

Evaluation of Thermal Stability by Comparison of Potassium Chloride and Potassium/Sodium Formate Fluids

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Abstract

Formate drilling fluid is a new type of clean brine drilling fluid system which has been developed from inorganic salt brine drilling fluid system. Currently there are mainly three kinds of format: sodium format, potassium format and cesium format. The laboratory research was carried out to determine the thermal stability of drilling fluid. It was formulated using sodium and potassium format salts, potassium chloride. Formate base mud is solid free system. So, mud cake is thin and resilient, it is conducive to improve cementing quality greatly. Formate base fluids because of their low percent of solid settling. Moreover, the low amount of plastic viscosity these muds help to better hydraulic in the well and better hole cleaning. Hence, drilling penetration rate as an extremely parameter in economic costs are decreased. Environmental pollution of formate salts is dramatically less than recent salts like potassium chloride and sodium chloride. It can be appropriate replacement for these environmental polluted salts.

Keywords: Formate drilling fluid; Environmental pollution; Potassium format salts; Thermal stability

Abbreviations: WBM: Water-based mud; FBM: Format base mud; ROP: Rate of penetration; YP: Yield point lb/100 ft²; PV: Plastic viscosity cP; Pcf: Pound per cubic feet (lb/ft³).

Introduction

The new techniques were aimed at creating increasingly extreme well configurations and included long horizontal, extended reach, slim hole, through tubing and coiled tubing drilling. These drilling techniques needed solids-free drilling fluids that could minimize circulating pressure losses and ECD. The format brines provided the ideal basis for such drilling fluids, with the added advantage that they could also function as completion fluids. Further laboratory work over the past 15 years has clearly shown that the format brines in general have very good environmental properties, stabilize shales, inhibit hydrate formation, minimize corrosion, reduce well control problems and minimize formation damage. In short, they appear to be the ideal universal drilling and completion fluids that the oil industry needs in the 21st century [1,2].

Shale oil reservoirs

Hydrocarbon accumulations in petroleum reservoirs around the world migrated from very fine-grained, dark-gray or black organic-rich sedimentary source rocks, referred to as organic-rich shales. For decades, organic-rich shale formations have been regarded as source rocks from which hydrocarbons originated and migrated into sandstone and limestone of various reservoir qualities. Oil- and gas-prone shales form when massive amounts of organic debris deposition occur in swamps, lakes, marine environments, followed by rapid burial without decay [3]. Subsequently, over geologic time, these organic constituents convert into hydrocarbons under the effect of temperature and pressure changes in the subsurface due to burial. Thus, these organic-rich shales undergo the necessary geologic processes from digenesis to catagenesis to convert dead organic contents into useful hydrocarbons [4].

Shale oil and conventional oil reservoirs require different development strategies for economic oil recovery. Low permeability shale reservoirs require extensive hydraulic fracture stimulation

treatments at the onset of economic oil recovery [5]. On the other hand, conventional reservoirs have relatively good permeability, and therefore produce at economic rates without hydraulic fractures. Understanding petro physical and geo- mechanical properties is essential for optimum stimulation treatment of shale reservoirs.

Formate fluids

Format drilling fluid is a new type of clean brine drilling fluid system which has been developed from inorganic salt brine drilling fluid system. Currently there are mainly three kinds of format: sodium format, potassium format and cesium format. Compared with conventional drilling fluid, format drilling fluid is characterized by no bentonite slurry. It is the theoretical foundation that format drilling fluid can achieve strong inhibitory, and it is also the key to being better than conventional water base drilling fluid. Wang Yong sheng has studied the application effect of the format drilling fluid in Yingtai gas field in 2012. And this drilling fluid system has helped to protect the reservoir and save the exploration cost. Based on the previous research, this paper is studied for some new findings and applications [6].

Format has the characteristics of high solubility, high density, high pH value, low crystallization point. With the increase of alkali metal atomic weight, saturation concentration, saturation density and pH value become higher, and crystallization point becomes lower.

Through indoor study, the following features of formate have been found:

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(1) There is the function of stabilizing shale. Shale is equivalent to the selective semi-permeable membrane in the non-fractured low permeability shale formation ($K \leq 10 \times 10^{-3} \mu\text{m}^2$). In the high concentration brine, due to the low water activity, the osmotic pressure can promote the shale pore water reflux. This reflux will make formation stress and effective stress of near wellbore zone increase to stabilize borehole wall.

(2) Format has a good compatibility with the oilfield commonly used polymer, and can slow the speed of hydrolysis and oxidation degradation of many thickeners and filtrate reducers under high temperature and pressure [7-12].

Field Evaluation

The vertical well to be drilled was an exploration well that could provide information on potential reservoirs and lithological information of the field. No offset data was available on the well and the nearest well information was 80 km away. Geologist forecast from this well required drilling through reactive shales in member (A). Table 1 lists the interval parameters for drilling.

The objective was to drill a 8 1/2-in. hole section from 10900 ft through member (A), to the casing point at a measured depth (MD) of 12500 ft. A 7-in. casing string was then to be run and cemented. The FBM optimized for member (A) was expected to provide maximum shale stabilization and inhibition to achieve maximum ROP without any incidents such as tight hole, pipe stuck and hole filling.

Laboratory Procedure

In this test, rheological properties and potassium/sodium formate fluid reduction before and after the applying the temperature to the potassium chloride (KCL) are being compared. These two fluid formulations regarding to the used polymers and other component are the same and the only difference is in the type of using salt. Figures 1-3 show the rheological properties of formate fluid and potassium chloride samples before and after applying temperature up to 250°F during the time period of 16 hours.

The salt mud was then displaced with the FBM with a density of 80 pcf per the mud program. After the FBM was circulated and conditioned for 5 hours as bypass. Drilling was performed without any problem with formation loss 1-3 BPH until reaching MD 11270 ft, where mud making is no possible because of shortage format salts. To control this problem, pull out of string (POOH) was done and is decided to change mud formulation system with oil based mud for continuing drill the hole. Drilling time of interval from 10800 to 11270 ft that using Format based mud was about 70 hours.

As it can be seen in the Figure 1, the amount of apparent viscosity in the formate fluids is more than potassium chloride fluid. Noticeable parameter is that the amount of apparent viscosity reduction after

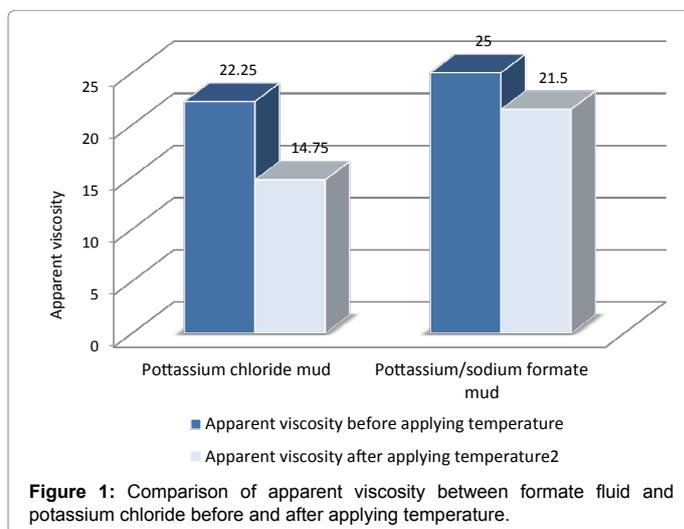


Figure 1: Comparison of apparent viscosity between formate fluid and potassium chloride before and after applying temperature.

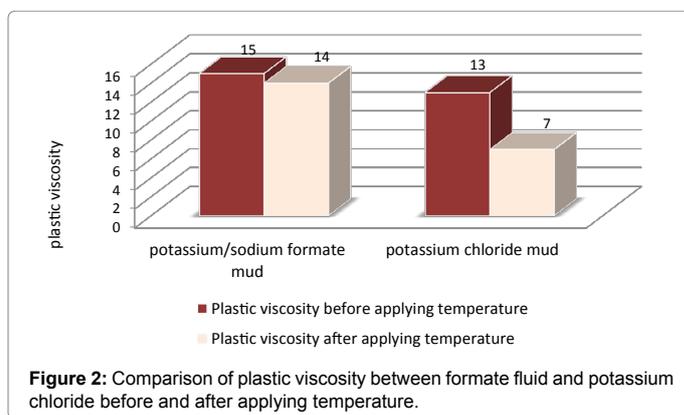


Figure 2: Comparison of plastic viscosity between formate fluid and potassium chloride before and after applying temperature.

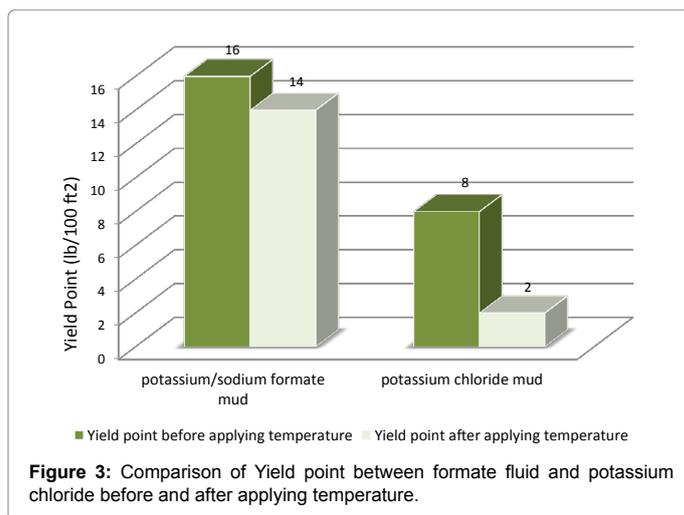


Figure 3: Comparison of Yield point between formate fluid and potassium chloride before and after applying temperature.

Interval parameters	
Formation Type	Member A compose of shale
Thickness interval depth	400 feet
Interval Hole size	8 1/2 inches
Fluid Type	Format based mud
Bit type	Mill Tooth bit
Nozzle size	3 × 16/32 inches
String Rotation speed (rpm)	100-130 rpm
Weight on Bit (WOB)	20-25 klb

Table 1: Interval parameters for drilling.

applying temperature in the formate fluid is less than potassium chloride fluid. In the other word, apparent viscosity of potassium chloride fluid after applying temperature has been reduced more. The apparent viscosity of mud systems with formate salts was maintained (50% of its original properties are retained), but in these cases without formate salts, the apparent viscosity was not maintained. It was observed that the desired rheological properties are obtained by using formate salt to

avoid of some problems in drilling operations such as filatures in rig pumps.

The thermal stability of mud systems were examined in the presence of potassium and sodium formate brines at aging condition. Figure 2 show the plastic viscosity of formate fluid and potassium chloride before and after applying temperature. As it can be seen in the Figure 2, the amount of plastic viscosity before applying temperature are the same. Even though, after applying temperature plastic viscosity of potassium chloride has a large reduction. Moreover in the formate fluid the loss of plastic viscosity is negligible.

Figure 3 show the yield point of formate fluid and potassium chloride before and after applying temperature. As it can be seen in the Figure 3, the amount of yield point after applying temperature has a noticeable reduction.

Figure 4 show the reduction level of formate fluid and potassium chloride before and after applying temperature. As it can be seen in the Figure 4, in spite of simultaneously formulation in terms of type and the amount of polymer that is used in the fluids combination, reduction level of formate fluid is less than potassium chloride.

Furthermore, it can be seen that amount of reduction level in potassium chloride fluid after applying temperature has increased dramatically. Although in formate fluid reduction level after applying temperature didn't have a shoot up and it relatively reached plateau. Thereby, it can be concluded that formate salts caused to increase the polymers and starch thermal stability and rose its efficiency in the high temperatures.

Figure 5 show the shale recovery for potassium/sodium formate fluid and potassium chloride fluid. As it can be seen in the Figure 5 the amount of shale recovery in the formate fluids are more than potassium chloride fluids. Therefore, it can be concluded that formate salts specially potassium formate have better shale stability than the other salts. In addition, environmental pollution of formate salts is dramatically less than recent salts like potassium chloride and sodium chloride. It can be appropriate replacement for these environmental polluted salts.

The possibility of using formate salts for the formulation of drilling mud had been investigated in experimental tests and field application. From the experimental results, the thermal stability of polymers in water based drilling fluid under aging condition was increased and the shale inhibition performance of drilling fluid was so close to oil-based drilling fluid that could effectively solve the problem of mud-making, bit balling, cuttings bed, tripping resistance, slow ROP and other issues.

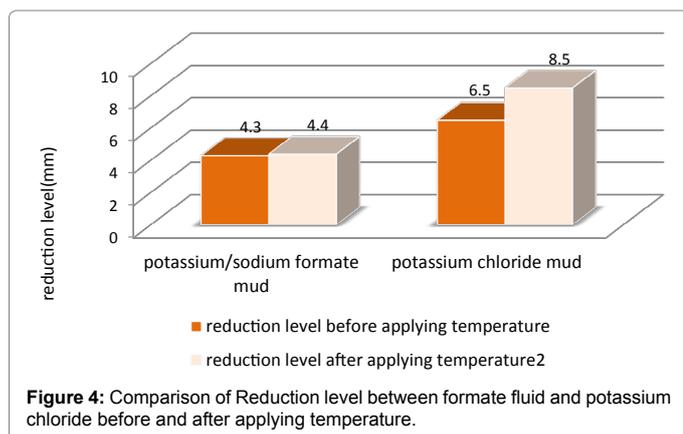


Figure 4: Comparison of Reduction level between formate fluid and potassium chloride before and after applying temperature.

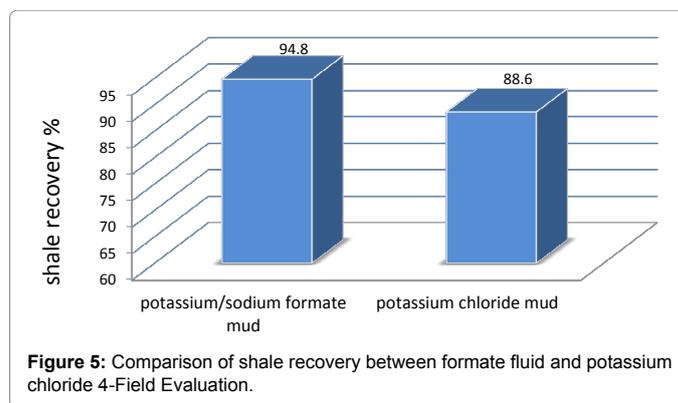


Figure 5: Comparison of shale recovery between formate fluid and potassium chloride 4-Field Evaluation.

The vertical well to be drilled was an exploration well that could provide information on potential reservoirs and lithological information of the field. No offset data was available on the well and the nearest well information was 80 km away. Geologist forecast from this well required drilling through reactive shales in member (A). Table 1 lists the interval parameters for drilling.

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Results and Conclusions

Results

- Apparent viscosity of potassium chloride fluid after applying temperature has been reduced more.
- After applying temperature plastic viscosity of potassium chloride has a large reduction. Moreover in the formate fluid the loss of plastic viscosity is negligible.
- The amount of yield point after applying temperature has a noticeable reduction.
- The amount of reduction level in potassium chloride fluid after applying temperature has increased dramatically. Although in formate fluid reduction level after applying temperature didn't have a shoot up and it relatively reached plateau.
- The amount of shale recovery in the formate fluids are more than potassium chloride fluids.

Conclusions

- The use of a format based drill fluid instead of salt based fluid allowed for beneficial modifications to the drilling practice with positive results:

(i) It exhibited superior hole-cleaning qualities throughout the interval and no significant drag was observed during drilling. It decreased the need for pills to assist with hole cleaning.

(ii) Flow rates could be increased from typical 350-400 gal/min to 450 gal/min because of the reduced frictional pressure losses of the format system.

(iii) It reduced the need for back reaming out of the hole for hole cleaning.

(iv) It achieved faster than expected penetration rates in total formation drilling time was achieved.

- It can be concluded that formate salts caused to increase the polymers and starch thermal stability and rose its efficiency in the high temperatures.
- Environmental pollution of formate salts is dramatically less than recent salts like potassium chloride and sodium chloride. It can be appropriate replacement for these environmental polluted salts.

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