Effect of Bore Hole Temperature on Density and Viscosity of Oil Base Drilling Fluid

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Abstract: The current energy crises need the more oil and gas recovery; this demand can be meet with deep drilling. Deep oil and gas well drilling has many issues but one major and predominant issue is increasing temperature of the bore hole during drilling deep well. In most drilling deep wells drilling engineer prefer the oil base drilling fluid. Oil base drilling fluid has more bearing tendency as compare to water base drilling fluid. During the drilling of oil and gas well bore hole temperature effect the two main and important properties of drilling fluid that are density and viscosity of the oil base fluid. Density and viscosity control the other properties that can affect the whole drilling operation. Any changes to these two properties, directly effects Rheological parameter of the drilling fluid like plastic viscosity, yield point and rate of penetration. In this research work two samples of oil based drilling fluid were design having density 9 lb/gal and 11 lb/gal. These two samples of density, viscosity and Rheological properties were determined at different temperature. These properties determine at temperature 77^{o}F, 122^{o}F and 176^{o}F. We observe some change occurs in density, viscosity and Rheological properties of drilling fluid as temperature being increased. Furthermore, Bingham plastic model was used to determine the effect of temperature on penetration rate. It was concluded by this laboratory work that increasing temperature effect the density of the drilling fluid at different temperature. With increasing bore hole depth, the temperature of the well increased it decrease the density of the fluid, that can lead towards the many problem but the major problem is blow out, that can destroy all the drilling operation. Viscosity is also decrease with increasing temperature. It prevents the fluid loss, lubricate the bit and move the formation cutting towards the surface.

Keywords: *Temperature, Fluid viscosity, Fluid density, Oil Base Drilling fluid.*

1. Introduction

Oil drilling fluid is very commonly known as oil based mud. These fluids are very intricate drilling fluids. They are consisting of different chemical components. In many cases oil base mud are invert emulsions in which oil by means of continuous phase and often droplets of brines are in aqueous phase of emulsions and for alkalinity lime is used in oil drilling fluid[1]. In oil based mud density of the drilling fluids is control by adding weight materials, while wetting agents may be added to increase the oil wetting of weight materials and other solids [2]. In oil base mud viscosifiers are added to increase the viscosity of drilling mud and drilling fluid loss control materials are also included to reduce the fluids flow from oil base mud into drilled formations during bore hole drilling operation [3]. Drilling fluid play many important roles in successful drilling, but most commonly drilling fluid have three main functions:(1) Transport drill cuttings from the subsurface to the surface and separate these cuttings at the surface from the drilling fluids to make it reusable.(2) drilling fluid make the thin mud cake on bore hole wall to stop inflow of drilling fluids into the formations. (3) and to prevent invasion of formation fluids into the bore hole [4]. It also lubricates and cools down the bit. In addition also, prevents the invasion of formation fluid into the wellbore and helps in maintaining the wellbore stability. Other benefits are maximizing drilling rates, support cementing operation [5]. It has been a recognize fact that the success of an oil and gas well drilling operation depend on a large extent on the rheological properties of the drilling fluid used to remove cutting from the well, make mud cake on the wall of the well and lubricating drill bits [6].

Improper designing of drilling mud may lead to the failure of mud to accomplish its basis functions, and this failure may lead to numerous problems that may increase drilling cost or cause whole drilling operation to fail [7].Behavior of drilling fluid at high temperature when its behavior is accurately predicted and knowledge is comprehensive is a major concern when drilling deep wells which leads to safe and efficient operation [8,9].

2. Non-Newtonian Drilling Mud

A drilling fluid said to be a non-newtonian mud if its properties does not similar to Newtonian drilling mud. In other words, we can say that a non-newtonian mud does not follow Newtonian law of viscosity [10]. By nature, drilling fluids are Non-Newtonian and the values of viscosity of

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drilling fluid changes with the change in shear rate [11]. Due to this variation, Rheological models which are mathematically designed are used to approach the complex flow behavior of non-newtonian drilling muds [12]. While drilling operation, the non-newtonian mud is used, and for this reason mathematically designed rheological model is used to compute the loss of pressure as a result of friction inside the circulatory system. This calculated value of frictional pressure is then used to optimize the flow properties of drilling fluid. Most commonly and widely used rheological model in oil industry is Bingham plastic model [13,14].

2.1 Bingham Plastic Model

Bingham plastic rheological model is most commonly used model in petroleum industry, this model is used to determines the drilling fluid rheology [15]. In Bingham plastic model, it is presumed that the shear rate is a straight-line function of the shear stress. At the point where the shear rate is zero is called as “Yield Point”. The slope of the straight line is termed as “Plastic Viscosity” [16]. This model provides adequate results for drilling mud analysis. Also, this model works very well when the provided shear rates are high similarly; provides significant error when shear rates are low. Below is the equation, describing mathematical relation of Bingham plastic model. [17]

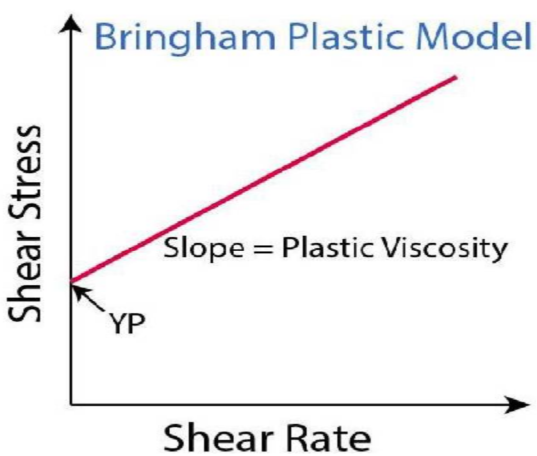

Figure. 1 shows the graphical shear rate- stress relationship of Bingham plastic model.

3. Experimental Work

3.1 Equipment used:

The Equipment used were used in this study consists of heater, thermometer and water based fluid samples, rotational viscometer, mud balance, multi-mixer.

3.2 Name and function of used chemical in experiment:

- Diesel: it is used as a continuous phase in the oil base drilling fluid.
- Fresh water: it is used as drop lets in oil base mud.
- Barite: it as weighting material to increase the hydrostatic pressure of oil base mud.
- Bentonite: it improves the viscosity and fluid loss control.
- Sodium carbonate: it maintains the ph level of the drilling fluid during drilling operation.
- Lignosulphate: It prevent the permeant thicking of drilling fluid.
- Starch: it maintains the Rheological properties of the drilling fluid.
- KCL: it avoids the clay swelling in the well bore while drilling a well.

3.3 Chemical composition of oil sample 01

This is the chemical composition of oil sample 01 having density 9.5 lb/gal. Table 02 show the measured viscosity at temperature 77^{o}F, 122^{o}F and 176^{o}F and at different rpm.

Table 1. Chemical composition of oil base drilling fluid sample no. 1.

Components of mud sample	Weight (grams)
Oil (Diesel)	205
Water	205
Caustic soda	06
Soda ash	06
Starch	45
Bentonite	45
Barite	60
KCL	30

Table 2 Calculated parameters of oil sample 01 Viscometer dial reading at temperature 77 ^{0}F, 122 ^{0}F, 176 ^{0}F

RPM	AT 77 ^{0}F	AT 122 ^{0}F	AT 176 ^{0}F
θ_{600}	15	12	11
θ_{300}	09	07	06
θ_{3}	05	04	04

Table. 3 Calculated Rheological propertiesat temperature 77 ^{0}F, 122 ^{0}F, 176 ^{0}F

PV(cp)	6	5	5
YP(Ib/100 ft^2)	3	2	1

3.4 Chemical composition of oil sample 02:

This is the chemical composition of oil sample 02 having density 11 lb/gal. Table 02 show the measured viscosity at temperature 77^{o}F, 122^{o}F and 176^{o}F and at different rpm.

Table 4: chemical composition of oil base drilling fluid sample no. 2.

Components of mud sample	**Weight (grams)**
Oil (Diesel)	210
Water	70
Caustic soda	13
Soda ash	13
Starch	65
Bentonite	80
Barite	100
KCL	35

Table . 5 Calculated parameters of oil sample 02: Viscometer dial reading at temperature 77^{0}F, 122^{0}F, 176 ^{0}F

RPM	**AT 77 ^{0}F**	**AT 122 ^{0}F**	**AT 176 ^{0}F**
θ_{600}	32	24	21
θ_{300}	24	17	15
θ_3	11	08	06

Table.. 6Calculated Rheological propertiesat temperature 77 ^{0}F, 122 ^{0}F, 176 ^{0}F

PV(cp)	8	**7**	6
YP (Ib/100 ft^2)	16	10	9

4. Results and Discussion

it has been proved from this research work that viscosity of drilling fluid decrease with respect to increase the bore hole temperature. When the depth of the well bore increases the temperature also increased the effect the physical behavior of the drilling fluid. This increasing temperature degrade the chemical which is used in the drilling fluid. Viscosity play vital role in drilling operation to remove cutting to the surface, lubricate the bit which increase the rate of penetration and also make the thick mud cake on the wall of the well. In this research work two samples of oil based fluid investigate at temperature 77 ^{o}F, 122 ^{o}F and 176 ^{o}F and at 600 rpm, 300 rpm, 3 rpm.

4.1 Temperature Effect on viscosity oil sample 01

The effect of temperature on the viscosity of oil sample no: 01 having density 9.5 lb/gal. viscosity is measured at three different temperature with three different rotation per minute. The temperatures were used in this research work is 77^{o}F to 176^{o}F.

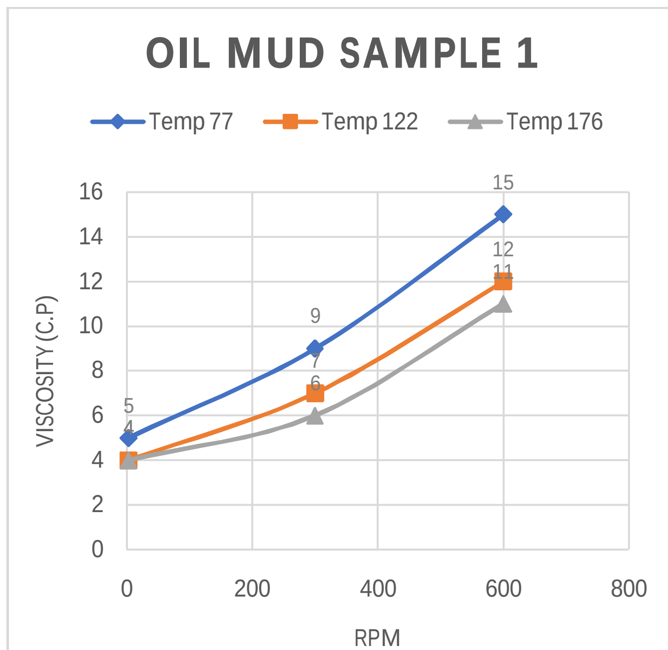

Figure: 2.viscosityvariationof fluid sample: 1 77 to 176^{0}F

As from the fig: 2 we can see that when viscosity was measured at room temperature(77^{0}F) it was 15 cp at 600 rpm, 9 cp at 300 rpm and 5 cp at 3 rpm, and when temperature was increased to 122 ^{0}F viscosity was reduce to 12 cp at 600 rpm, 7cp at 300 rpm and 4 cp at 3 rpm. Further increased of temperature to 176 ^{0}F viscosity is reduces to11, 6, 4 cp at 600, 300 and 3 rpm. From this investigation we can see that temperature effect the drilling fluid parameter at different temperature.

4.2 Temperature Effect on viscosity oil sample 02

The effect of temperature on the viscosity of oil sample no: 02 having density 11 lb/gal. viscosity is measured at three different temperature with three different rotation per minute. The temperature was used in this research work is 77°F to 176°F.

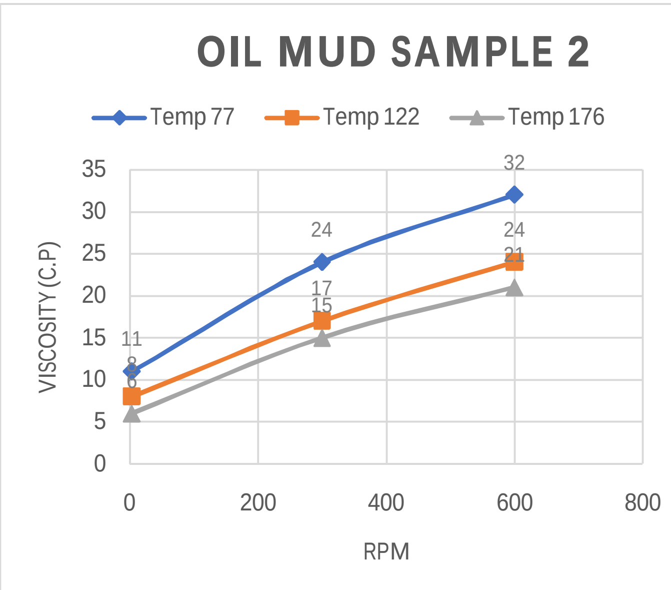

Figure: 3. Variation in viscosity of fluid sample no. 2 from 77 to 176 ^{0}F

As from the fig: 3 we can see that when viscosity was measured at room temperature (77 ^{0}F) it was 32 cp at 600 rpm, 24 cp at 300 rpm and 11 cp at 3 rpm, and when temperature was increased to 122 ^{0}F viscosity was reduce to 24 cp at 600 rpm, 17cp at 300 rpm and 8 cp at 3 rpm. Further increased of temperature to 176 ^{0}F viscosity is reduces to 21, 15, 6 cp at 600, 300 and 3 rpm. From this investigation we can see that temperature effect the drilling fluid parameter at different temperature.

4.3 Temperature effect on density oil sample 01

It is well known that density is reduced when heat is applied on fluid. Density play important role in the drilling fluid during drilling operation. Density create the hydrostatic pressure on the well column which prevent the blow out. In this research work density of oil base drilling fluid is also determine that how much temperature effect the density of the drilling fluid. When drilling fluid is circulated in the well bore its density become change due to bore hole temperature. So it is necessary to determine the temperature effect on the oil base drilling fluid.

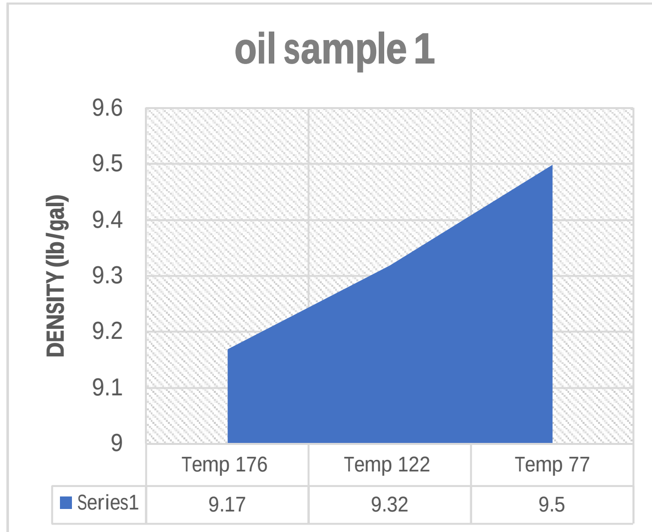

Figure: 4. Temperature effect on the density of oil mud sample no. 1

From the fig: 4 we can see that when drilling fluid was at room temperature (77°F) its density was 9.5 ppg. when this drilling fluid was heated at temperature at 122°F its density become reduce to 9.32 ppg. Further when drilling fluid is heated to 176°F density of the drilling fluid is also decrease to 9.17 ppg. From this result we can conclude that when temperature will increase it will reduce the density of the drilling fluid.

4.4 Temperature effect on density oil sample 02

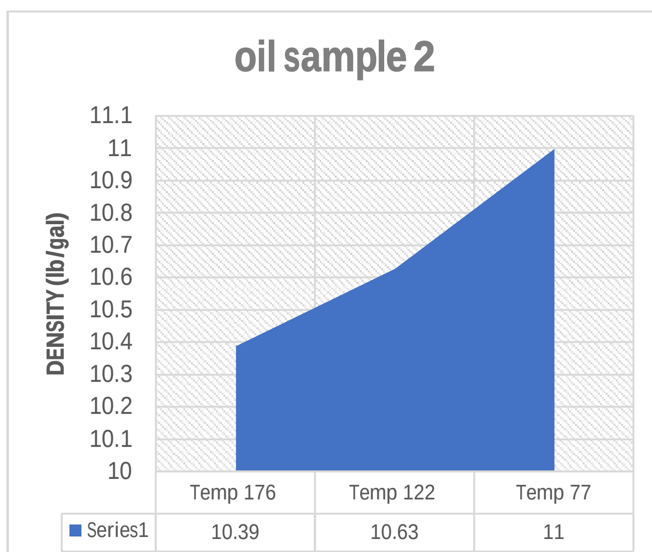

Figure: 5. Effect of temperature on the density of oil mud sample no. 2

From the fig: 5 we can see that when drilling fluid was at room temperature (77°F) its density was 11 ppg. when this drilling fluid was heated at temperature at 122°F its density become reduce to 10.63 ppg. Further when drilling fluid is heated to 176°F density of the drilling fluid is also decrease to 10.39 ppg. From this result we can conclude that when temperature will increase it will reduce the density of the drilling fluid.

4.5 Effect on Frictional Pressure Losses

Frictional pressure losses has prime importance during drilling operation. Height the frictional pressure losses it means more energy is being consumed in pumping the mud down hole. If frictional pressure losses throughout the circulatory system is minimum, it means more energy is being provided to the drill bit and this will provide maximum removal of drilled cuttings from the bottom of the hole. As a result of this, penetration rates will be maximum [18].

In this study, when drilling fluid is circulated into the well bore frictional pressure losses occurs. If more frictional pressure losses occur then fluid will not circulate properly and it cannot remove the cutting to the surface. Hole cleaning in an important factor during drilling it can perform only with proper calculation of frictional pressure loses. In this research work Bingham plastic model was used to determine the fractional pressure losses.

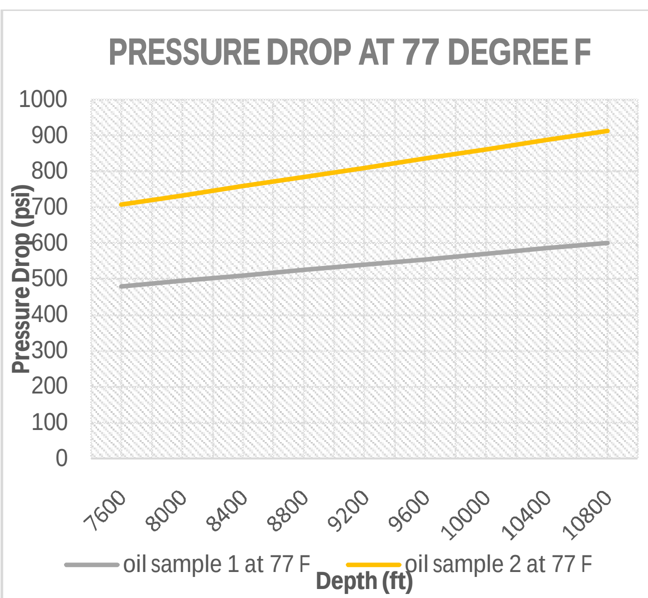

Figure: 6. Shows drop in pressure at various depth at temperature 77 ^{0}F

Bingham Plastic model is used to determine the fractional pressure losses of oil sample 1 and 2. Both the result of sample one and two were compared in the graph. In the above figure 6 shows drop in pressure for both the oil sample 1 and 2 having flow rate 380 G/min. Sample one has density 9.5 ppg and sample two have density 11ppg. We can easily determine form the graph that oil sample one shows minimum fractional pressure losses as compare to oil sample two at temperature 77°F. Oil sample one has better results as compare to oil sample two at temperature 77°F.

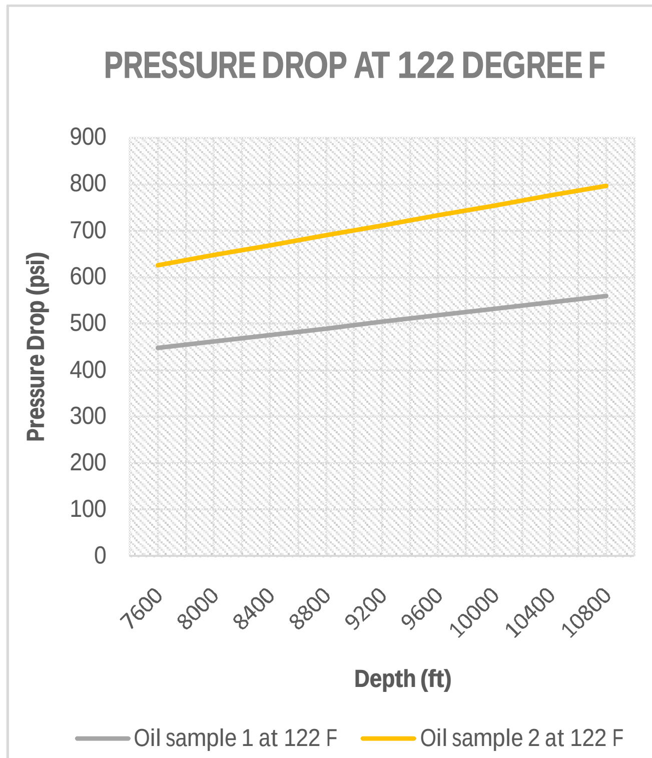

Figure: 7 Shows drop in pressure at various depth at temperature 122 ^{0}F

Bingham Plastic model is used to determine the fractional pressure losses of oil sample 1 and 2. Both the result of sample one and two were compared in the graph. In the above figure 7 shows drop in pressure for both the oil sample 1 and 2 having flow rate 380 G/min. Sample one has density 9.32ppg and sample two have density 10.63ppg. We can easily determine form the graph that oil sample one shows minimum fractional pressure losses as compare to oil sample two at temperature 122°F. Oil sample one has better results as compare to oil sample two at temperature 122°F.

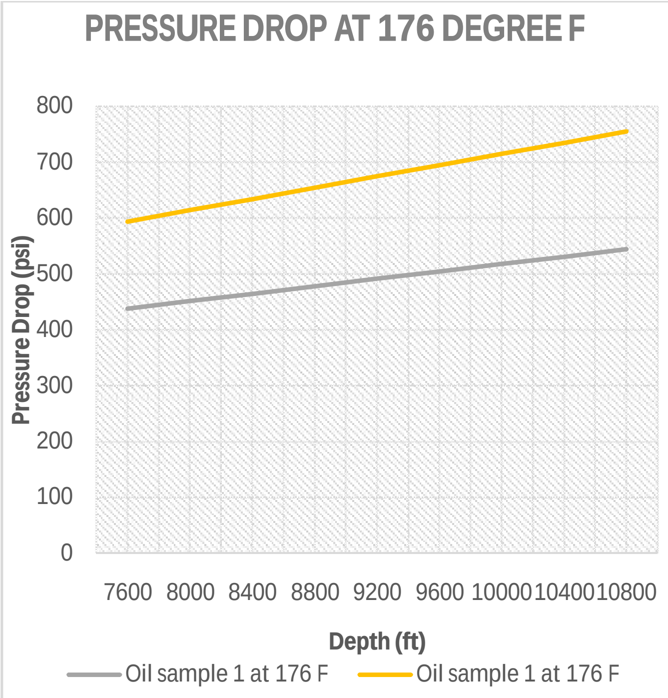

Figure: 8. Shows drop in pressure at various depth at temperature 176 ^{0}F

Bingham Plastic model is used to determine the fractional pressure losses of oil sample 1 and 2. Both the result of sample one and two were compared in the graph. In the above figure 8 shows drop in pressure for both the oil sample 1 and 2 having flow rate 380 G/min. Sample one has density 9.17ppg and sample two have density 10.39ppg. We can easily determine form the graph that oil sample one shows minimum fractional pressure losses as compare to oil sample two at temperature 176^{o}F. Oil sample one has better results as compare to oil sample two at temperature 176^{o}F.

5. Conclusions

In this research work it found that temperature effect the viscosity, density and Rheological properties of oil based drilling fluid. From this investigation work some important conclusion have been drawn.

1. From this research work it is concluded that temperature effect the viscosity of the oil based drilling fluid and oil based drilling fluid is better in high temperature environment as compare to water based drilling fluid.
2. Density of the oil based fluid is also effect due to high borehole temperature. As compare to oil sample one and two oil sample one reduce low density as compare to oil sample two. It means oil sample one has better density result as compare to oil sample two.
3. Rheological parameter such plastic viscosity yield point is also reduce due to temperature.
4. Bingham plastic model is used to determine the fractional pressure losses. At all three temperature ranges such as 77^{o}F, 122^{o}F and 176^{o}F oil sample one show less drop in pressure as compare to oil sample 02.
5. Drilling optimization can be achieved, if the temperature of the drilling mud is maintained at 176^{o}F and the pressure drop is 544 psi for mud sample 2. This will lead to an optimized drilling operation by providing higher rates of drilling.

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