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Experimental Evaluation of Temperature Effects on *Detarium microcarpum*, *Brachystegia eurycoma* and Pleurotus Biomaterial Mud

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Abstract

Three sets of drilling fluids were formulated from biomaterials such as *Detarium microcarpum*, *Brachystegia eurycoma* and Pleurotus. The laboratory measurements were carried out on plastic viscosity, yield point and fluid loss exposed at required temperatures and then evaluated. The field Polyanionic cellulose additive that is currently in use was also formulated and used as a control sample to biomaterial products. Xanthan gumpolymer on equal concentration was added to both muds. The three sets of muds comprises the one without weighting material and the ones weighted up with calcium carbonate and barite respectively for both biomaterial mud and Polyanionic mud were examined as per American Petroleum Institute Standard. The graphs of the rheological properties and fluid loss against temperature were plotted. It was shown from the plots that the yield point and plastic viscosity decreased with increase in temperature while fluid loss increased with increase in temperature for both biomaterial mud and Polyanionic mud. It was also shown from the tables that the plastic viscosity and yield point are slightly better than the Polyanionic mud but less active in fluid loss than the Polyanionic mud.

Keywords

Biomaterial Mud, Polyanionic Mud, *Detarium microcarpum*, *Brachystegia eurycoma*, Pleurotus

1. Introduction

Drilling fluid properties include both physical and chemical properties that define the degree of the effectiveness of the drilling fluid during drilling operations.

The drilling fluids properties include: mud weight, yield point, low shear rate yield point, plastic viscosity, fluid loss, gel strength, electrical stability, alkalinity and lubricity. The functions of drilling fluids that are dependent on these properties include:

Cuttings transportation along the wellbore annulus; Cooling and lubricating the bit and drill string; Maintaining sufficient hydrostatic pressure to withstand the borehole pressure; Being capable of suspending drilled cuttings and high gravity solids when the circulation is stopped; Depositing of impermeable filter cake on the wall of the wellbore; Transmitting hydraulic horsepower to the bit; Ability to remove cuttings under the bit to avoid smaller particles from adversely affecting the penetration rate, bit life and mud properties.

The temperature of the earth normally increases with depth and the heat emanating from the earth is transmitted to the surface [1]. Due to temperature and pressure effect, the rheology, visco-elastic and physical properties of the drilling fluids changes, and as a result, affects the performance of the drilling fluids. As formations are burned deep into the earth, their temperature will also increase. If the formations are totally sealed preventing escape of fluid then abnormal pressure will occur. The unstable flow of heat induced to the earth's core causes the subsurface temperature to increase with depth. Drilling mud, either oil or water base is most popular in the drilling program owing to their important functions required for a successful drilling operation. The failure of the drilling fluid as a result of factors such as elevated temperatures and pressures that limit tool, down hole equipment selection, down hole pressure determination, lost circulation, low penetration rates, acid gases, and compliance with safety and environmental regulations and in most cases contaminants can adversely impair its performance down hole and results in problems. The above factors are responsible for non-deliverability of the drilling fluids are known to have disrupted the flow properties and hence require a proper balance of mud properties under such high temperature conditions. Formulating a drilling fluid system that can adequately withstand drilling in high temperature environment is very challenging, but very often little attention is given to proper fluids design. Generally drilling into deeper formation requires drilling fluids that can withstand higher temperatures and pressures. The combined pressure and temperature effect on drilling fluid's rheology is complex. This provides a wide range of difficult challenges and mechanical issues that have negative impact on rheological properties when exposed to high temperature condition and contaminated with other minerals, which are common in deep drilling.

2. Literature Review

Generally, properly designed drilling mud should be able to perform some of the major functions that are aimed at efficient, economical and safe operation of the drilling program. Therefore, efficient monitoring and well formulation is important for a safe drilling program as the depth increases. Vasan and Gatlin, (1958) [2] of the University of Tulsa, Oklahoma, conducted experiment on effect of temperature on the flow properties of oil mud, and investigated that plastic viscosity and apparent viscosity decrease with temperature increase. Sinha (1961) [3] conducted related studies on the determination of the equivalent viscosity of drilling fluids under high temperature and pressure, and revealed that both temperature and pressure fervently affect the equivalent viscosity of oil based mud. Annis (1967) [4] reported that flow properties of water base mud samples were measure at temperature up to 300˚F. Plastic viscosity decreased with increase in temperature at reasonably same rate as the viscosity of water up to 225˚F; it then began to increase slowly, remaining almost constant till 300˚F. The effect on invert emulsion fluids is more significant than on water-based fluids. Barlett, L.E, (1967) [5] studied the effect of temperature and discovered significant decrease in viscosity (by half) of a particular ligno-sulfonate mud when its temperature was increased from 80˚F to 140˚F. Drilling fluid viscous behavior is a critical issue in the success of drilling operations, particularly for drill cuttings removal. The properties that drilling fluids should possess are appropriate viscosity, high-shear thinning behavior and a finite yield stress for suspending and transferring drill cuttings to the surface [6]. Nevertheless, the rheological characterization of these systems is not a trivial task because of the inherent heterogeneous nature of the system. The use of non-conventional geometries, such as helical ribbons and blade turbines, has become valuable tools for characterizing the viscous flow behavior of disperse systems, mainly due to the elimination of serious wall slip effects of apparent yield stress materials [7]. As expected, drilling fluid plastic viscosity always decreases with temperature [8], being its dependence very similar to that of the base oil. These results suggest that the viscous flow behavior of these fluids is largely governed by the viscosity of the base oil, as has been reported elsewhere [9]. The plastic viscosity depends on the viscosity of the liquid phase and the concentration and size of solids present. The solids present in the mud can be considered either active or inactive. Increasing the concentration by volume of solids in the mud can increase plastic viscosity of the mud. If the volume percent of solids remains constant, then reducing the size of the solids would also increase the plastic viscosity due to the increased surface area exposed. Plastic viscosity is also a function of the viscosity of the fluid phase. As the viscosity of the fluid phase decreases with increased temperature, the plastic viscosity will decrease proportionally [10]. Higher temperature may also increase the solubility of contaminants and, therefore, decrease the effective of filtrate loss control chemicals [11]. In addition, the colloidal fraction tends to flocculate and increase the filtration at elevated temperature.

3. Methodology

3.1. Processing of Biomaterial

The seeds of *Detarium microcarpum*, *Brachystegia eurycoma* and Preurotus were grinded separately using Hamilton grinder to powder form, dried in the sun for 24 hrs and finally re-grinded. The coarse powdered materials were sieved until the fine powder of each specimen was obtained.

3.2. Lists of Laboratory Equipment

The lists of some laboratory equipment are presented in Table 1 below.

3.3. Mud Formulations/Experimental Procedures

Table 2 shows mud formulations from biomaterial and the existing Polypac muds as shown in each column of the Table 2. There are three columns that consist of the un-weighted muds, low solids muds and the weighted muds. Column 1 has no weighting materials at all. Column 2 called low solids muds was weighted up with Calcium Carbonate of low specific gravity (2.6). Column 3 was weighted up with barite of high specific gravity (4.2). *Detarium microcarpum*, *Brachystegia eurycoma* are biomaterial viscosifiers while Pleurotus acts as biomaterial fluid loss additive. Polypac exists as both the viscosifier and fluid loss additive. XCD polymer and Caustic soda were added as viscosity supplement and alkalinity control respectively. Potassium chloride was also added for inhibition. Un-wighted muds, low solids muds and weighted muds of both the biomaterial and the existing polypac additives were prepared separately to 1 barrel of

Table 1. Laboratory equipment used.

API Filter Press
Hamilton Beach Blender
Hamilton Beach Mixer
No. 200 Sieve
Six speed Viscometer
Thermometer
2 (50 ml) Graduated Cylinders

Table 2. Un-weighted, low solids and weighted muds compositions.

Mud Compositions		
Un-weighted *Detarium microcarpum*, Brachstegeaeurycoma and Pleurotus Mud	Low Solids *Detarium microcarpum*, *Brachystegia eurycoma*, and Pleurotus Mud	Weighted Detariummicrocapium, *Brachystegia eurycoma* and Pleurotus Mud
Fresh Water 1 BBL Caustic Soda 0.25 ppb *Detarium m.* 3 ppb *Brachystegea e.* 3 ppb Pleurotus 3 ppb XCD Polymer 0.75 ppb	Fresh Water 1 BBL Potassium Chloride 10 ppb Caustic Soda 0.25 ppb *Detarium m.* 5 ppb *Brachystegea e.* 5 ppb Pleurotus 5 ppb XCD Polymer 1 ppb Calcium Carbonate 103.7 ppb	Fresh Water 1 BBL Potassium Chloride 10 ppb Caustic Soda 0.25 ppb *Detarium m.* 6 ppb *Brachystegea e.* 6 ppb Pleurotus 6 ppb XCD Polymer 1 ppb Barite 75.4 ppb
Existing Un-weighted Mud	Existing Low Solids Mud	Existing Weighted Mud
Fresh Water 1 BBL Caustic Soda 0.25 ppb Polypac 3 ppb XCD Polymer 0.75 ppb	Fresh Water 1 BBL Potassium Chloride 10 ppb Caustic Soda 0.25 ppb Polypac 5 ppb XCD Polymer 1 ppb Calcium Carbonate 103.7 ppb	Fresh Water 1 BBL Potassium Chloride 10 ppb Caustic Soda 0.25 ppb Polypac 6 ppb XCD Polymer 1 ppb Barite 75.4 ppb

fresh water as shown in the table. Each formulated sample was sheared for 1 hour. Laboratory measurements were conducted as per API standard. Fann six speed Model 35 A Viscometer was used to measure readings at 600 rpm, 300 rpm, 200 rpm, 100 rpm, 6 rpm, 3 rpm, at temperatures of 80˚F, 120˚F, 150˚F and 180˚F. These temperatures were controlled using thermostat. The filter press was used to measure the 30 minutes static fluid loss properties of un-weighted, low solids and weighted of both biomaterial and the existing muds. The obtained experimental results were used to make plots of the evaluated mud properties versus the temperatures and their relationships then deduced.

4. Results Analysis

4.1. The Viscometric and Fluid Loss Readings

The viscometric and fluid loss data as shown in Tables 3-5 were readings obtained from laboratory measurements for both rheology and API filtrate at the

Table 3. Viscometric and floss loss readings for un-weighted muds.

Constituents	Room temperature	120˚F	150˚F	180˚F
Proposed Mud	Fann Readings	Fann Readings	Fann Readings	Fann Readings
Fresh Water 1 BBL Caustic soda 0.25 ppb *Detarium m* 3 ppb *Brachystegia e* 3 ppb *Pleurotus* 3 ppb XCD Polymer 0.75 ppb	29, 19, 14, 10, 4, 3 Fluid Loss = 14 ml	24, 16, 13, 9, 3, 2 Fluid Loss = 15.6 ml	22, 15, 12, 9, 3, 2 Fluid Loss = 17 ml	21, 14, 11, 8, 2, 2 Fluid Loss = 18.5 ml
Existing Polymer Mud				
Fresh Water 1 BBL Caustic soda 0.25 ppb Polypac 3 ppb XCD Ploymer 0.75 ppb	26, 17, 13, 9, 3, 2 Fluid Loss = 12 ml	23, 15, 12, 9, 3, 2 Fluid Loss = 14 ml	21, 14, 11, 8, 3, 2 Fluid Loss = 14.3 ml	20, 13, 18, 8, 2, 2 Fluid Loss = 15.4 ml

Table 4. Viscometric and filtrate readings of low solids muds.

Constituents	Room Temp.	120˚F	150˚F	180˚F
Proposed Mud				
Fresh Water 1 BBL Potassium Chloride 10 ppb Caustic soda 0.25 ppb *Detarium m.* 5 ppb *Brachystegia e.* 5 ppb *Pleurotus* 5 ppb Calcium carbonate 103.7 ppb XCD Ploymer 1 ppb	Fann Readings 116, 87, 72, 52, 11, 9 Fluid Loss = 8.9 ml	Fann Readings 79, 59, 47, 34, 9, 8 Fluid Loss = 9.9 ml	Fann Readings 77, 57, 47, 33, 9, 8 Fluid Loss = 10.4 ml	72, 52, 40, 30, 7, 6 Fluid Loss = 11 ml
Existing Polymer mud				
Fresh Water 1 BBL Caustic soda 0.25 ppb Polypac 5 ppb XCD Polymer 1 ppb Potassium Chloride 10 ppb Calcium carbonate 103.7 ppb	106, 75, 62, 50, 10, 8 Fluid Loss = 7 ml	73, 52, 44, 32, 8, 6 Fluid Loss = 8.2 ml	70, 50, 42, 30, 7, 6 Fluid Loss = 8.8 ml	67, 47, 38, 28, 6, 5 Fluid Loss = 9.5 ml

Table 5. Viscometric and floss loss readings for weighted muds.

Constituents	Room temperature	120˚F	150˚F	180˚F
Proposed Mud				
FreshWater 1 BBL Caustic soda 0.25 ppb *Detarium m* 6 ppb *Brachystegia e* 6 ppb *Pleurotus* 6 ppb Potassium chloride 20 ppb XCD Polymer 1 ppb Barite 75.4 ppb	Fann Readings 95, 67, 56, 40, 9, 7 Fluid Loss = 8 ml	Fann Readings 86, 60, 50, 36, 7, 6 Fluid Loss = 9 ml	Fann Readings 75, 54, 44, 31, 6, 5 Fluid Loss = 9.8 ml	Fann Readings 64, 46, 37, 25, 6, 5 Fluid Loss = 11 ml
Existing Polymer Mud				
Fresh Water 1 BBL Caustic soda 0.25 ppb Polypac 6 ppb Potassium Chloride 20 ppb XCD Ploymer 1 ppb Barite 75.4 ppb	90, 62, 51, 37, 8, 7 Fluid Loss = 5 ml	81, 57, 46, 32, 6, 5 Fluid Loss = 6 ml	72, 51, 42, 30, 6, 5 Fluid Loss = 6.9 ml	60, 42, 36, 25, 5, 4 Fluid Loss = 7.5 ml

given temperatures, and Plastic viscosity and Yield point were calculated as shown in the appendix. Table 3 gave the plastic viscosity of 10 cP and 9 cP and yield point of 9 lbs/100ft^2 and 8 lbs/100ft^2 at room temperature for biomaterial mud and the polypac mud mud respectively. As the temperature increased from room temperature to 180˚F, the plastic viscosity of both muds decreased to 7 cP, and their yield point decreased to 8 lbs/100ft^2 and 6 lbs/100ft^2. Filtrate volume of 14 ml and 12 ml were also obtained at room temperature for biomaterial and polypac muds. As the temperature increased to 180˚F, their fluid loss also increased to 18.5 ml and 15.4 ml.

In Table 4, the plastic viscosity of 29 cP and 31 cP were obtained at room temperature for biomaterial and existing muds. As the temperature increased to 180˚F, the plastic viscosity of the two mud types decreased to 20 cP. The yield point decreased from 58 lbs/100 ft^2 and 44 lbs/100ft^2 at room temperature to 32 lbs/100ft^2 and 27 lbs/100ft^2. Both showed the same trend like in Table 3. There is a greater percentage decrease in both plastic viscosity and yield point from the room temperature to 120˚F API testing temperature for low solids muds than the un-weighted muds. The percentage increase in fluid loss due to temperature effect is better for polypac than biomaterial muds.

Table 5 show that the plastic viscosity is 28 cP for both muds at room temperature and the yield point of 39 lbs/100ft^2 and 34 lbs/100ft^2 for biomaterial and polypac muds. Both decreased to plastic viscosity of 18 cP, and yield point of 28 lbs/100ft^2 and 24 lbs/100ft^2 respectively. The fluid loss also increased from 8.9 ml and 7 ml to 11 ml and 9.5 ml for biomaterial and the polypac muds but polypac mud gave the lower percentage filtrate volume increase than biomaterial mud. The percentage reduction in terms of yield point and plastic viscosity due to temperature increased from room temperature to 180˚F are close in magnitude and similar in effect.

4.2. Effects of Temperature on Plastic Viscosity

Figures 1-3 show the effect of Temperature on plastic viscosity for un-weighted muds, low solids muds and weighted muds. As the temperature increased from

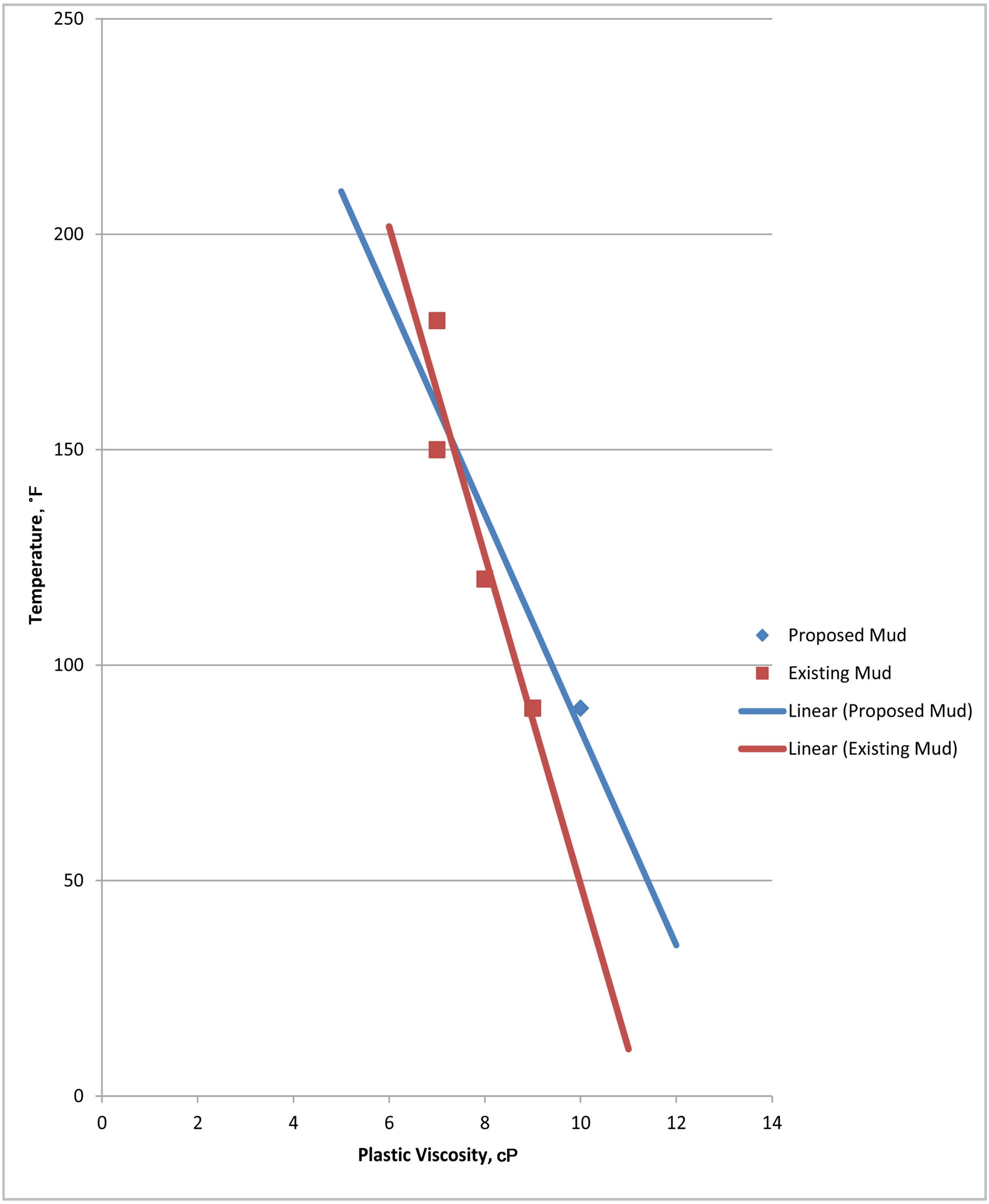

Figure 1. The effect of temperature on plastic viscosity for un-weighted and existing muds.

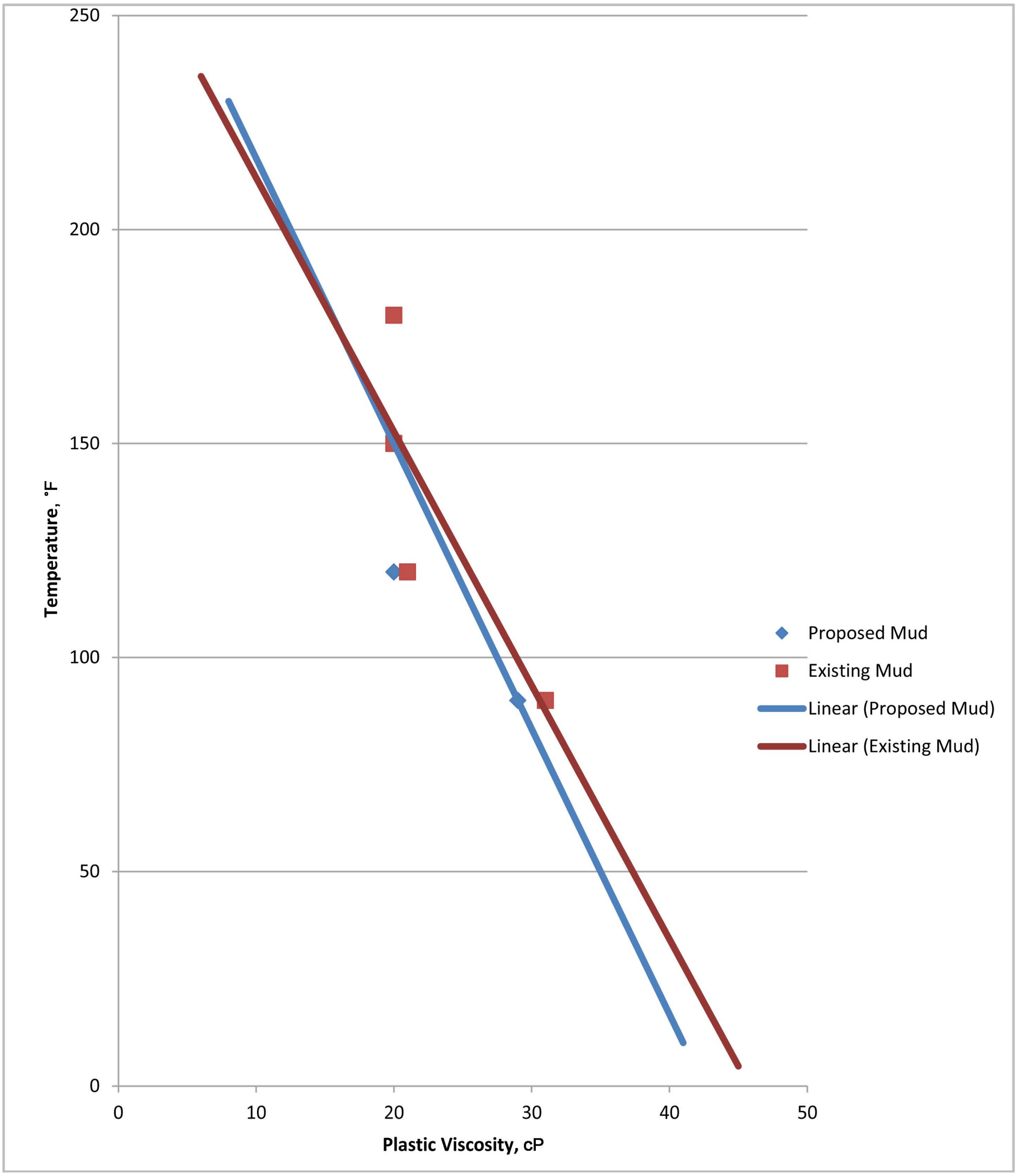

Figure 2. The effect of temperature on plastic viscosity for low solids biomaterial (proposed) and existing muds.

room temperature to 180˚F, the plastic viscosity which is the quantity and quality of solids present in the mud decreased thereby increased filtrate volume.

4.3. Effect of Temperature on Yield Point

Figures 4-6 show the effect of temperature on yield point for un-weighted

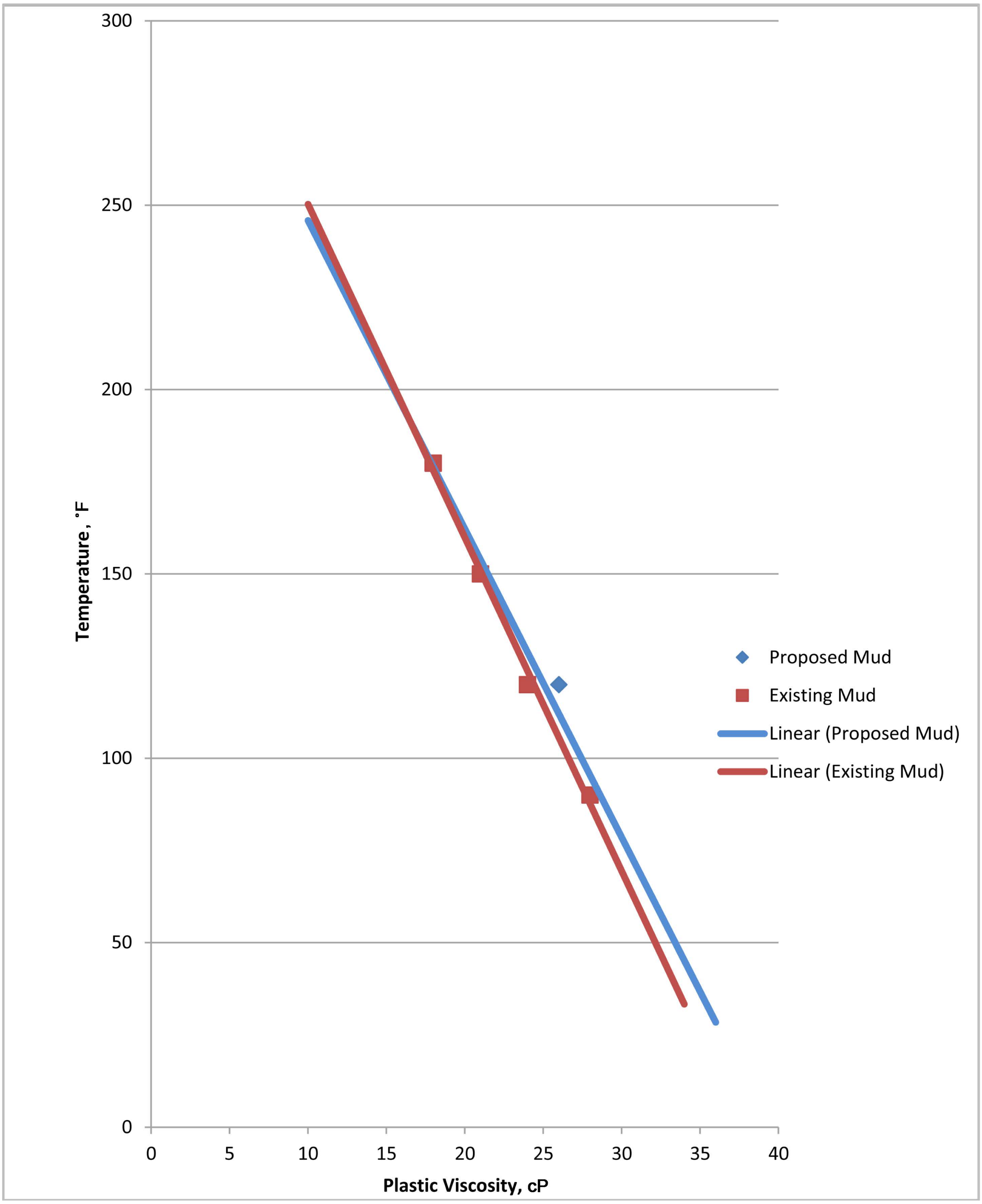

Figure 3. The effect of temperature on plastic viscosity for weighted biomaterial (proposed) and existing muds.

muds, low solids muds and weighted muds. As the temperature increased from room temperature to 180˚F, yield point which is a chemical property and the forces between particles, reduced leading to increase in fluid loss.

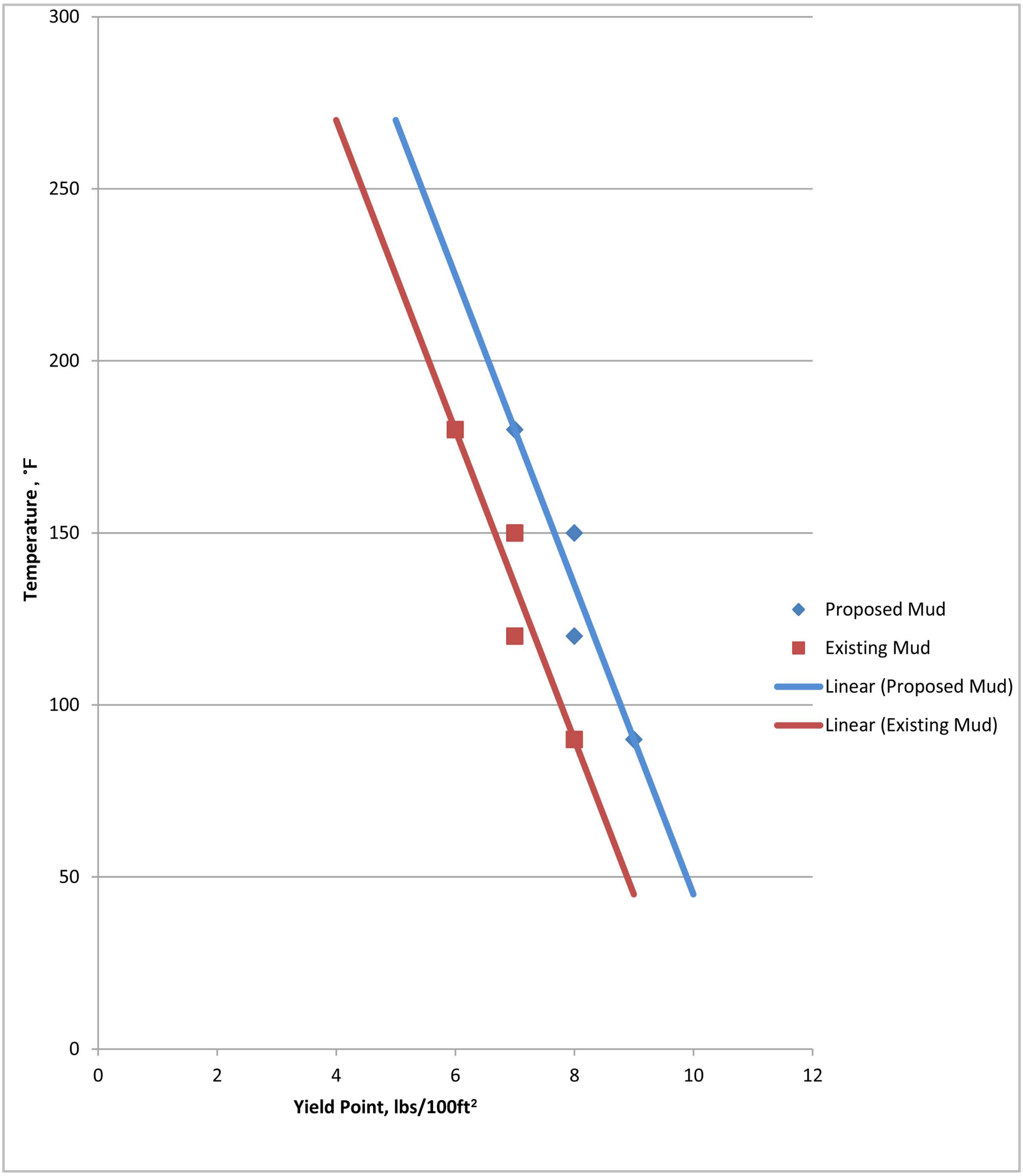

Figure 4. The effect of temperature on yield point for un-weighted biomaterial (proposed) and existing muds.

4.4. Effect of Temperature on Fluid Loss

Figures 7-9 show the effect of temperature on fluid loss. Fluid loss which is the amount of filtrate loss to the formation either during static or dynamic condition. As the yield point which is the measure of the effectiveness of the mud decreased resulted to increase in filtrate volume of the given mud designs.

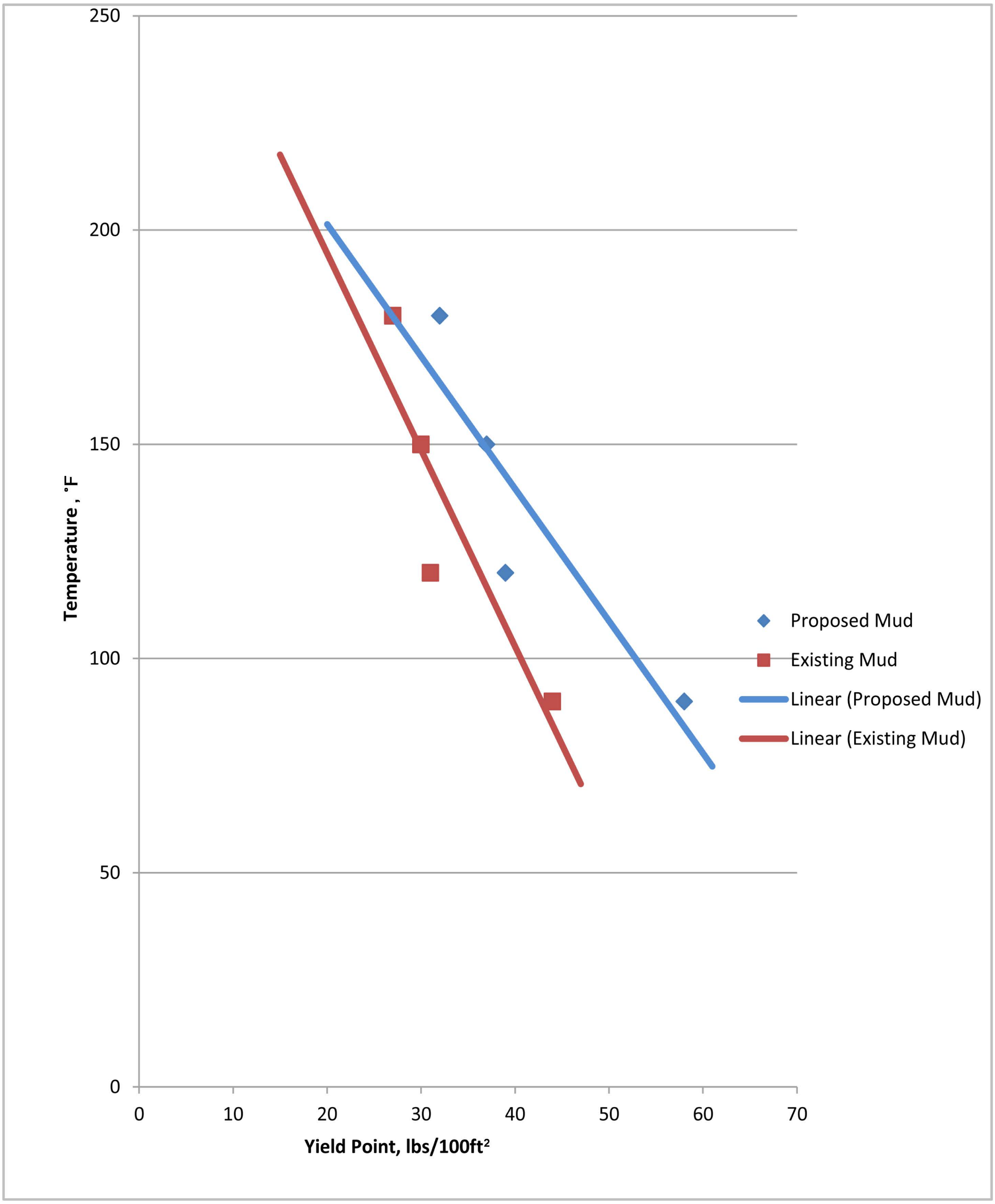

Figure 5. The effect of temperature on yield point for low solids biomaterial (proposed) and existing muds.

5. Conclusion

In conclusion, it has been verified from the plots that the temperature affects the water based mud obtained from *Detarium microcarpum*, *Brachystegia eurycoma*

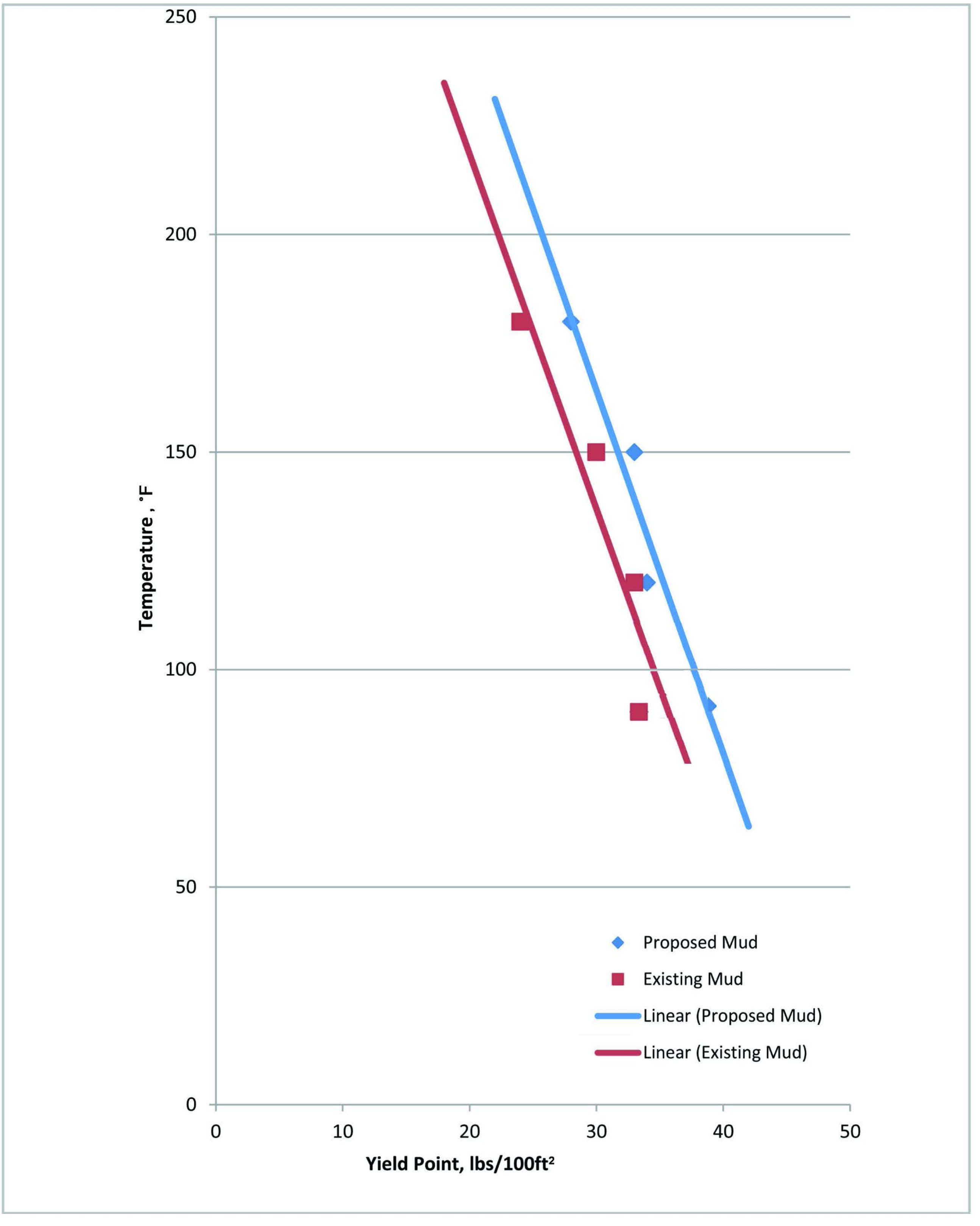

Figure 6. The effect of temperature on yield point for weighted biomaterial (proposed) and existing muds.

and Pleurotus products. The rheological properties of biomaterial muds are slightly better than the existing polypac muds of equal concentrations. The fluid

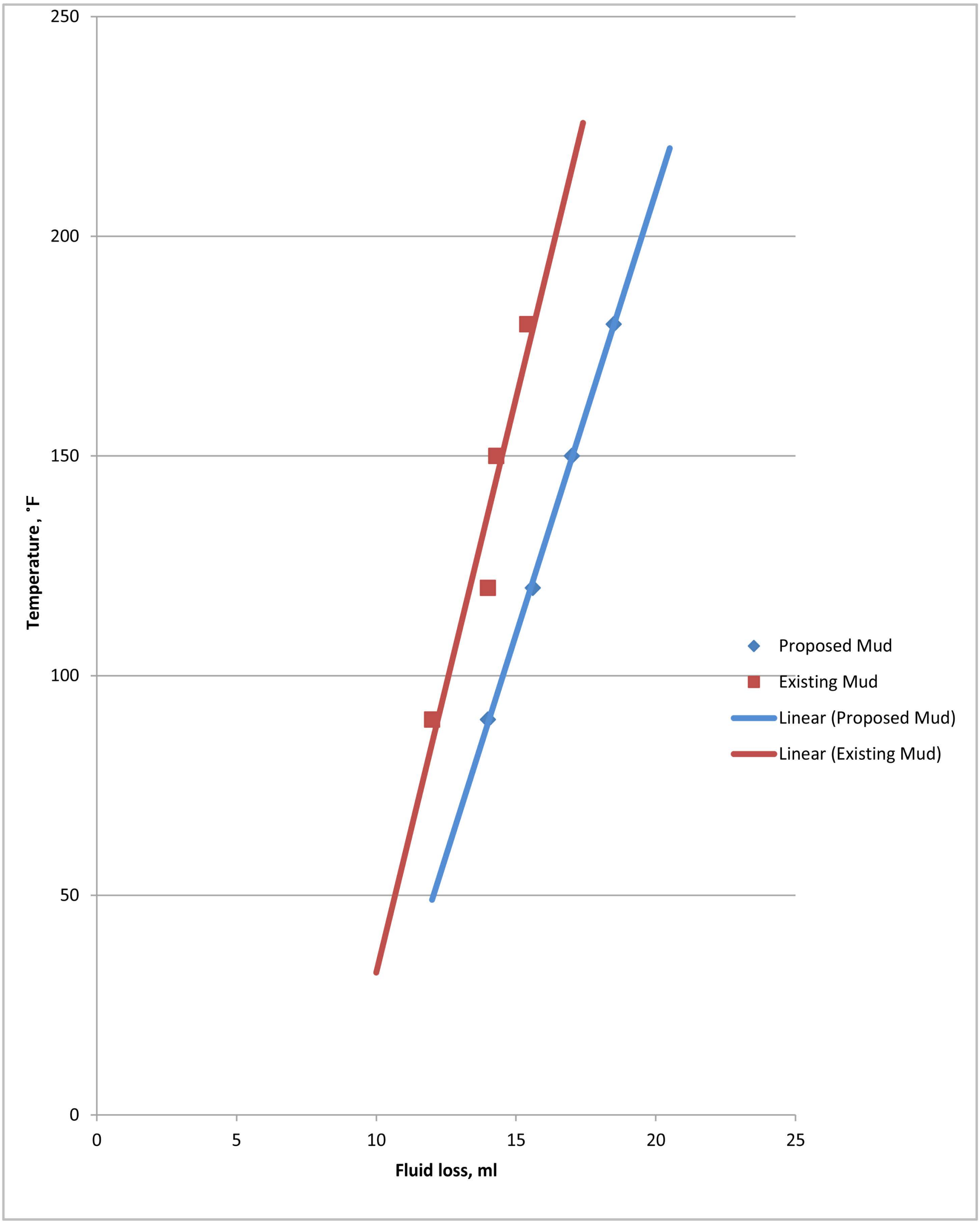

Figure 7. The effect of temperature on fluid loss for un-weighted biomaterial (proposed) and existing muds.

loss of polypac muds are better than that of biomaterial muds. Rheological properties decreased with increase in temperature for both biomaterial muds

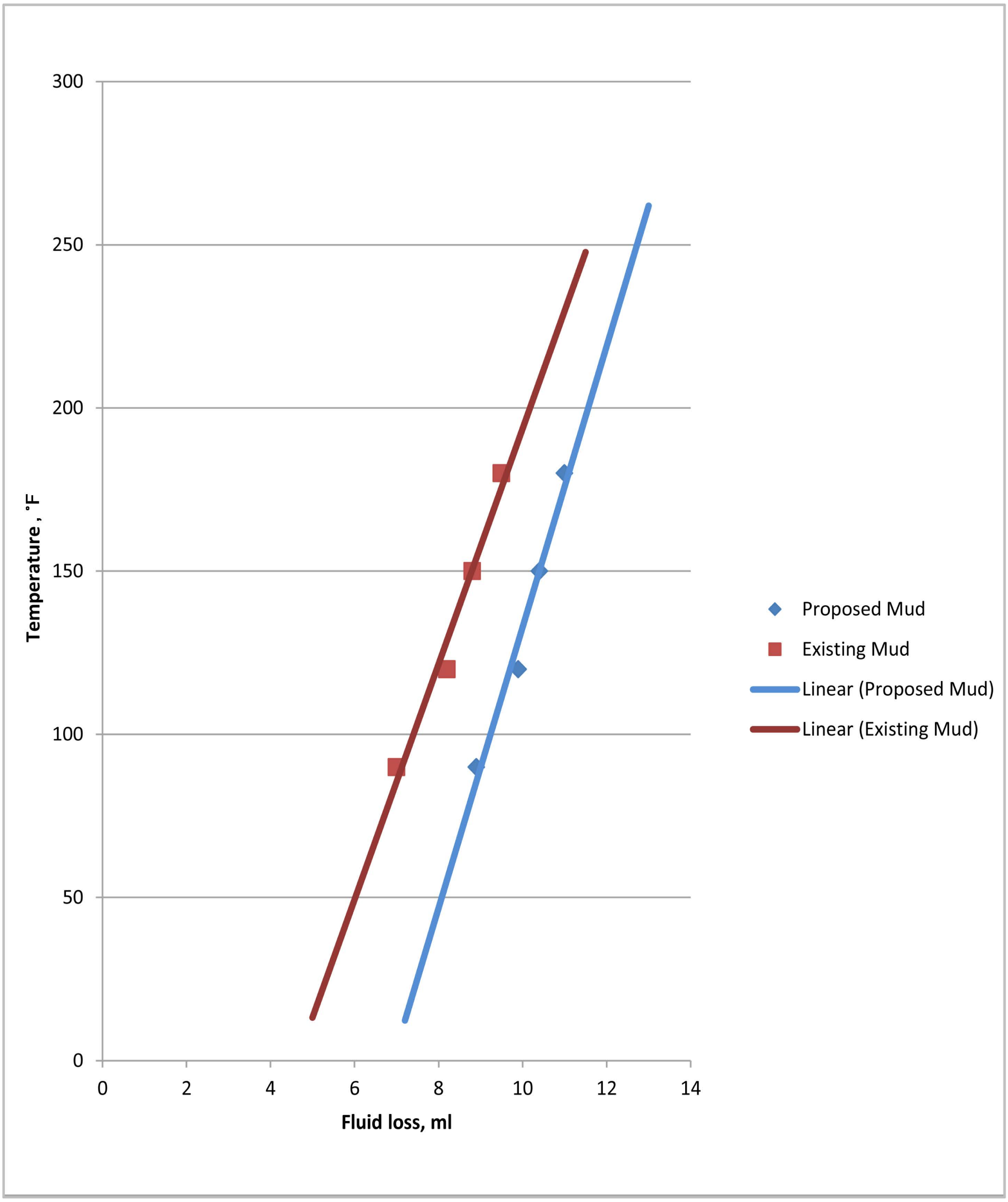

Figure 8. The effect of temperature on fluid loss for low solids biomaterial (proposed) and existing muds.

and polypac muds, as it affects other water based muds. Plastic viscosity, yield point decrease with temperature for un-weighted muds, low solids muds and weighted muds while fluid loss increase with temperature for both biomaterial muds and polypac muds.

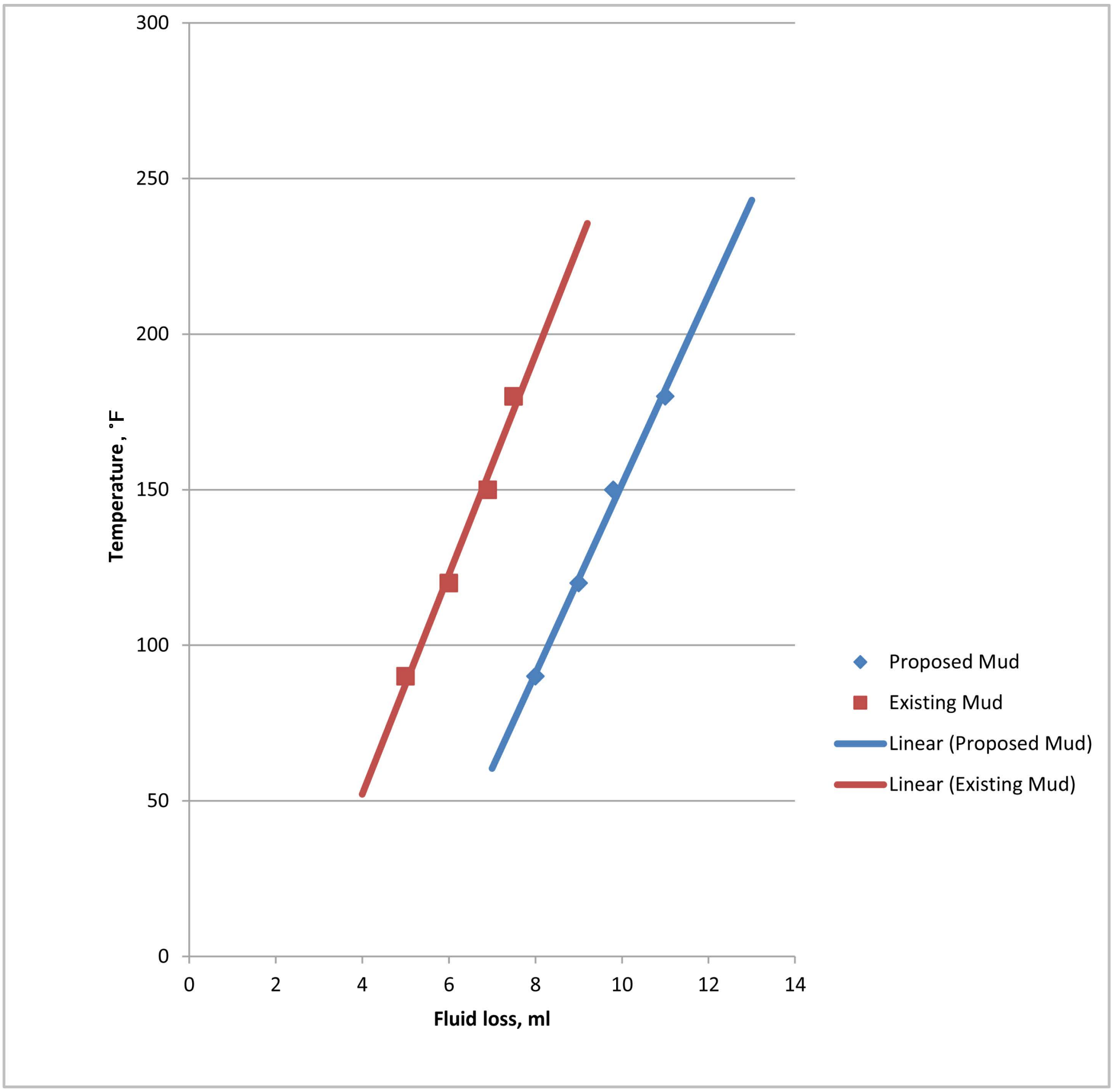

Figure 9. The effect of temperature on fluid loss for weighted biomaterial (proposed) and existing muds.

6. Contribution to Knowledge

The major contribution of this study was to formulate drilling fluids from locally obtained biomaterials for effective drilling. Based on the results of the work, the biomaterial mud is not good for high temperature wells.

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Appendix

$$\text{Plastic viscosity} = \text{O}_{600} - \text{O}_{300}\text{, cP}$$

$$\text{Yield point} = 2 \times \text{O}_{300} - \text{O}_{600}\text{, lbs/100 ft}^2$$

Nomenclature

XCD	Xanthan Gum
Polypac	Polyanionic Cellulose
ppb	pounds per barrel
ppg	pounds per gallon
BBL	Barrel
rmp	revolutions per minure