Proceedings World Geothermal Congress 2005
Antalya, Turkey, 24-29 April 2005

Laboratory Study of High Temperature Additive to Rheology Properties of Drilling Mud under Dynamic Conditions

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Keywords: Additive,HPHT, Rheological Properties

ABSTRACT

Sometimes when drilling is in progress, we have to deal with high pressure and high temperature. It happens specially when the target is deep enough or geothermal well. HPHT condition will be able effect the performance of drilling fluids by altering its rheological at high pressure up to 3000 psig and high temperature up to 200oC by Fann Model 70. Research was done with various additive, such as Chemtrol-X, CMC LV, Polyplus and Ligco, with have objective to repair mud rheological at HPHT. Based on this research by API recommended on pound per barrel (ppb). Results of this research are the composition is 2-3 ppb additive to be added on water based mud and stable rheology up to 200 ^{o}C.

1. INTRODUCTION

Drilling operation problems such as abnormal pressure, swelling and high temperature condition usually found during drilling progress. Drilling mud characteristic and rheological properties will be effected by high temperature effect. With increasing temperature of drilling fluids, viscosity will decreasing, this condition will make cuttings or chips are not effective carried and sludge will be occurs at base hole bore (pipe sticking). The solution for this problem is to add additional additives which resistant to High pressure and high temperature (HPHT) condition.

The purpose of this research is to search additives stabilities by altering its rheological characteristic in HPHT condition. This research used fresh water mud (Wyoming Bentonite) and HPHT Viscometer Fann Model-70 to measure the rheologi of drilling fluids. This research will be studied the rheological properties of drilling mud and additional resistant additives in based drilling mud with variation of additive concentrate and variation of experiment temperature. The best combination of additives from base mud at certain HPHT will be obtained from the result of this research.

2. LITERATURES STUDY

2.1. Chemical Composition of Drilling Mud

Generally speaking, drilling mud may be defined as a suspension of solids in a liquid phase. Drilling mud consists of solid liquid fractions, solid fractions and chemical additives (Lummus, 1989).

A liquid fraction is the greatest quantities of drilling mud such as water, oil, gaseous, and air. The solid fractions of mud consist of the reactive fraction such as bentonite and attapulgite and the inert solids include barite, limestone, sand, chert, etc. Chemical additives are used to control viscosity, yield point, gel, density and fluid loss properties of mud.

2.2. Physical Properties of Drilling Mud

The basic physical properties of mud is to control drilling operation in oil and geothermal field include: (a) weigh or density; (b) rheological properties (viscosity and gel strength); (c) filtration loss.

Mud weight or more precisely, mud density is the ability of mud to endure formation pressure in order to prevent blow out and break down formation.

Viscosity is the velocity of the fluid to flow (rheologi), gel strength is the ability of mud to develop and retain a gel structure at certain condition in static condition. Viscosity is property, which controls the magnitude of shear stress and shear rate. Viscosity is dependent on mud rheologi to clean base of hole bore.

Filtration loss is described as the filtrate lost from liquid component of mud drilling system to the formation (rock) where penetrated by rock bit. The layer of solids deposited on the rock surface is described as filtrate cake (mud cake). The effects of filtration loss are the formation damage or swelling and reducing of diameter hole bore because mud cake on the formation.

2.3. Function of Drilling Mud

Drilling mud serve many purposes. The major function include the following (Adam, 1989):

1. Control formation pressure. Drilling interval that have abnormally high pressure require that the mud system be able to provide sufficient pressure to equal or exceed the formation pressure. The hydrostatic pressure of the mud system achieves this purpose.

2. Carry cuttings out of the hole and to the surface, which will be separated from the mud and to be recirculated. The carrying capacity of mud depends on several factors, including viscosity and dimension of cuttings or chips.

3. Reducing weight of drill string, which is depend on buoyancy factor.

4. Lubricate and cool the drill string and bit which are depends on the capacity to absorb heat from drilling mud and stability of resistant mud at HPHT condition.

5. Provide logging information and interpretation of the well which depend on mud resisitivity for filtrate loss/mud cake around hole bore.

3. LABORATORY RESEARCH METHODS

Laboratory study of a certain mud composition is necessary to obtain kind of resistant additive at HPHT condition where is to carries cuttings out of the hole to the surface or to clean of base hole bore.

The following studies of laboratory: Equipments preparation (Figure 3.1):

- Tests procedure
- Mud material and additives preparation
- Made of mud suspension
- Conditions mud suspension
- Mud characteristic tests

Equipment preparation is the first step before start of the research.

Study that conducted of this research was the rheologi property of mud drilling at condition from 50 ^{o}C to 200 ^{o}C with interval is 25 ^{o}C. Concentrations of adding additive considered from API specification where a certain additive or combination additives are added in based drilling mud system (fresh water mud) at dynamic condition.

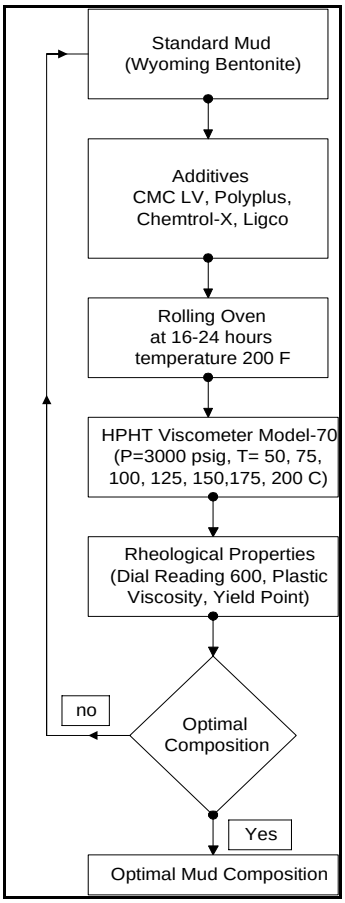

Figure 3.1. Research Flow

3.1. Materials of The Research

Materials used on this research are Fresh water mud (350 ml aquadest + 22.5 gr Wyoming Bentonite) that was the based mud. Mud alternative to HPHT condition with adding additives CMC-LV with concentrates 1-4 ppb, Polypus with concentrates 0.75-3 ppb, Chemtroll-X with concentrates 2-3, and Ligco 2-8 ppb.

3.2. Equipment of The Research

Equipments are used for research of resistant additives at HPHT condition consist of Viscometer Fann VG Model-70 (Figure 3.2), digital scale (Figure 3.3), multi mixer (Figure 3.4), aging cell (Figure 3.5), roll oven (Figure 3.6), and measure glass.

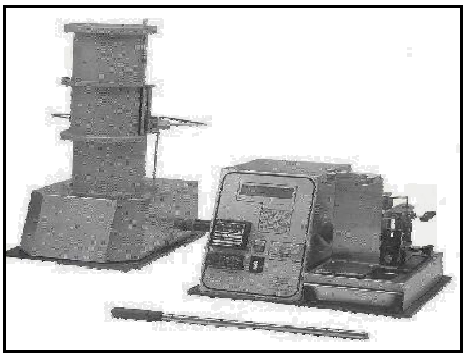

Figure 3.2. HPHT Viscometer Fann Model-70[10]

Figure 3.3. Digital Scale

Figure 3.4. Multi Mixer

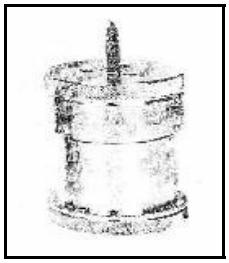

Figure 3.5. Aging Cell

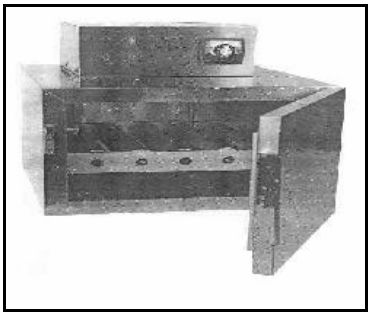

Figure 3.6. Roll Oven

3.3. Test Conditions

Variation temperatures are 50 ^{o}C, 75 ^{o}C, 100 ^{o} C, 125 ^{o} C, 150 ^{o}C, 175 ^{o}C, and 200 ^{o}C at the pressure of 3000 psig. Prior to the each run the mud need to be placed in rolling oven during 16-24 hours at temperature accord by experiment temperature.

3.4. Tests Procedure and Additives Preparation

The mud is placed in rolling oven during 16-24 hours at temperature accord by the experiment temperature used in Viscometer Fann VG Model-70 for each composition measurement. After that the rheologi properties measured for dial reading 600 rpm and 300 rpm at pressure 3000 psig.

4. RESULTS AND DISCUSSIONS

The results and discussions from laboratory tests are the density and rheology properties mud drilling as follow

4.1. Standard Mud

Dial reading 600 rpm and 300 rpm showed inclined increase (33.21-58 and 20.9-45.5) from temperature 50 ^{o}C – 125 ^{o}C its mean with increasing temperature, the viscosity of standard mud (fresh water mud) is thicker (12.31 –13 cp). It is similar with yield point value where as from 8.59-32.5 lb/100sq.

Dial reading 600 rpm and 300 rpm for temperature 125 ^{o}C to 200 ^{o}C are 52 and 43, plastic viscosity (PV) is 9 cp and yield point (YP) is 34 which higher than API specification (3 x PV) because it was aggregation between individual plates become solid blocks or can not to flow again (Figure 4.1 and Table 1).

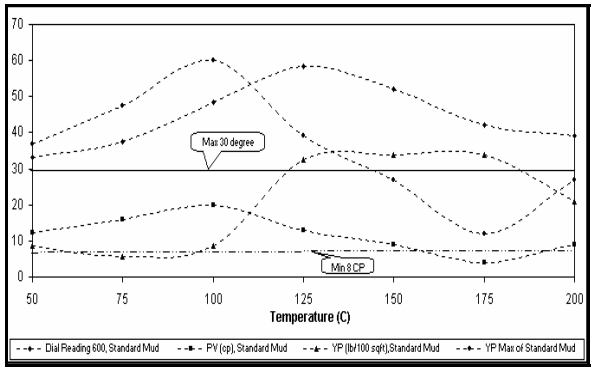

Figure 4.1. Standard Mud

Table 1. Standard Mud

Temperature (C)	Dial Reading 600	Dial Reading 300	Plastic Viscosity	Yield Point	3 PV
50	33.21	20.9	12.31	8.59	36.93
75	37.4	21.6	15.8	5.8	47.4
100	48.5	28.5	20	8.5	60
125	58.5	45.5	13	32.5	39
150	52	43	9	34	27
175	42	38	4	34	12
200	39	30	9	21	27

4.2. Standard Mud + 3 ppb CMC-LV

Added 3 ppb CMC-LV into standard mud where as filtration loss reducer, shale control agent, and viscosivier. Results of this experiment that as follow dial reading 600 rpm at 50 ^{o}C – 200 ^{o}C which are decreased temperature occurs (71.0, 45.2, 39.8, 40, 35, 32, 35) but still in API specification (minimum is 30). Graphic show is decreasing at temperature 75 ^{o}C relatively very small (2-6) its mean additive begin to active reaction.

Plastic viscosity has little bit fluctuation with increasing temperature until temperature 200 ^{o}C (42, 25.5, 18.8, 18.33, 17.3, 30, 35) but still agree with API specification (minimal 8 cp). Yield point has increase with increasing temperature and still agree with API specification.

According API specification CMC-LV stabile at temperature between 121^{o}C – 140 ^{o}C with addition concentrates 1.0 – 4.0 into standard mud. The research concern from concentrates limit addition additive where tests were done in laboratory at maximum concentrate is 3 ppb.

Addition additive of CMC-LV 3 ppb can make rheology of drilling mud more resistant until 200 ^{o}C. This composition could be using for rheology stability solution until temperature 200 ^{o}C (Figure 4.2 and Table 2).

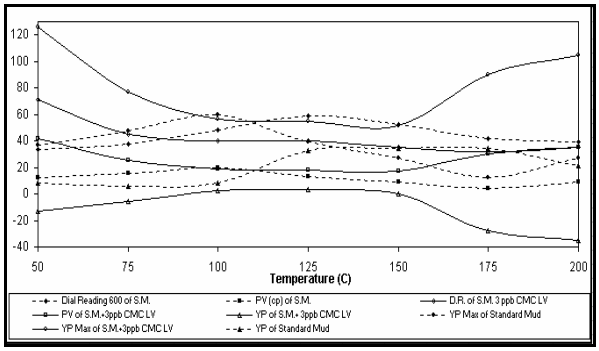

Figure 4.2. Standard Mud + 3 ppb CMC LV

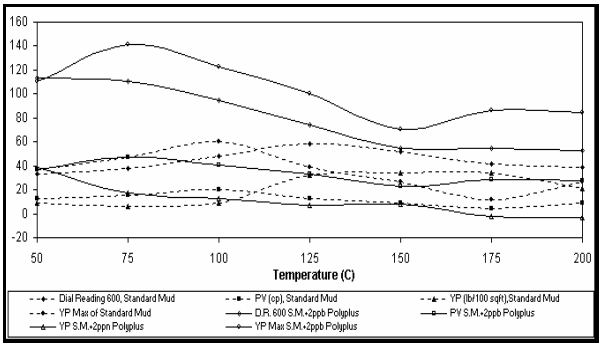

Figure 4.3. Standard Mud + 2 ppb Polyplus

Table 2. Standard Mud + 3 ppb CMC-LV

Temperature (C)	Dial Reading 600	Dial Reading 300	Plastic Viscosity	Yield Point	3 PV
50	71	29	42	-13	126
75	45.2	19.7	25.5	-5.8	76.5
100	39.8	21	18.8	2.2	56.4
125	40	21.67	18.33	3.34	54.99
150	35	17.7	17.3	0.4	51.9
175	32	2	30	-28	90
200	35	0	35	-35	105

Table 3. Standard Mud + 2 ppb Polyplus

Temperature (C)	Dial Reading 600	Dial Reading 300	Plastic Viscosity	Yield Point	3 PV
50	113	76	37	39	111
75	111	64	47	17	141
100	95	54	41	13	123
125	74	40.66	33.34	7.32	100.02
150	55	31.66	23.34	8.32	70.02
175	55	26.33	28.67	-2.34	86.01
200	53	25	28	-3	84

4.3. Standard Mud + 2 ppb Polyplus

Polyplus is liquid polymer anionic which as application molecule weight for stabilization shale or stabilize cuttings to prevent them from caving. Its can be used for low solid mud system and weighted solid mud and fresh until salt-water mud. According API specification adding polyplus into mud system agree with 0.75 ppb-3.0 ppb at temperature 176 ^{o}C start to active reaction.

The optimum polyplus added into the standard mud is 2 ppb. As its function as shale control agent, filtration reducer and flocculent where shows increasing temperature decreasing rheology mud and the lowest decrease at temperature 150 ^{o}C – 200 ^{o}C with dial reading 600 is 55, 55, and 53 its mean polyplus begin active at temperature 150 ^{o}C.

Plastic viscosity decreased from temperature 175 ^{o}C – 200 ^{o}C are 47 cp – 28 cp but still in API specification and yield point is good until 200 ^{o}C (Figure 4.3 and Table 3).

Concern result above, this composition start to active at temperature 150 ^{o}C and will be able for HPHT condition.

4.4. Standard Mud + 3 ppb CMC-LV + 2 ppb Chemtroll-X

Chemtroll-X as filtration loss control additive where stabile for water base mud system at temperature 176 ^{o}C with concentrates from 2 ppb – 3 ppb. Research was done with variation concentrates such as 2 ppb; 2.5 ppb and 3 ppb and result of this experiment show the optimum addition this additive at 2 ppb (Figure 4.4 and Table 4).

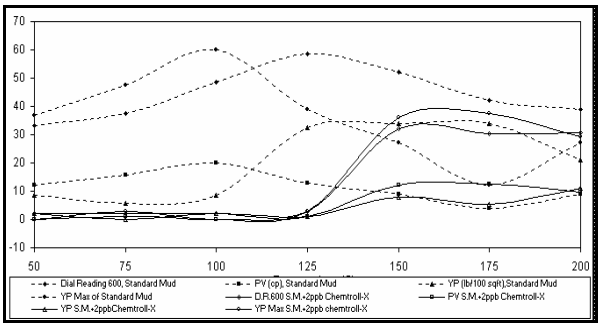

Figure 4.4. Standard Mud + 2 ppb Chemtroll-X

Table 4. Standard Mud + 2 ppb Chemtroll-X

Temperature (C)	Dial Reading 600	Dial Reading 300	Plastic Viscosity	Yield Point	3 PV
50	2	2	0	2	0
75	2	1	1	0	3
100	2	2	0	2	0
125	3	2	1	1	3
150	32	20	12	8	36
175	30.2	17.7	12.5	5.2	37.5
200	30.8	21	9.8	11.2	29.4

Accord that experiment, researchers tried to combine with 3 ppb CMC-LV and 2 ppb Chemtroll-X and result of that is increasing temperature from 75 ^{o} – 200 ^{o}C, viscosity has decrease from 15 cp – 11.9 cp but still in API specification until temperature 200 ^{o}C. So this composition will be able until temperature 200 ^{o}C (Figure 4.5 and Table 5).

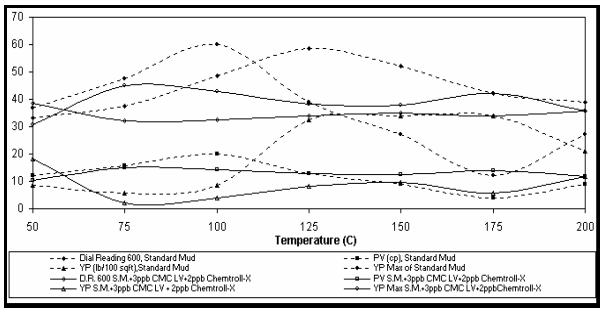

Figure 4.5. Standard Mud + 3 ppb CMC LV + 2 ppb Chemtroll-X

Table 5. Standard Mud+3 ppb CMC-LV+2 ppb Chemtroll-X

Temperature (C)	Dial Reading 600	Dial Reading 300	Plastic Viscosity	Yield Point	3 PV
50	38.6	28.4	10.2	18.2	30.6
75	32	17	15	2	45
100	32.6	18.35	14.25	4.1	42.75
125	33.8	21.03	12.77	8.26	38.31
150	35	22.4	12.6	9.8	37.8
175	33.8	19.7	14.1	5.6	42.3
200	35.6	23.7	11.9	11.8	35.7

4.5. Standard Mud + 3 ppb CMC-LV + 2 ppb Ligco

Ligco is highly 0xydize leonardite for filtration loss control water base mud system. The effective of Ligco at temperature 176 ^{o}C with concentrates from 2.0 ppb – 8.00 ppb. Research was done to found optimum concentrate with concentrates is 2 ppb, 4 ppb, 6 ppb, and 8 ppb of Ligco. The most optimum of Ligco addition is 2 pbb (Figure 4.6 and Table 6).

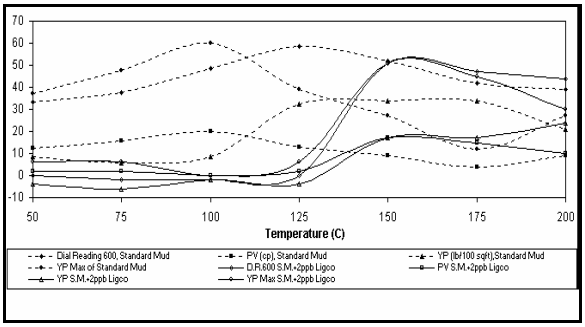

Figure 4.6. Standard Mud + 2 ppb Ligco

Table 6. Standard Mud + 2 ppb Ligco

Temperature (C)	Dial Reading 600	Dial Reading 300	Plastic Viscosity	Yield Point	3 PV
50	0	-2	2	-4	6
75	-2	-4	2	-6	6
100	-2	-2	0	-2	0
125	0	-2	2	-4	6
150	51	34	17	17	51
175	47	32	15	17	45
200	44	34	10	24	30

Combination additives 3 ppb CMC-LV and 2 ppb Ligco show as increasing temperature dial reading 600 has increase from 36.2 – 48.2. Plastic viscosity decreases but still in API specification until temperature 175 ^{o}C are from 22.9 cp – 9 cp, yield point increase with rising temperature but still agree with API specification. So this composition it can make resistant rheology of mud until temperature 175 ^{o}C (Figure 4.7 and Table 7).

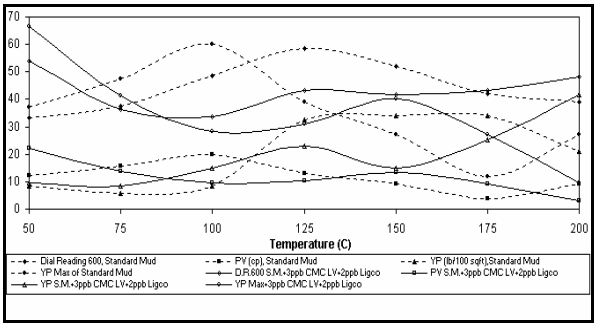

Figure 4.7. Standard Mud + 3 ppb CMC LV + 2 ppb Ligco

Table 7. Standard Mud + 3 ppb CMC LV + 2 ppb Ligco

Temperature (C)	Dial Reading 600	Dial Reading 300	Plastic Viscosity	Yield Point	3 PV
50	54	31.8	22.2	9.6	66.6
75	36.2	22.4	13.8	8.6	41.4
100	33.8	24.4	9.4	15	28.2
125	43.4	33.1	10.3	22.8	30.9
150	41.6	28.2	13.4	14.8	40.2
175	43.4	34.4	9	25.4	27
200	48.2	45	3.2	41.8	9.6

4.6. Standard Mud+2 ppb Polyplus+2 ppb Chemtroll-X

Combination of adding additives 2 ppb Polyplus and 2 ppb Chemtroll-X into standard mud show that increasing temperature until 200 ^{o}C the rheology of mud has little bit change and fluctuation as show at dial reading 600 rpm from 57 – 93, yield point are 5.6 – 5.5 lb/100 sq.ft and plastic viscosity are 25.7 cp – 9.9 cp where as agree with API specification. So this composition can make mud rheology resistant until temperature 200 ^{o}C (Figure 4.8 and Table 8).

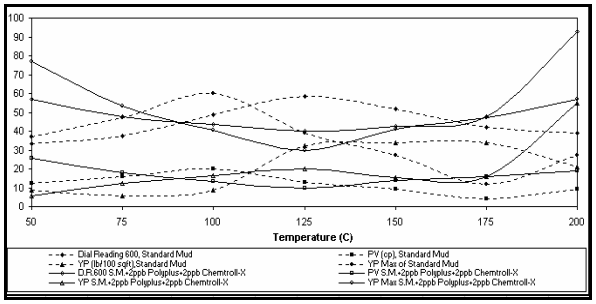

Figure 4.8. Standard Mud + 2 ppb Polyplus + 2 ppb Chemtroll-X

Table 8. Standard Mud+2 ppb Polyplus+2 ppb Chemtroll-X

Temperature (C)	Dial Reading 600	Dial Reading 300	Plastic Viscosity	Yield Point	3 PV
50	57	31.3	25.7	5.6	77.1
75	47.6	29.9	17.7	12.2	53.1
100	43.4	29.9	13.5	16.4	40.5
125	39.8	29.9	9.9	20	29.7
150	42.8	29.2	13.6	15.6	40.8
175	47.6	31.8	15.8	16	47.4
200	93	74	19	55	57

4.7. Standard Mud + 2 ppb Polyplus + 2 ppb Ligco

Added combination additive 2ppb Polyplus + 2 ppb Ligco into standard mud show rheology of mud is little bit change with increasing temperature. It shows as dial reading 600 rpm at 50 ^{o}C – 150 ^{o}C decrease from 145 – 92 but at temperature 175 ^{o}C rising again and still in API specification. Yield point increase from 38 – 58 lb/100 sq.ft with temperature increase until 175 ^{o}C and then drastic increase where is more than maximum of API specification as 3 x PV (104). Plastic Viscosity is decrease from 55 cp – 22 cp until temperature 175 ^{o}C and getting up again but agree with API specification standard. Those show this combination can make resistant for rheology of mud until temperature 175 ^{o}C (Figure 4.9 and Table 9).

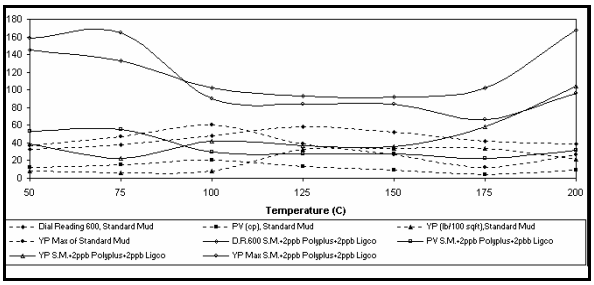

Figure 4.9. Standard Mud + 2 ppb Polyplus + 2 ppb Ligco

Table 9. Standard Mud + 2 ppb Polyplus + 2 ppb Ligco

Temperature (C)	Dial Reading 600	Dial Reading 300	Plastic Viscosity	Yield Point	3 PV
50	145	92	53	39	159
75	133	78	55	23	165
100	102	72	30	42	90
125	93	65	28	37	84
150	92	64	28	36	84
175	102	80	22	58	66
200	168	136	32	104	96

According discussion above mud standard although an addition singular or combination additive shows temperature influential can make different stability and resistant rheology of mud. The purpose of added combination additive is to increase rheology stability mud concern increase temperature if compare with addition singular additive

All polymers used have stability on temperature 135-175^{o}C, but each one additve can used have stability until on 200^{0}C because to be added Chemtroll X .

The negative 600 rpm dan 300 rpm readings and negative Yield Point its mean the fluid system to be change (thinner) or bellow zerro point of Newtonian fluid system, and caused the cutting transport is any problem.

5. CONCLUSIONS

1. Rheology of drilling mud depends on temperature; increasing temperature it will be decreasing the viscosity (rheology).

2. Standard mud (Wyoming bentonite) only has strength until temperature 150 ^{o}C. After adding resistant additives shows those additives can make mud more resistant for high temperature.

3. Additional additives 3 ppb CMC-LV, 2 ppb Polyplus, 3 ppb CMC-LV + 2 ppb Chemtroll X, 2 ppb Polyplus + 2 ppb Chemtrol X into standard mud can make rheology drilling mud more resistant until temperature 200 ^{o}C, see Table 8.

4. Additional additives 3 ppb CMC-LV + 2 ppb Ligco, 2 ppb Polyplus + 2 ppb Ligco into standard mud can make rheology drilling mud more resistant until temperature 175 ^{o}C.

ACKNOWLEDGEMENTS

We would like to thanks to Dr. Ing. Ir. Rudi Rubiandini RS for them opportunity to done this research within RUT DIKTI research members at 1999-2001.

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