STUDIES OF WEIGHTING AGENTS IN HIGH TEMPERATURE WATER BASE MUD (HTWBM)

By

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CERTIFICATION OF APPROVAL

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertake or done by unspecified sources or persons.

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MUS'AB UMAIR BIN MAZLAN

ABSTRACT

This project is about studies of weighting agent in High Temperature Water Base Mud (HTWBM). As the name suggested, the high temperature water base mud (HTWBM) is designed to drill wells with extreme temperature, often together with the high pressure conditions. The 17 ppg drilling fluid system to be tested at 250°F has been chosen for this project .The API Barite that has been used as the weighting agent in High Temperature Water Base Mud (HTWBM) has a density of 4.39 Specific Gravity. But nowadays, in reality it is common that API Barite provide in actual drilling has a density of 4.2 Specific Gravity. Thus, in this study, different types of weighting agent such as Fine Grind Barite, High Purity Barite, Heamatite and Micromax are evaluated. These weighting agent materials were blended in a ratio with API Barite to study the trend and impact of each weighting material in High Temperature Water Base Mud (HTWBM) in order to enhance the rheology of the system.

TABLE OF CONTENT

List of Figures

Page

List of Table

Page

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND OF STUDY

This research project is about the studies of weighting agents is High Temperature Water Base Mud (HTWBM). Thus this project will explain the effect of the blended weighting agents in HTWBM system. An ideal weighting agent requires to be high density, chemically inert of controllable particle size, non abrasive, available in large quantities and cheap. The common weighting agent use in high temperature water base mud (HTWBM) is API Barite. The API Barite has a 4.2 specific gravity and chemically very stable. API Barite also can easily be ground to oilfield particle size requirement and does not degrade significantly during drilling operations. The high temperature water base mud (HTWBM) system that containing barite is not severely abrasive, besides the API Barite is natural product which is cheap and readily available. But, as the mud weight rises the quantity of the barite in the mud becomes much more significant. As result, mud properties such as rheology could be affected.

Thus in this study, others weighting agent which are High Purity Barite, Fine Grind Barite, Heamatite and Micromac are evaluated in the HTWBM system mixing with the API Barite. The reason why mixing to others weighting agents with API Barite are to maximize the rheology properties of the HTWBM system and also to study the effect of the blended weighting agents with API Barite since the API Barite is the common weighting agent that use for high temperature water base mud system.

1.2 PROBLEM STATEMENT

The more high temperature and high pressure well we dealing with, the more mud weight of the drilling fluids we need to use to prevent from the well problem such as blow out, lost circulation and etc.As the mud weight rises, the quantity of API Barite in the mud system becomes much more significant, as the result, the mud properties such as rheology could be affected. This project is about the studies of Weighting agents in High temperature Water Base Mud (HTWBM), so the of blend the weighting agents which are Fine Grind Barite, High Purity Barite, Heamatite and Micromax with the API Barite in ratio to study the trend and impact of each weighting agents in High Temperature Water Base Mud (HTWBM) whether this studied can enhance the mud properties of the High Temperature Water Base Mud (HTWBM) system or not.

1.3 OBJECTIVES

The objectives of this research are:

- To study and to understand the characteristic of the High Temperature Water Base mud System.
- To study the effect of blended Weighting agents in High Temperature Water Base Mud (HTWBM)
- To optimize the mud properties such as rheology
- To mix the mud with 17 ppg mud weight and get low plastic viscosity with no sagging.

1.4 <u>SCOPE OF STUDY</u>

The scope of this study is to do research about effect of the weighting agents blended with the API Barite in High Temperature Water Base mud System. Based on the understanding of drilling fluids system, the more high temperature and high pressure well. The more mud weight of the drilling fluids we need to use to prevent from the well problem such as blow out, lost circulation and etc. So as the mud weight rises, the quantity of API Barite in the mud system becomes much more significant, as the result, the mud properties such as rheology could be affected.

Furthermore this experiment were plan to add some experiment which are shale inhibitor test to make sure that the blended of weighting agents in High Temperature Water Base Mud System is applicable is real situation or not. Thus this experiment will investigate the effect of these weighting agents in high temperature well that we are going to dealing with. The temperature and the Mud weight of the mud is already decided which are 17 ppg and 250^{o}F

CHAPTER 2: LITERATURE REVIEW

Statistics show an increase in the average depth of wells drilled recent years. As a corollary to this trend, drilling fluids have been improved in an effort to meet the problems inherent at temperature approaching 500F.the most importance are (1) deterioration of mud components and (2) the effects of solids on filtration and rheological properties.**[1]**. The acquisition and management of drilling data is of critical importance for high pressure, high temperature wells if well objectives are to be achieved and well control incidents avoided. Key decisions such as when to set casing or when to raise mud weight are often crucial.**[2]**. In addition, Most of deep wells have been drilled with water base mud.**[1]**

2.1 HIGH TEMPERATURE WATER BASE MUD

High temperature water base mud system are used in high temperature well usually comes with high temperature also. Water based drilling mud system most commonly consists of bentonite (gel) with additives such as barium sulfate (barite), calcium carbonate (chalk) or hematite. Various thickeners are used to influence the viscosity of clay based mud such as xanthan gum, guar gum, glycol carboxymethylcellulose and starch **[3]**. Some other common additives include lubricants, shale inhibitor, fluid loss additives (to control loss of drilling fluids into permeable formations). A weighting agents such as barite is added to increase the overall density of drilling fluid so that sufficient bottom hole pressure can be determined thereby preventing an unwanted influx of formation fluids.**[3]**.

The classification of a deep high temperature and high pressure well in the UKCS is many well where the undistributed bottom hole total depth or prospective reservoir section is greater than 300F and either the maximum anticipated pore pressure exceeds a hydrostatics gradient of 0.8 psi/ft or pressure control equipment with a working pressure of greater than 10,000 psi is required **[2]**. These are some of the characteristic of the high temperature and high pressure well:

1- The considerable depth at which a reservoir are encountered, 3600m to 6000m, resulting in long circulation times and heavy casing strings
2- 15,000 psi drilling equipment being operated and tested at the limit of its design
3- High mud weights of 2.1 and above to control reservoir pressure between 12,000 and 18,000 psi.
4- High temperature excess of 350^0F requiring specially prepared gown hole tools and high temperature seals for well control equipment
5- The high likelihood of having to deal with an influx

All these are the characteristic of the high pressure and high temperature well **[2]**. so the more high temperature and high pressure well the more we need to increase the mud weights, there is weighting agents take its role in the high temperature water base mud system in order to control the reservoir pressure.

2.2 WHAT IS WEIGHTING AGENTS

Weighting agents is a high specific gravity and finely divided solid material used to increase density of the drilling fluid. Barite is the common, with minimum specific gravity of 4.20 g/cm^3. Hematite is a more dense material, with minimum specific gravity of 5.05 g/cm^3, per API and ISO specifications. Calcium carbonate, specific gravity 2.7 to 2.8, is considered weighting material but is used more for its acid solubility than for density. Siderite, specific gravity around 3.8, has been used to density mud, but can cause problems by dissolving into the mud at high pH. Ilmenite, specific gravity of 4.6 has been used in drilling fluid and cement. Only barite and hematite have API/ISO standards. **[4].** But in some cases ilmenite also can be used as the weighting agents in drilling fluids system.

These are weighting agents that are going to be used for this project which are studies of weighting agents in high temperature water base mud:

1- API Barite

- API Barite is the barite that have API standards.Barite is a mineral consisting of barium sulfate ($BaSO_4$). The barite group consists of barite, celestine, anglesite and anhydrite. Barite itself is generally white or colorless and is the main source of barium. the specific gravity of the barite is 4.3-5 **SG[5]**

Figure 1: Baryte crystals on dolomite from Cumbria,

- Commonly used as a weighting agent for all types of drilling fluids, barites are mined in many areas worldwide and shipped as ore to grinding plants in strategic locations, where API specifies grinding to a particle size of 3 to74 microns. Pure barium sulfate has a specific gravity of 4.50 g/cm^3, but drilling-grade barite is expected to have a specific gravity of at least 4.20 g/cm^3 to meet API specifications. **[6]**
- Contaminants in barite, such as calcite, siderite, pyrrhotite, gypsum and anhydrite, can cause problems in certain mud systems and should be evaluated in any quality assurance program for drilling-mud additives.**[6]**

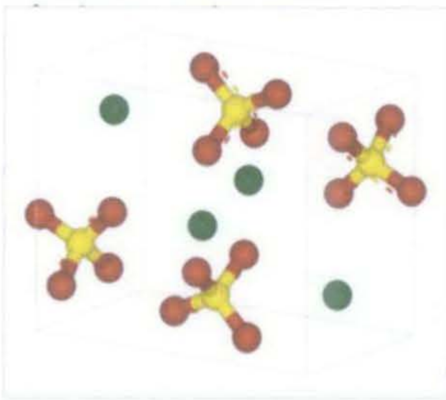


Figure 2: The unit cell of barite

2- Fine Grind Barite

- The properties of the fine grind barite are same with the API barite but the size distribution is different. The fine grind barite particle is way smaller than API barite particle size.

3- High Purity Barite

- The properties is also same with the fine grind barite and API barite but the high purity barite is more pure barite compare to the fine grind barite and the API barite.

4- Ilmenite

- Ilmenite is a weakly magnetic which is iron-black or or steel-gray. It is crystalline iron titanium ($FeTiO_3$) it crystallizes in the trigonal system, and it has the same crystal structure as corundum and hematite. The specific gravity of the ilmenite is 4.70-4.79 SG. **[7]**

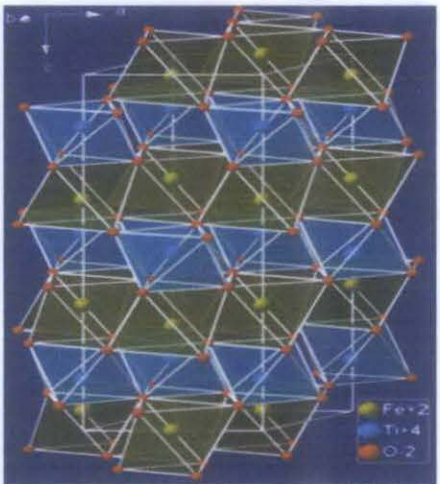


Figure 3: Crystal structure of ilmenite

- Ilmenite most often contains appreciable quantities of magnesium and manganese and the full chemical formula can be expressed as (Fe, Mg, Mn, Ti) O3. ilmenite is a common accessory mineral found in metamorphic rock and igneous rocks.**[7]**

5- Hematite

- Hematite, also spelled as haematite, is the mineral form of iron (III) oxide (Fe_2O_3), one of several iron oxides. Hematite is a mineral, colored black to steel or silver-gray, brown to reddish brown, or red. It is mined as the main ore of iron. Varieties include *kidney ore*, *martite* (pseudomorphs after magnetite), *iron rose* and *specularite* (specular hematite). While the forms of hematite vary, they all have a rust-red streak. Hematite is harder than pure iron, but much more brittle. Maghemite is a hematite- and magnetite-related oxide mineral. Has a specific gravity up to 4.9 – 5.3 SG**[8]**

Figure 4: Hematite (blood ore)

- The mineral form of ferric oxide [Fe_2O_3]. The hematite ore used as a weighting material in drilling muds has a mica-like crystal structure that grinds to particle size suitable for use in drilling fluids. To check for potential wear, an abrasion test is usually run on hematite as a quality control pilot test.**[9]**

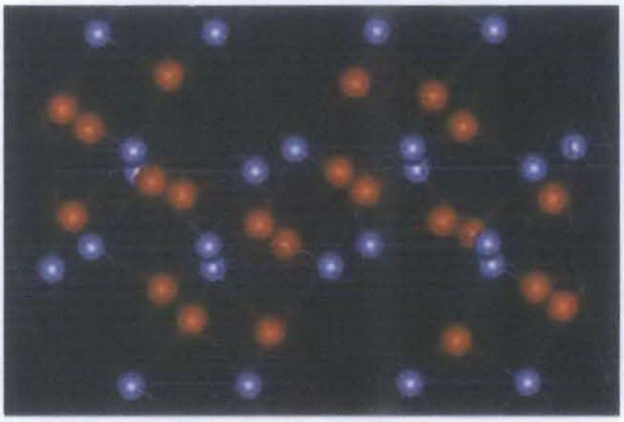


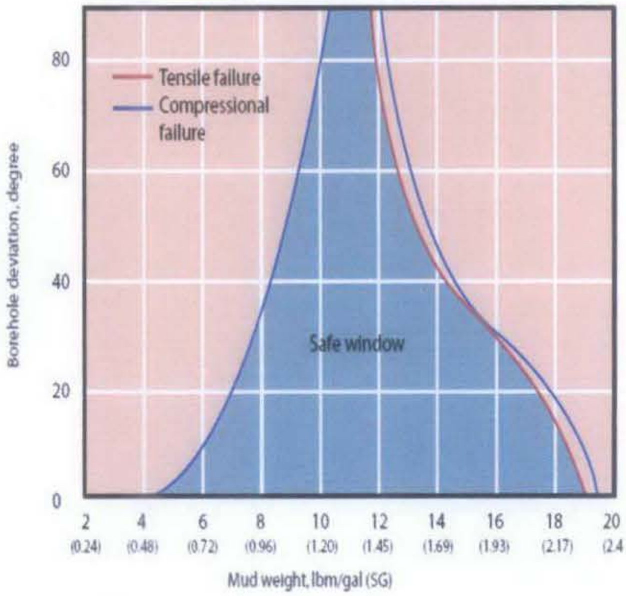
Figure 5: Crystal structure of hematite

6- MICROMAX

- MICROMAX is a weight additive increases slurry density with hausmannite ore ground to an average particle size of 5 microns. Unlike most weighting materials, MICROMAX weight additive remains in suspension when added directly to mixing water. MICROMAX weight additives can be used at bottomhole circulating temperatures between 80° and 500°F (27° to 260°C). In deep wells with high temperatures and pressures, MICROMAX weight additives can help restrain formation pressures and improve mud displacement. Additive concentrations depend on the slurry weight designed for individual wells. Because of the fine-ground ore in MICROMAX additive, higher concentrations of retarders might be required to achieve the thickening times provided by other types of weight additives. Slurries containing MICROMAX additive might also require the addition of dispersants. The Environmental Protection Agency does not classify MICROMAX weight additives as hazardous waste. **[10]**

2.3 PROPERTIES OF DRILLING FLUIDS

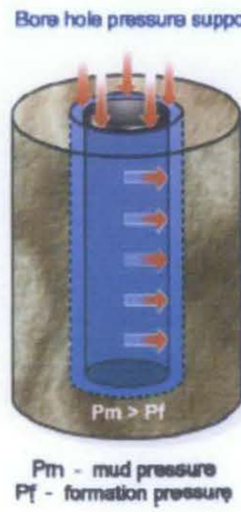
Drilling fluids are designed specifically to suit each well that is going to be drilled. The engineering design of drilling fluids takes into account all the mud properties to produce mud with the desired functions. The main properties of drilling fluids are: **[11]**



- Mud Density
- Rheology
- Shear rate and stress
- Fluid Loss
- Inhibition
- Solids Content

1- Mud Density

Mud density, or more commonly mud weight, is the column of mud that replaces the rock that is drilled. The mud column provides bore pressure support to the walls of the wellbore. In most cases, mud pressure (Pm) should be higher that formation pressure (Pf) to prevent the walls from caving in and formation fluids from entering into the wellbore causing a kick or a blowout.



The first critical step towards designing a drilling fluid is to establish the mud weight required to provide the correct level of bore pressure support. Common practice in determining the suitable mud weight is based on the predicted formation pore pressure gradient plus an additional pressure of 200 to 500 psi, so that in constantly remains within the equivalent circulating density of the formation (ECD)- within the stable window. **[11]**

Mud pressure column should not be lower than the pore pressure gradient to avoid hole erosion, cave-ins, under/overgauged hole and sloughing of the well wall. However, if the mud weight is too high, propagation of formation fracture will be initiated. This can lead to mud losses and formation damage. Therefore one of the key elements to successfully drilling a stable, near gauge wellbore depends upon planning the correct mud weight overbalance. **[11]**

2- Rheology

Rheology is the science of deformation and flow of matter. By making certain measurements on a fluid, it is possible to determine how that fluid will flow under a variety of conditions, including temperature, pressure and shear. **[11]**

3- Viscosity

Viscosity is the substance's resistance to flow and is required in addition to flow rate for hole cleaning. **[11]**

Viscosity = shear stress (flow pressure)/ shear rate (flow rate)

4- Shear Rate and Shear Stress

Shear rate is the velocity variation with distance while shear stress is defined as a stress which is applied parallel or tangential to a face of a material, as opposed to a normal stress which is applied perpendicularly. Higher shear rates causes greater resistive force (shear stress). In normal drilling activity, shear stresses in the drill string (where higher shear rate exist) exceed those in the annulus (where lower shear rates exist). **[11]**

5- Plastic Viscosity

Friction is fluid is caused by solids concentration, size and shape of solid & viscosity of the fluid phase. PV is usually regarded as a guide to solids control. PV increases when the volume of solids increases or when the size of particle decreases. **[11]**

6- Yield Point

Yield Point is the initial resistance to flow caused by electrochemical forces between the particles. This is due to charges on the surface of the particles dispersed in fluid phase. Thus, yield point is dependent upon the surface properties of the mud solids, the volume concentration of the solids and the ionic environment of the liquid surrounding the solids. The high viscosity resulting from high yield point is caused by introduction of soluble contaminant (ions) such as salt, cement, anhydrite or gypsum which interacts with the negative charges on the clay particles. Yield point can be treated with proper chemical treatment. **[11]**

7- Gel Strength

The gel strength (10 second gel and 10 minute gel) indicate the attractive force (gellation) in drilling fluid under static conditions. Progressive gels indicate increase in gellation over a period, Excessive gellation can cause problems by swabbing, surging, difficulty getting logging tools to the bottom, retaining of entrapped air or gas in the mud and retaining of sand and cuttings while drilling. **[11]**

8- Fluid Loss (Filtration)

Fluid loss is an indication of the amount of water lost from the formation (the passage of filtrate into the formation due to the differential pressure), the solids in the mud usually forms as a filter cake which prevents excessive fluid loss. Desired mud cake properties are :

- Thin and low friction coefficient
- Low permeability

9- Inhibition

Clay has a tendency of swelling when it comes into contact with water and this causes wellbore stability problems. An inhibitive mud tends to retard or prevent the appreciable hydration or dispersion of formation clays and shales by chemical and physical means. **[11]**

10- Solids Content

All mud contains solids (weighting agent, bridging agents, clays, polymers). In addition to that, drill cuttings and fine solids builds up periodically in the mud when drilling. Solids in mud can be determined by its plastic viscosity. The higher the PV is the more solids are in the mud. **[11]**

2.4 THE FORMULATION OF HTWBM

Chemicals	Hamilton Beach Mixer		
	Mixing order	Mixing Time (min)	Mixing Speed
Water	1		High
Soda Ash	2	2	High
Potassium Chloride	3	2	High
Viscosifier	4	5	High
Filtration Control	5	5	High
Viscosifier	6	5	High
Glycol	7	2	High
Weighting material A	9	5	High
Weighting material B			
Caustic soda	10	2	High
Corrosion Preventer	11		High
Total mixing time		45	

Table 1: HTWBM mixing procedure

CHAPTER 3: METHODOLOGY

3.1 PROJECT FLOW

The overall project work will follow the chart below:

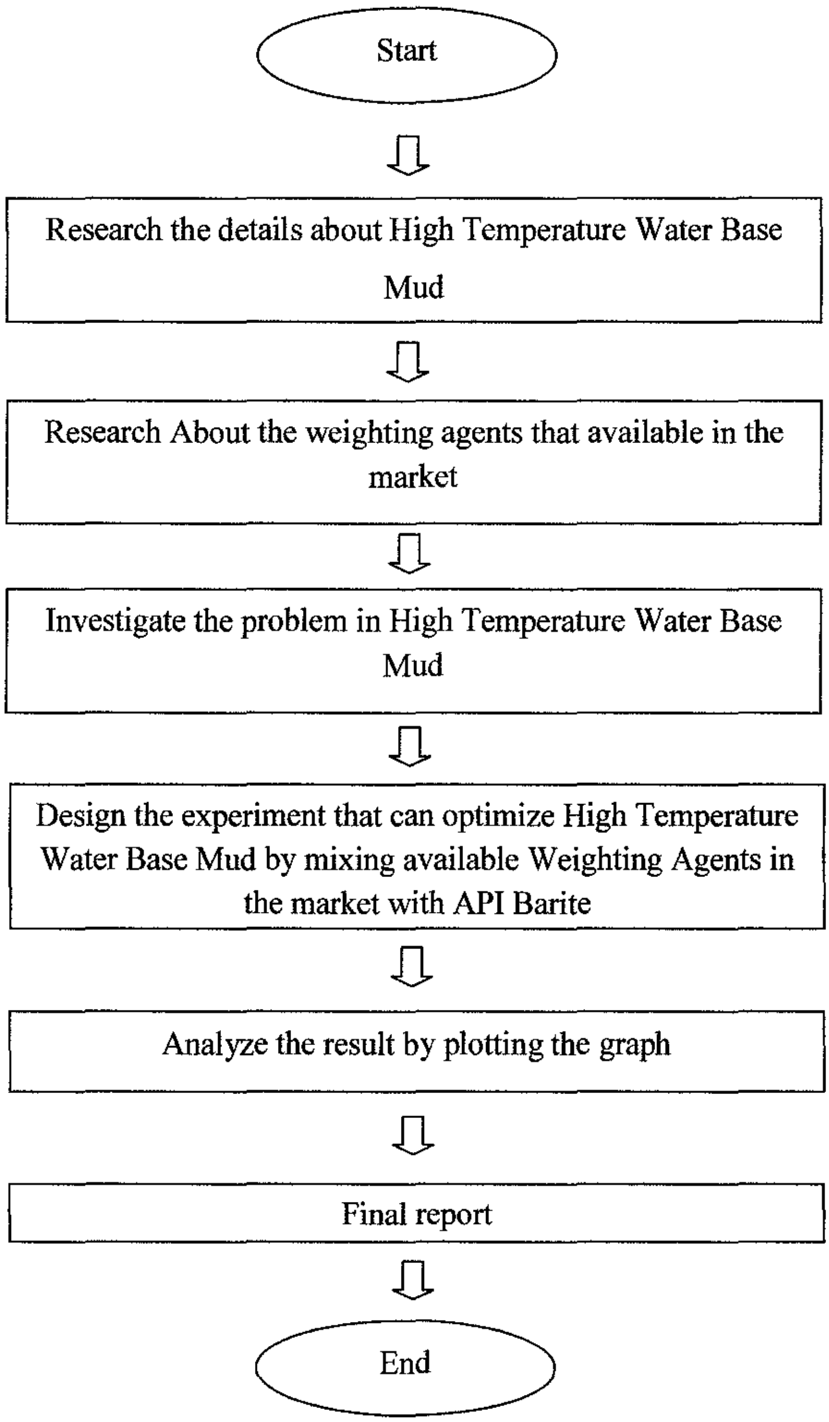


Figure 6: Project Work Flow

3.2 PROJECT ACTIVITIES

The overall experiment work flow will follow the chart below:

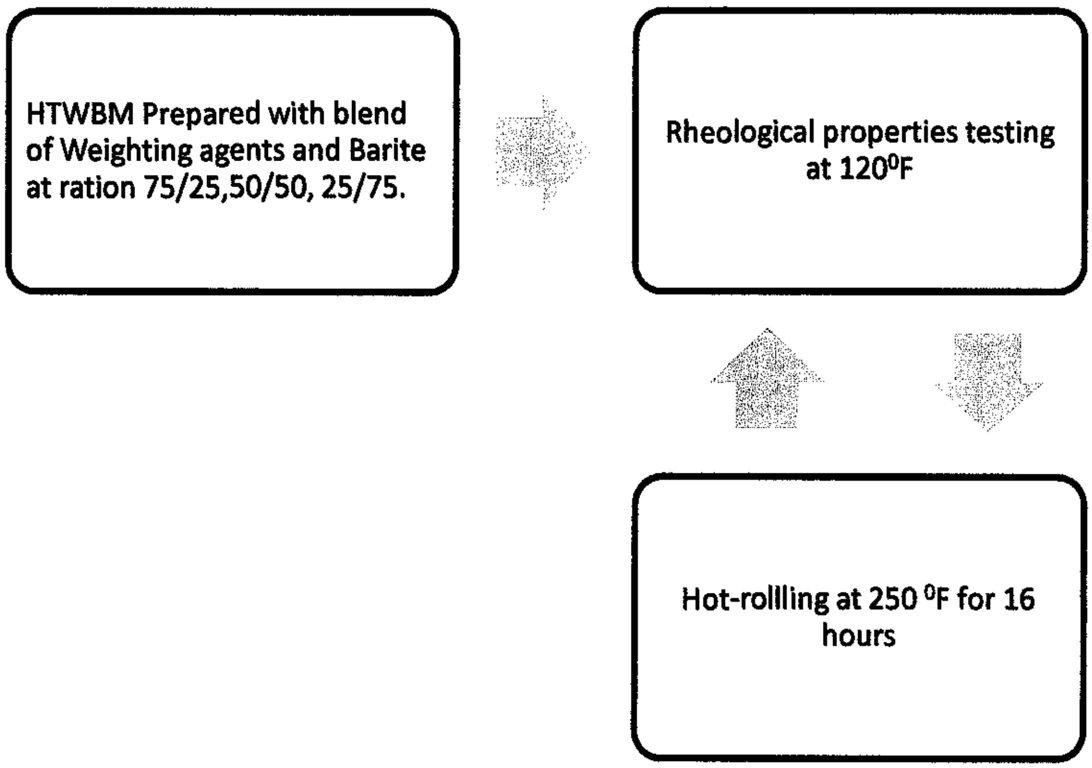


Figure 7: Experiment work flow

3.3 TOOLS

So far for the final year project 1, the tools that have been used are as follows:

- **Microsoft excel 2007:**

  For this project, I will do the Formulation of High Temperature Water Base Mud by using excels.

- **Information Resource Centre:**

  The library is the source of information that can be used to extract important information for this project. The main focus of research is at the journal section and the available book. Information gained from this location is of the properties of Drilling Fluids.

- **Online journal reviews:**

  Online journals can be found on the internet. Among the site to find journals are like OnePetro and ScienceDirect. Most of the journals available are SPE paper and PETSOC paper. The SPE paper is really helpful cause most of the paper was wrote by experienced people and have field background.

3.4 MATERIALS AND EQUIPMENT

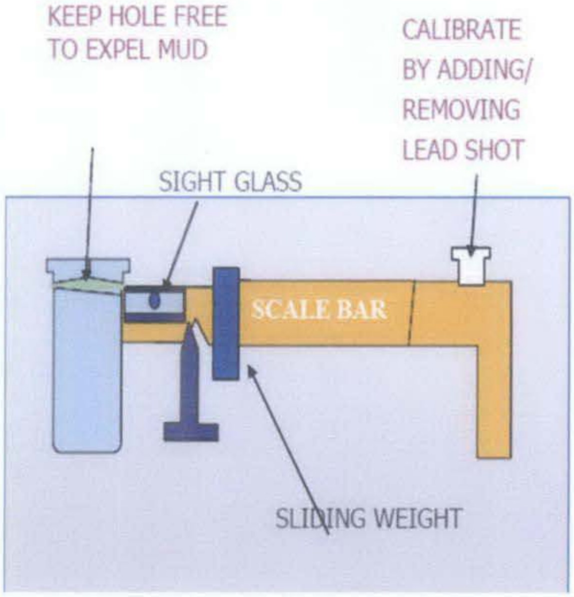
3.4.1 Materials

There are several materials needed to conduct the experiment in order to investigate the effect of weighting agents in high temperature water base mud. The materials needed are weighting agents which are API Barite, Fine Grind Barite, High Purity Barit, Heamatite and Micromax. Are needed viscosifier, pH control, Fluid loss additives and others chemical additives to ensure the stability of the high temperature water base mud.

3.4.2 Equipments and Mud tests

Basic properties that will be measured for the drilling fluid are:

- Density
- Rheology
- Fluid Loss



3.4.3) Density

- Density is by convention called the mud weight
- Units are lb/gal or g/cc,
- Correct and frequent measurement is essential
- Two types of balance
    - ➢ Pressurized
    - ➢ Non pressurized

Figure 8: Mud Weight Balance

3.4.4) Rheology

Rheology is tested using the Fann 35 and Fann 75 instrument.

The Fann 35:

- Measure viscosity of mud
- Speed : 600,300,200,100,6 and 3 rpm
- Plastic Viscosity (PV) & Yield Point (YP)
  PV = 600rpm – 300rpm
  YP = 300rpm – PV
- Determine 10 seconds and 10 minutes gel
  - Suspension at static condition
  - Progressive/Non-Progressive gel

Figure 9: Fann 75

3.4.5) Fluid Loss

i) High Temperature High Pressure Filtrate Loss equipment will be run to determine the filtrate losses under a differential pressure of 500. Pressure applied is positive downwards, so gravity affects the results, but it is usually negligible.

Figure 10: HTHP Filtrate Loss

3.5 PROJECT PLANNING

Activities	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep
Research on Weighting agents in HTWBM		■							
Detail Studies on weighting agents in HTWBM		■							
Design experiment procedure			■						
Determine material, tools and equipment for experiment			■						
Conduct the Tests					■	■			
Weekly Observation of the Tests					■	■	■		
Record data and present in graphical form						■	■		
Evaluation and discussion base on result							■		
Research documentation				■				■	

Figure 11: Project Planning

CHAPTER 4: RESULT AND DISCUSSION

4.1 Result

4.1.1 Barite Vs Fine Grind Barite

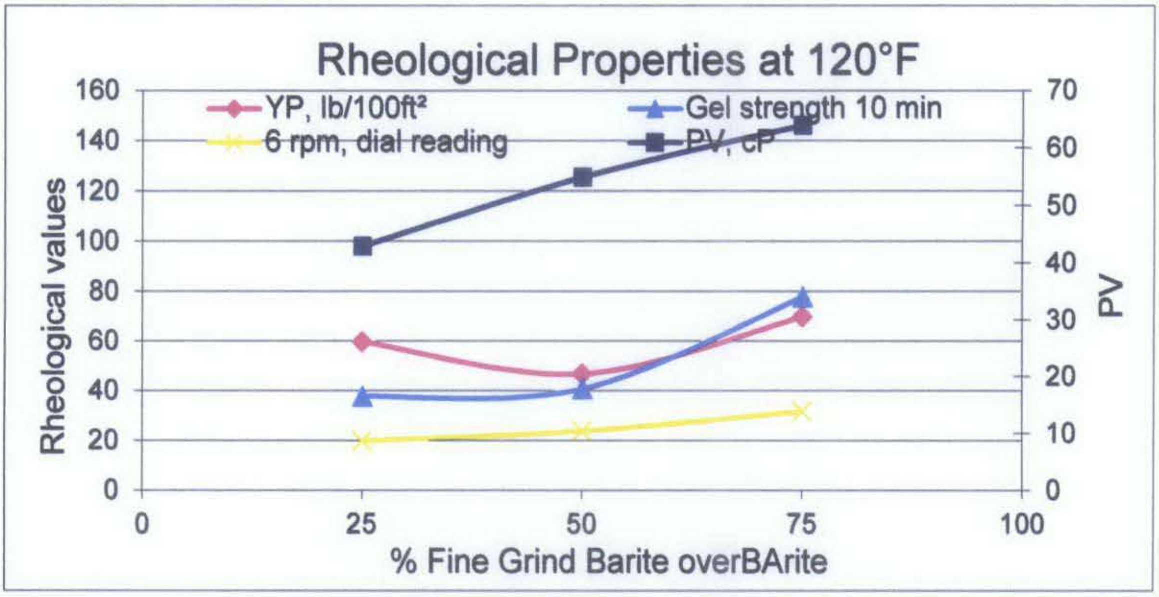


Figure 12: Result Barite Vs Fine Grind Barite (before hot roll)

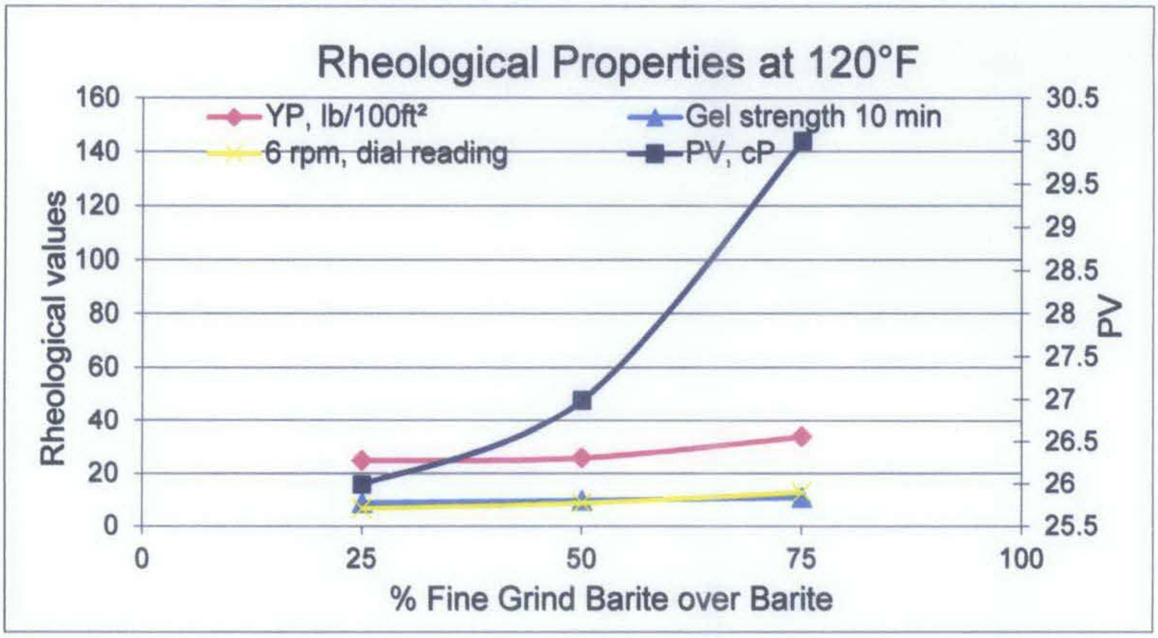


Figure 13: Result Barite Vs Fine Grind Barite (after hot roll)

4.1.2 Barite Vs High Purity Barite

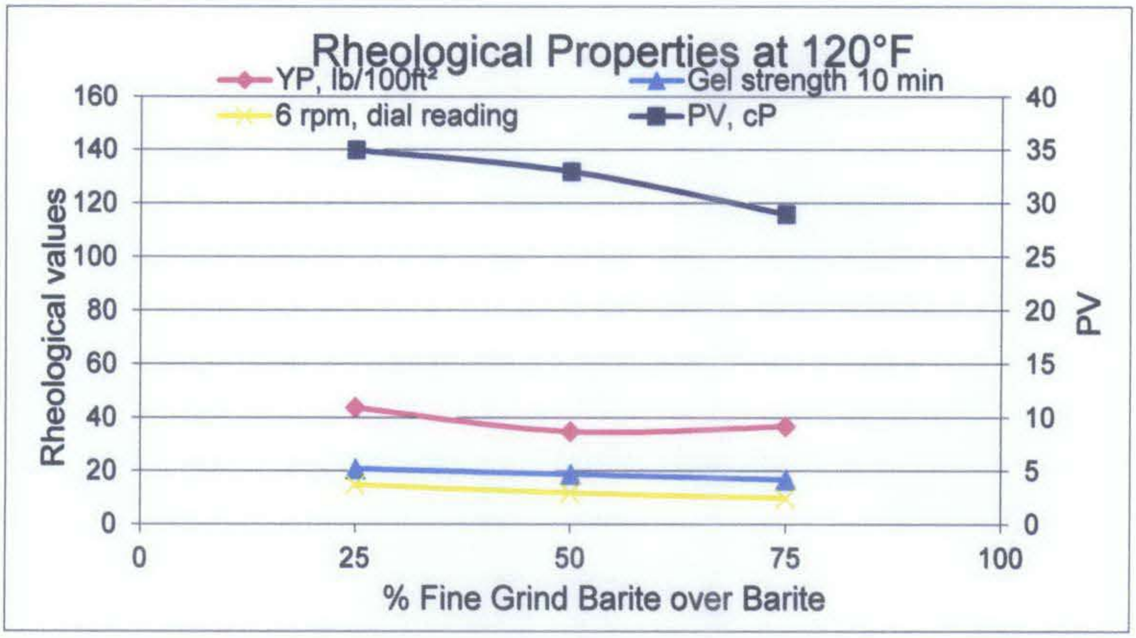


Figure 14: Result Barite Vs Fine Grind Barite (before hot roll)

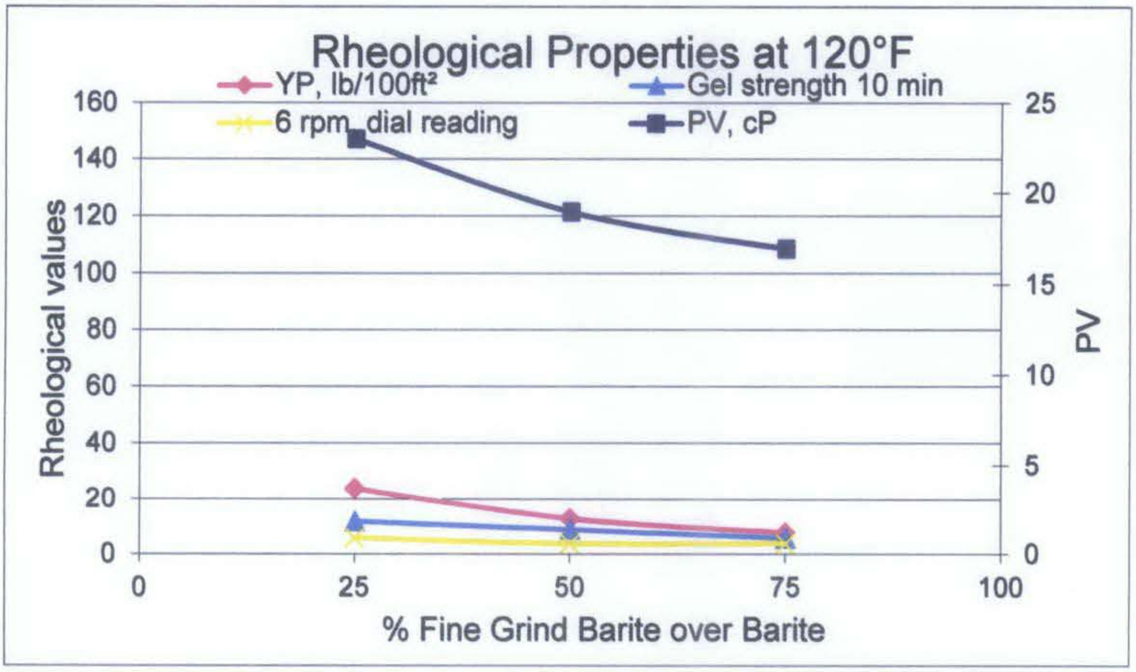


Figure 15: Result Barite Vs Fine Grind Barite (after hot roll)

4.1.3 Barite Vs HAEMATITE

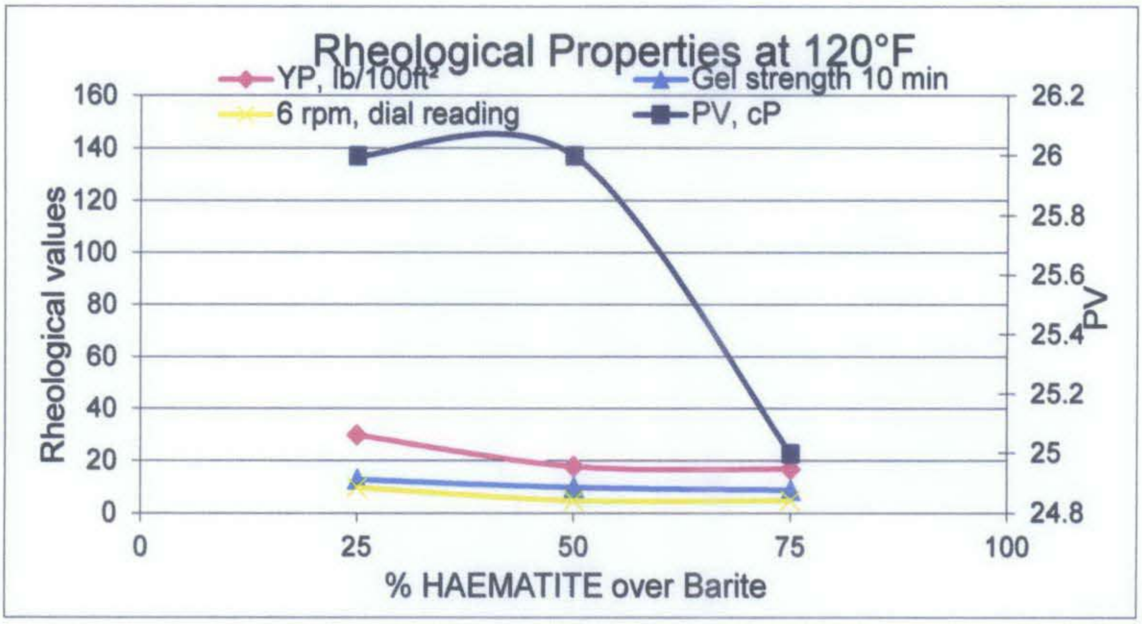


Figure 16: Result Barite Vs HAEMATITE (before hot roll)

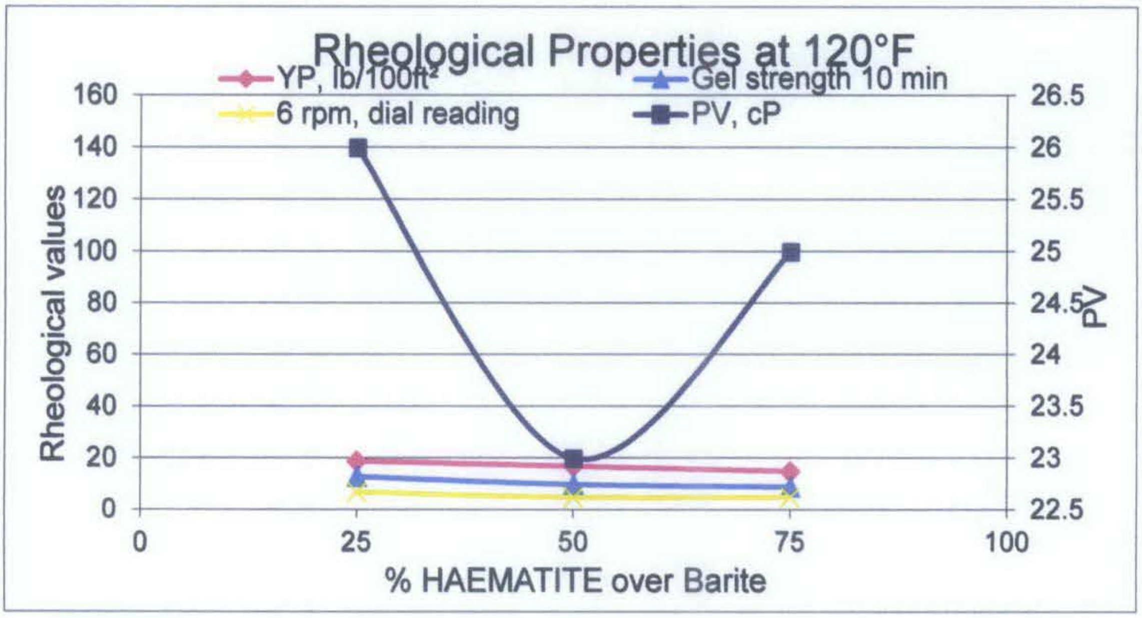


Figure 17: Result Barite Vs HAEMATITE (after hot roll)

4.1.4 Barite Vs Micromax

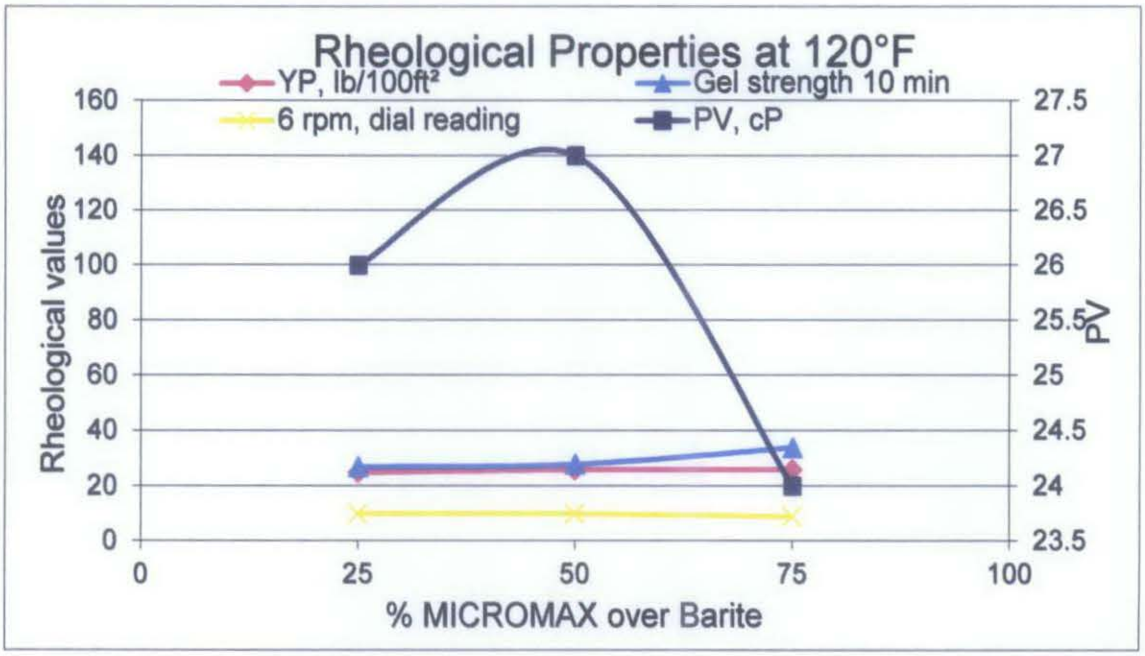


Figure 18: Result Barite Vs Micromax (before hot roll)

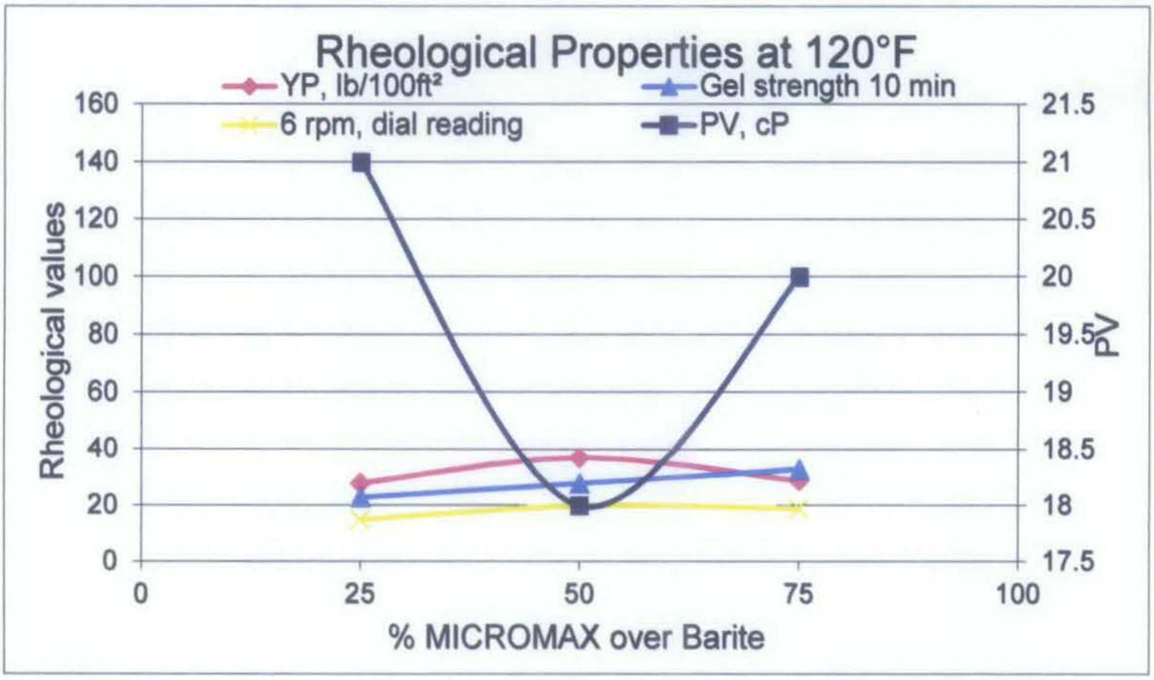


Figure 19: Result Barite Vs Micromax (after hot roll)

4.2 Discussion

The yield point of the mud indicates represents stress required to start fluid movement. Besides yield point, plastic viscosity (PV) is also an important criterion since excessive PV would cause high equivalent circulation density (ECD). The 6 rpm dial reading, gel strength 10 minutes and gel strength 10 seconds are also recorded.

The blended weighting agent between Fine Grind Barite and API Barite in HTWBM shows increasing trend of rheological properties across the graph. From figure 14 (before hot roll), it has been observed that the plastic viscosity changes drastically upon addition of Fine Grind Barite in HTWBM. It was noted that with increasing Fine Grind Barite will also increase the PV value. With the inclusion of Fine Grind Barite the YP remain above 30 $lb/100ft^2$. The gel strength at 10 minutes is also progressive. In figure 15 (after hot roll) the rheological properties seems like a little bit decreasing with the value but still in the trend which is increasing Fine Grind Barite in the mud will also increase the rheological properties in terms of 600 rpm reading and PV value.

As for the blended particles of High Purity Barite and API Barite, it could be seen in figures 16 and 17 that there is decreasing trend in rheological properties across the graph. As amount of High Purity Barite increase, the rheological properties decrease. The value of YP after hot roll at 250F for 16 hours reduces from 24 $lb/100ft^2$ at 75% API Barite to 8 $lb/100ft^2$ at 25% API Barite.

As expected, the HTWBM with blend of Haematite and API Barite reduces rheological properties as depicted in figures 18 and 19. The rhelogical properties decrease with increasing percentage of Haematite in HTWBM.

The last weighting agent studied was blend of micromax in API Barite. Results were shown in figure 20 and 21. The value of Gel 10 minutes after Hot roll at 250F for 16 hours are increasing with the increasing amount of Micromax.

Appropriate blend of weighting materials will provide desirable rheological properties. The interest of using fine particles such as Fine Grind Barite blended with API Barite in HTWBM is to reduce sag in HTWBM. According to Stoke's Law **[12]**, the finer the size of weighting material used, the slower settling velocity. Hence it reduces the potential of sagging. Fine weighting materials such as Fine Grind Barite also have larger surface area. As the result, higher interaction between Fine Grind Barite surface with other solid particle and polymer in the fluid has resulted in severe flocculation.

Higher density weighting materials has lower contaminants content. Most of the contaminant in weighting material would be clay. Reduction of clay in HTWBM would assist in preventing heat flocculation of drilling fluid. The HTWBM containing blend of API Barite and high density weighting materials should gives lower rheological properties because of the reduced solid content. This trend was shown in HTWBM containing blend of High Purity Barite and API Barite, and blends of Haematite and API Barite. This is because High Purity Barite is a higher purity barite with 4.51 SG. Hence High Purity Barite gives less viscosity. The specific gravity of Haematite, is 5.14, which is significantly higher than barite. Therefore, less solid was used in fluid formulated with haematite. The optimization of Haematite and API Barite should be carried out because of the high potential of obtaining better mud properties. Micromax is manganese oxide with specific gravity of 4.82. Micromax should give lower rheology because of higher density. However its lower particle size and high surface area may lead to flocculation when used in a high ratio.

CHAPTER 5: CONCLUSION

Weighting agents with higher specific gravity can be used to supplement API Barite as it can further improve rheological properties. Further optimization of 50% Haematite vs. 50% API Barite and 50% micromax vs. 50% API Barite should be carried out to assess its potential. Addition of fine weighting material with similar density should be avoided at 17 ppg fluid due to the high possibility of promoting flocculation in the fluid. The aim of the project is to studies the effect of blended weighting agents in high temperature water base mud and get the sample with low plastic viscosity (PV) and no sagging. After done all the experiment no sagging appeared in the muds.

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