with HGS5000 without $CaCO_3$, rheological properties are very high. 70 cp plastic viscosity shows that HGS behave as a solid material in that composition and 40 lb/100ft2 yield point is also high. Plastic viscosity and yield point values of both fluids including HGS8000X increase sharply with respect to its base fluids. Gelation is not observed. 10 seconds and 10 minutes gel strengths are in the limits. pH slightly decreases in both combinations with respect to their base fluid.

3.1.3 Polymer Based Mud

Polymer based muds are different from KCl/Polymer muds in terms of not containing any type of salts. For that reason mud density of the base fluids are lower than the compositions that contain any type of salt such as KCl, NaCl etc. Polymer based mud is also tested with 2 types of hollow glass spheres namely HGS5000 and HGS8000X. 6.88 ppg mud densities are achieved in all compositions. Gelation does not occur in polymer based drilling fluids. In HGS5000 added drilling fluids, fluid losses decrease with respect to its base fluids. Both HGS5000 added compositions' fluid losses are low and they have good quality filter cakes. Composition with HGS5000 and $CaCO_3$'s filter cake has the best properties: impermeable, thin and strong. The bridging agent-$CaCO_3$ and HGS5000 give the best results. Detailed tests for seeing the effect of $CaCO_3$ is conducted in the $CaCO_3$optimization section. Fluid loss of the HGS8000X added composition's fluid loss decreases from 100 cc to 17.5 cc with respect to its base fluid since there is no bridging agent in the first composition. HGS8000X behaves as a bridging agent but still fluid loss is high, its filter cake is thick and weak. For the composition with HGS8000X which contains calcium carbonate as a bridging agent, addition of HGS8000X increases fluid loss. Rheological properties of drilling fluids increase after adding HGS but in terms of plastic viscosity and yield point, test results are good. It shows that hollow glass spheres behave as a solid material in drilling fluid but yield point doesn't increase very much.

3.2 Selection of Hollow Glass Sphere (HGS)

After conducting tests with 3 types of water based muds, performance of HGS5000 and HGS8000X are compared in terms of mud properties. Each water based mud has 2 different combinations as tested with calcium carbonate and without calcium carbonate. To obtain high performance in terms of physical and chemical mud properties; fluid loss, plastic viscosity, yield point and gel strengths of different type of water based muds are compared. HGS5000 is an engineered hollow glass sphere that has a pressure resistance of 5000 psi. It has a density of 0.38 g/cc. It is tested with 3 types of water based muds to lower mud density and obtain high performance mud properties. Along with mud densities and rheologies, the bridging effect of the material is inspected in terms of fluid loss values and filter cake properties. HGS8000X is another type of hollow glass sphere which has a pressure resistance up to 8000 psi. Its density is higher than HGS5000 and its particle size diameter is lower than HGS5000. HGS8000X is also tested with different types of water based muds to achieve a mud density of 6.88 ppg and proper physical and chemical mud properties. Fluid loss comparisons are made to see the behavior of different hollow glass spheres in 3 different water based mud types. HGS5000 has lower fluid losses than HGS8000X in all combinations. In Flo-Pro mud, fluid losses for HGS8000X are both very high without and with calcium carbonate ($CaCO_3$) concentrations respectively 140cc and 120cc. In 5% KCl/Polymer mud and Polymer based mud, HGS5000 behaves as a bridging agent and lowers fluid losses both combinations with and without calcium carbonate ($CaCO_3$). HGS8000X's fluid loss values are high in comparison with HGS5000. Plastic viscosity (PV) of both Flo-Pro concentrations increase with addition of hollow glass spheres. HGS8000X's plastic viscosity values are higher than of HGS5000's. For 5% KCl/Polymer mud and Polymer based mud, plastic viscosity also increases with addition of both hollow glass spheres but plastic viscosity does not go above 41 cp in 5% KCl/Polymer and Polymer based muds which is acceptable. The rheological properties of Flo-Pro mud are very high. Yield point values of Flo-Pro mud with HGS5000 and HGS8000 compositions without calcium carbonate are respectively 77 and 84 lb/100ft2. For Flo-Pro mud with calcium carbonate, yield point values of HGS5000 and HGS8000X are respectively 99 and 98 lb/100ft2. For polymer based mud tests, HGS8000X's yield point values are slightly lower than HGS5000's in combinations with and without calcium carbonate. All four values are in the acceptable range. Hollow glass spheres cause gelation in different rates. For Flo-Pro mud, gel strengths of the base fluid are high and with addition of hollow glass spheres 10 seconds and 10 minutes gel strengths become aggressive and have an increasing trend. Gel strengths of 5% KCl/Polymer mud and polymer based mud with hollow glass spheres are not aggressive and easy to break. By interpreting the test results, it can be said that HGS5000 shows better performance than HGS8000X in terms of physical and chemical mud properties namely: fluid loss, plastic viscosity, yield point and gel strength.

3.3 Sieve Analysis of HGS5000

Sieve analysis is performed to see the behavior of HGS5000 in the solids control equipment namely shaker screens in the field operations. Two types of sieve analysis; wet sieve analysis and dry sieve analysis of HGS5000 are carried out following ASTM STP 447-B. Dry sieve analysis is conducted with 100, 120 and 200 mesh size sieves. Residue greater than 100 mesh and 120 mesh size sieves are 0%, residue greater than 200 mesh is 3.11%. It can be said that 120 mesh, 100 mesh and lower size sieves are appropriate to use in the field operations while using a drilling fluid having HGS5000. Wet sieve analysis of HGS5000 is carried out. Test is conducted with 200 mesh and 325 mesh size sieves. It is seen that residue greater than 200 mesh and 325 mesh size sieves are 7.65% and 37.3% respectively. As a result of dry and wet sieve analyses, it is concluded that sieves above 120 mesh are not applicable to HGS5000. For field applications, shaker screens lower than 120 mesh is recommended.

3.4 Optimization of Selected Drilling Fluid

After selecting the drilling fluid as polymer based mud and selecting hollow glass sphere type as HGS5000, optimization on the selected drilling fluid is conducted to achieve higher performance in low density drilling fluids in terms of chemical and physical properties. In this section; $CaCO_3$ optimization, polymer optimization and PHPA optimization are presented. Elimination method is used in every part, 3 different concentrations are tested.

3.4.1 $CaCO_3$ Optimization

Bridging material used in all tests is calcium carbonate ($CaCO_3$). In this section optimization of calcium carbonate amount is performed. In these tests fine size calcium carbonate are used. 5ppb, 10ppb and 15ppb concentrations are tested. The amount of calcium carbonate is determined. The amount of HGS5000 added to the drilling fluids differs due to different base fluid mud densities. The amounts of HGS5000 added to the drilling fluids are calculated with respect to 3M-HGS5000 excel sheet. Plastic viscosity does not change depending on calcium carbonate amount. Plastic viscosities of 5ppb, 10ppb and 15ppb are respectively: 38 cp, 37 cp and 38 cp which are not very high. Yield point also does not change with $CaCO_3$ amount change. Yield points of 5ppb, 10ppb and 15ppb are respectively: 15 lb/100ft2, 13 lb/100ft2 and 16 lb/100ft2. Change in yield points is because of measurement uncertanities and heterogenity. Fluid loss is the essential parameter on choosing the amount of $CaCO_3$ to be used. 5ppb $CaCO_3$ composition has a 7.5cc fluid loss which is above acceptable limits and its filter cake is thick and permeable. Fluid losses of 10ppb and 15ppb compositions are 3.9cc and 6.5cc respectively. Eventough, in theory increasing bridging material leads to decrease in fluid losses, it differs in laboratory tests. 10ppb $CaCO_3$ composition has the lowest fluid loss of 3.9cc and has the best filter cake. The filter cake of 15ppb $CaCO_3$ composition is also strong and impermeable but thicker than 10ppb $CaCO_3$ composition's. That's why 10ppb is the optimum amount of $CaCO_3$ as a bridging material.

3.4.2 Polymer Optimization

After selecting hollow glass spheres (HGS) and water based mud, optimization of polymer concentration is carried out. 7 ppb (4 ppb Pac-Lv + 3 ppb Modified Starch) is used on the tests for HGS and drilling fluid selection. In order to find the optimum polymer concentration, different compositions such as 11 ppb (6 ppb Pac-Lv + 5 ppb Modified Starch) and 3.5 ppb (2 ppb Pac-Lv + 1.5 ppb Modified Starch) are tested. Fluid loss of 3.5 ppb (2 ppb Pac-Lv+ 1.5 ppb Modified Starch) polymer concentration is higher than other two compositions. 7 ppb (4 ppb Pac-Lv+ 3 ppb Modified Starch) and 11 ppb (6 ppb Pac-Lv+ 5 ppb Modified Starch) polymer concentrations give similar results in terms of fluid loss. 600 rpm reading of 11 ppb (6 ppb Pac-Lv+ 5 ppb Modified Starch) polymer concentration is above 300 and could not be read exactly. For plastic viscosity (PV) and yield point (YP) calculations, 600 rpm reading is recorded as 300. Gel Strengths of 11 ppb (6 ppb Pac-Lv+ 5 ppb Modified Starch) polymer concentration is also higher than other two compositions as figured in Figure 5.10. The excess usages of polymers cause gelation. 7 ppb (4 ppb Pac-Lv+ 3 ppb Modified Starch) and 3.5 ppb (2 ppb Pac-Lv+ 1.5 ppb Modified Starch) concentrations have similar 10 seconds and 10 minutes gel strengths and they are not too aggressive. Plastic viscosity (PV) increases with increasing polymer concentration. Eventhough PV values of 7 ppb (4 ppb Pac-Lv+ 3 ppb Modified Starch) and 3.5 ppb (2 ppb Pac-Lv+ 1.5 ppb Modified Starch) concentrations which are 37 cp and 26 cp respectively are reasonable, 78 cp of 11 ppb (6 ppb Pac-Lv+ 5 ppb Modified Starch) concentration is very high. Higher polymer concentrations affect rheological properties of drilling fluid. 11 ppb (6 ppb Pac-Lv+ 5 ppb Modified Starch) concentration has a yield point (YP) of 144 lbs/100ft2. Other two compositions have similar YP values and fine flow properties physically. In the light of these interprets, polymer concentration of the base drilling fluid is determined as 7 ppb (4ppb Pac-Lc+ 3ppb Modified Starch).

3.4.3 PHPA Optimization

PHPA which is an acrylic copolymer is a dispersible additive used for cuttings encapsulation, shale stabilization and micro fracture sealing. It is commonly used in drilling of shale and clay based formations where shale stabilization is an issue. Fluid loss values increase with increasing PHPA concentration. As the capacity for holding cuttings on suspension increases, settling rate decreases and it reduces the quality of filter cake. Plastic viscosity increases sharply due to increase in PHPA concentration. 1.5 ppb PHPA concentration has a PV value of 111 cp which is way above acceptable limits. 10 seconds and 10 minutes gel strengths of base fluid and 0.5 ppb PHPA concentration are even and 3 and 4 respectively. Gel strengths of 1 ppb PHPA concentration are also fair and 6 and 7 respectively but gel strengths of 1.5 ppb PHPA concentration is high; numerically 11 and 14 and tends to be more aggressive. The need for PHPA in a low pressure reservoir is not important and laboratory test results show that different concentrations of PHPA cause increase in plastic viscosity and gel strength. PHPA is not efficient in low density drilling fluids according to laboratory test results. Not only it affects the chemical properties, but also affects the flow of the drilling fluid physically.

3.5 Results after Hot Roll

Selected drilling fluid is tested after hot roll procedure at 150ºF for 16 hours to see the behavior of the fluid at higher temperatures for geothermal wells. Mud density is measured as 6.88 ppg as it is on the selected drilling fluid. Rheological properties of the selected drilling fluid with hollow glass spheres (HGS) increase after hot-roll procedure slightly. Plastic viscosity and yield point values increase from 37 & 13 to 43 & 19 respectively as seen in Table 1 and Table 2. Despite the slight increase, rheological properties of the selected drilling fluid is still in the acceptable limits and convenient to use in the geothermal fields. Gelation is not observed after hot-roll, 10 seconds and 10 minutes gel strengths are 4 & 5 respectively as seen in Table 2. Fluid loss value increases after hot-roll from 3.8cc to 6.8cc and filter cake thickness increases. Even though fluid loss value increases, it is still convenient to use at higher temperatures at vertical geothermal wells.

4. CONCLUSION

During this study, performance of light weight drilling fluids which contain hollow glas spheres (HGS) is examined. Different water based muds with different types of HGS are tested. The results are interpreted and the following conclusions are drawn from the study:

- Water based mud is selected between Flo-Pro, KCl/Polymer and Polymer based muds with tests carried out both HGS5000 and HGS8000X. Polymer based mud is seen to be the best option in terms of chemical and physical properties.
- Since the base fluid density of KCl/Polymer mud is higher than Polymer based mud, the amount of HGS needed to achieve 6.88ppg is higher. Laboratory tests show that, homogenity of the drilling fluid affects the test results sharply. It is seen that; as the amount of HGS in the drilling fluid increases, homogenity of the drilling fluid decreases thus its mud properties do not fulfill the necessities.

- Polymer based mud without potassium chloride (KCl) gives the best result in terms of fluid loss, filter cake properties, rheological properties and gelation. Its filter cake is strong, impermeable and thin. Rheological properties do not increase too much. 10 second and 10 minute gel strengths do not increase aggressively.

- Hollow glass sphere (HGS) selection is made. As the pressure in the well to encounter is lower than 5000 psi, pressure resistances of HGSs are higher than 5000psi. HGS5000 and HGS8000X are tested with different water based muds.

- Even though HGS8000X is more resistant to pressure than HGS5000; muds with HGS8000X do not fulfill the necessities. Especially, fluid losses are much higher with HGS8000X in every water based mud composition. Filter cake thicknesses are measured and qualities are observed. Compositions with HGS5000 has lower filter cake thicknesses and it is selected as the optimum HGS.

- Different amounts of calcium carbonate are tested with the selected drilling fluid. It is seen that from some point, increasing the calcium carbonate ratio does not lower the fluid loss. 10 ppb $CaCO_3$ gives the best fluid loss and best filter cake.

- Distinctly from mixing chemicals in conventional methods to the drilling fluid. HGS need more attention to be mixed. Since the material is light and flyer. Homogeneity should be ensured. The mixture of HGS and drilling fluid should be stable.

- In field applications; proper working pits, good mixing equipment, subsurface guns and air pumps are needed to ensure the homogeneity of drilling fluid.

- It is seen that performance of the selected drilling does not change excessively after kept in roller oven for 16 hours at 150ºF.

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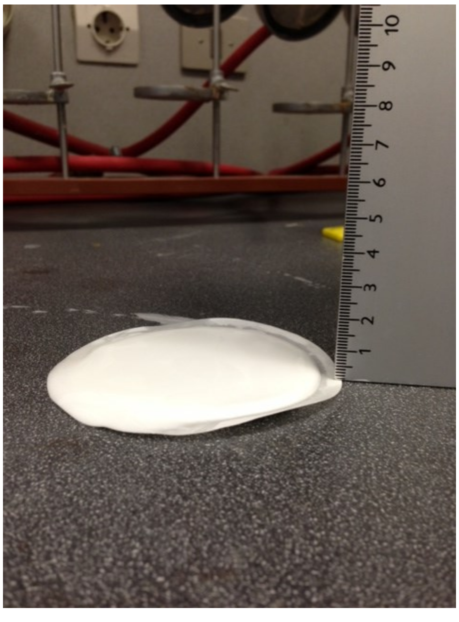

Figure 1: Filter cake of polymer based mud with HGS5000 and $CaCO_3$

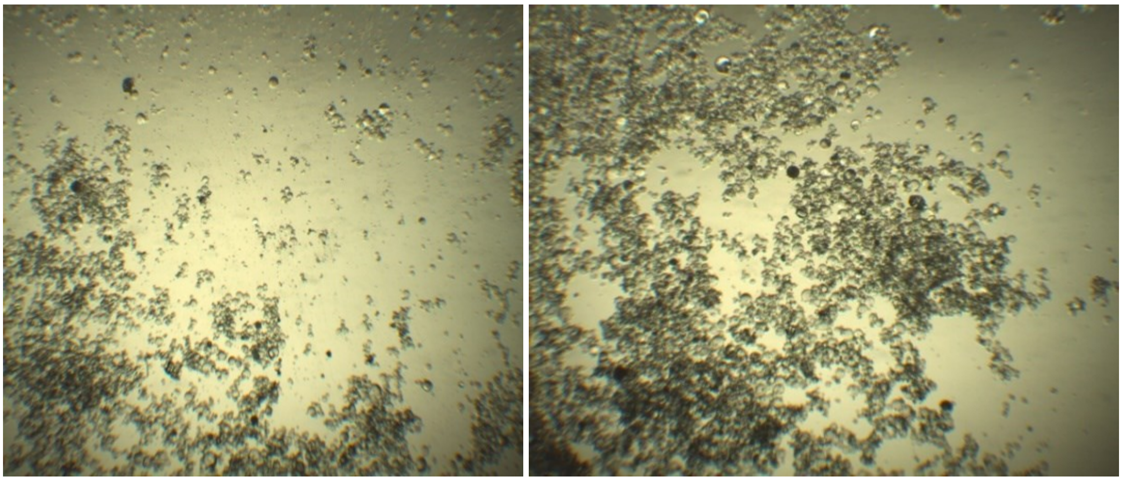

Figure 2: Microscopic image of hollow glass spheres (HGS)

Figure 3: Mixing of chemicals in Multi-mixer

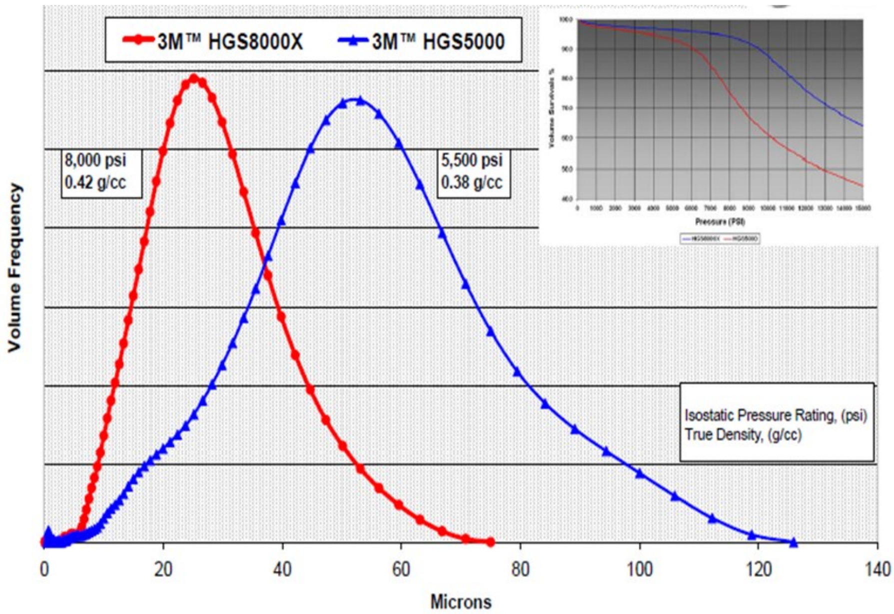

Figure 4: Comparison between HGS5000 and HGS8000X

Table 1: Test results of the selected mud

ADDITIVES	**TD*:6.88 ppg**
Water, cc	350
M. Starch, ppb	4
Pac-Lv, ppb	3
XCD, ppb	0.25
$CaCO_3$, ppb	10
NaOH, ppb	0.1
HGS5000, ppb	48.47
Volume of base fluid, bbl	0.84
Mud, cc	292.6
RESULTS	
600	87
300	50
200	36
100	21
6	3
3	2
pH	9.7
PV, cp	37
YP, lb/100ft^2	13
Gel Strength 10sec/10min	3/4
Fluid Loss, cc	3.8
Mud Density, ppg	6.88

* TD: Target Density

Table 2: Test results of the selected mud after hot-roll

ADDITIVES	**TD*: 6.88 ppg**
Water, cc	350
M. Starch, ppb	4
Pac-Lv, ppb	3
XCD, ppb	0.25
$CaCO_3$, ppb	10
NaOH, ppb	0.1
HGS5000, ppb	48.44
Volume of base fluid, bbl	0.84
Mud, cc	294
RESULTS	
600	105
300	62
200	46
100	27
6	4
3	3
pH	9.7
PV, cp	43
YP, lb/100ft^2	19
Gel Strength 10sec/10min	4/5
Fluid Loss, cc	6.8
Mud Density, ppg	6.88

* TD: Target Density