ISSN 2278 – 0211 (Online)

Potential Usage of Local Weighting Materials in Drilling Fluid a Substitute to Barite

Omoniyi, Omotayo Ádewale
Lecturer, Department of Petroleum Engineering Abubakar Tafawa Balewa, University Bauchi, Bauchi State, Nigeria
Mubarak, Salihu
Department of Petroleum Engineering Abubakar Tafawa Balewa, University Bauchi, Bauchi State, Nigeria

Abstract:
Barite has been used to increase the density of drilling fluids (DF) since 1922. However, circumstances and needs are changing:The API has recently introduced a new standard of 4.10 sg barite in recognition of diminishing supplies of readily available barite that meet API's standard minimum density specification of 4.20 sg - high quality barite is running out. The search for new hydrocarbon resources to replace reserves has resulted in more difficult drilling conditions & fluid requirements e.g. deepwater, ERD, HPHT etc., where ECD management, sag control&formationdamagemitigationarecriticaltosuccess.Alternative weighting materials (WM) such as manganese tetraoxide, treated micronized barite & cesium formate have been successfully used to handle many of the problems mentioned, but they are expensive & not produced in large volumes[Menzel, Dieter, and Sachtleben Chemie]1. Therefore, their application tends to be restricted. There is, therefore, a need for alternative weighting materials capable of providing better functionality than barite, available in sufficient volumes to meet requirements and be competitively priced. This study considers the feasibility of locally available ore minerals as a weighting agent, suitable for use in drilling and completion fluids, which offers significant advantages in the control of ECD, sag & formation damage. It is denser than barite, available in large volumes and is significantly cheaper than the current , high-end weighting materials. Test results are given showing stable fluids with low plastic viscosity, gel strength and sag. Accordingly, it provides a viable alternative product, intermediate between barite and the more expensive weighting material.

Keywords: *Barite, Hydrocarbon, Drilling, Formation damage, Gel strength, Plastic viscosity.*

1. Introduction

Weightmaterials are compounds that are dissolved or suspended in drilling fluid to increase its density. They are usedto control formation pressures and to help combat the effects of sloughingor heaving shales that may be encountered instressed areas. While minimizing the increase inresistance to flow of the drilling fluid [Haaland, Ellen, Pettersen gier, and Tuntland].8Until now ground barite with a specific gravity of 4.2 has been the most common weight material for drilling fluids. The demand of the free world is now approximately 2 million tons per year corresponding to 55% of the total barite production [Mohamed Al-Bagoury, and Chris Steele]2. Because of increasingdrillingactivities, the demand of high quality barite as drilling fluid weightingagent is expected to be increasingly difficult to meet; in addition, the supply of barite is geographically limited, with high transportation cost. However, for the horizontal, small bore, extended long-reach, and other challenging drilling techniques employed routinely today, API specification barite can be troublesome.Other than the density requirements, API specification barite provides little value to a drilling fluid. Conversely, barite is prone to sag, and so requires viscosifiers and other gellants to keep it in suspension. Also, drilled solids that incorporate into a drilling fluid quickly assume the particle size of API specification barite, resulting in reduced solids separation efficiency at the shakers and Centrifuges [Gatlin C]3. However, there is need for an alternative weighting agent that will be available in significant quantity, competitively priced and that will provide better functionalitythan barite. In the past, numerous trials have been undertaken to substitute barite with other heavy metal compounds with specific gravities higher than 4.2.None of these materials however proved successful, because the price was too high, the required amounts were not available in sufficient quantities or the properties in drilling mud showed disadvantages. Weighting materials such as magnetite, lead oxide, siderite and dolomite have only been used to a limited extent. Locally available minerals have now been introduced; these materials are; generally applicable, available in sufficient quantities, produced with constant quality, and comparable with barite price.

1.1. Choice of Weighting Agent

The choice of weighting agent to be used in drilling fluids is determined by the need to;

1) Provide low rheology (low plastic viscosity) particularly in high density fluids
2) Show low settling tendency, providing low sag.
3) To be easily removable from the reservoir by mechanical or chemical means
4) To be hard enough not to create fines during drilling which may cause formation damage or high gel values.
5) Should contain a minimum of coarse particles to prevent abrasion.
6) To be sustainable and readily available and in large quantities
7) To have a good HSE profile.
8) To be cost effective

Hence, in this project, five [5] different locally available mineral (minerals found within Nigeria) are used and analyzed namely:- BARITE [Baso4], CALCITE (Caco3], GALENA [Pbs], ILLMENITE [Feo.tio2], HEMATITE [Fe2O3]

1.2. Objectives of the Study

Evaluation of five [5] different local weighting materials with respect to their specific gravity, solubility, pH, viscosity, gel strength, mud weight. Plastic viscosities, apparent viscosity, yield points, hardness and cost effectiveness in drilling fluid. Evaluation of five [5] different local weighting materials in drilling fluid from the economic point of view. Possible suggestion of local weighting material that will serve as a substitute to imported Barite in drilling fluid.

1.3. Scope and Limitation

This research is limited to laboratory preparation of equal volume of drilling fluid using five(5) different locally available weighting materials and subsequently evaluating their respective mud weights, PH, solubility, viscosities[plastic and apparent] , gel strength, hardness and cost effectiveness

2. Drilling Fluid

Drilling fluid is usually a mixture of water, clay, weighting material and a few chemicals. Sometimes oil may be used instead of water, or oil added to the water to give the mud certain desirable properties [Gatlin, C] 3. Drilling fluid is used to raise the cuttings made by the bit and lift them to the surface for disposal. But equally important, it also provides a means of keeping underground pressures in check. The heavier or denser the mud is, the more pressure it exerts. So weighting materials are added to the mud to make it exert as much pressure as needed to contain formation pressures.

2.1. Drilling Fluid Additives

There are fundamental aspects that have to be controlled in order to have an effective, successful, and purposeful drilling fluid. These aspects can be categorized as:

-Weight Control
-Viscosity Control
-Fluid Loss Control
-Corrosion Control

<u>2.1.1 Weight Control:</u>

Weight Materials

They are substances with high specific gravity which can be added to the mud to increase its density usually to control formation pressure and to help combat the effects of sloughing or heaving shales that may be encountered in stressed areas while minimizing the increase in resistance to flow of the drilling fluid. [Menzel, SachtlebenChemie GmbH]1.

Any substance that is denser than water and that does not adversely affect other properties of the drilling fluid can be used as a weighting material [Blomberg and nils E. 1984].16

There are two generic types of weighting agents;

[A] -high concentrated water-soluble salts such as chlorides (Na, Ca), bromides, formates and phosphate brines.

[B] -solid weighting materials.

<u>2.1.2. WATER- Soluble Salts</u>

Soluble salts are used primarily in workover and completion operations to formulate solids-free fluids. Fluid densities ranging from 9.0 to 21.5 ppg can be attained, depending on the salt(s) used [Christopher G, struchtemaver, james P, and Mustapha. el-shahed] 12. The Table1 below outlines the maximum densities that can be attained for single-salt systems at a temperature of 70°F.Although sodium chloride and calcium bromide increase the density of water-base and oil-base fluids, they are usually added for reasons other than to increase density.

2.2. Solid Weighting Materials

Any solid substance that is denser than water and that does not adversely affect other properties of the drilling fluid can be used as a weighting material (see table 2) such as;-

2.2.1. BARITE [BaSO4]:

Barite is a name that was derived from the Greek word "barus" (heavy), it is the mineralogical name for barium sulfate [BaSO4]. In commerce, the mineral is sometimes referred to as "barytes." It is usually colorless or milky white, but can be almost any color, depending on the impurities trapped in the crystals during their formation. Barite is relatively soft, measuring 3-3.5 on Mohr's scale of hardness. It is usually heavy for a non-metallic mineral. The high density is responsible for its value in many applications. Barite is chemically inert and insoluble. It occurs as a vein filling and as a gangue mineral in silver, zinc, copper, nickel and lead ores.[Arcos, D., Zhu, D. and Bickel, E,] 4

Although barite contains a "heavy" metal (barium), it is not a toxic chemical under Section 313 of the Emergency Planning and Community Right-to-Know Act of 1986, because it is very insoluble.

Chemical Formula: BaSO4

-Composition: Molecular Weight = 233.39 gm

Barium 58.84 % Ba 65.70 % BaO

Sulfur 13.74 % S 34.30 % SO3

Oxygen 27.42 % O

100.00 % 100.00 % = TOTAL OXIDE

-Empirical Formula: Ba(SO4)

-Environment: Sedimentary rocks and late gangue mineral in ore vein

-Uses

By far, the principal use for barite is as a "weighting agent" in oil and natural gas drilling. In this process, barite is crushed and mixed with water and other materials. It is then pumped into the drill hole. The weight of this mixture counteracts the force of the oil and gas when it is released from the ground. This allows the oil and gas rig operators to prevent the explosive release of the oil and gas from the ground.

Currently, over 75% of barite consumption in the U.S. is for this drilling application [Mclean. HR and Addis, MA]5. However, the consumption in drilling "mud" fluctuates from year to year, as it is dependent on the amount of exploration drilling for oil and gas, which in turn depends on oil and gas prices.

Application of barite

- Increase mud density up to 21 lb/gal (2.5 g/cm3)
- Control formation pressure
- Stabilize the borehole
- Prepare solids-laden plugs for well control Application

2.2.2. Galena

Galena is the principal lead ore mineral. It is lead sulfide (PbS). When pure, it contains 86.6 percent lead [pb] and 13.4 percent sulfur[S]. Galena is bluish-gray with a bright metallic luster when freshly broken, and dull gray when weathered. It is soft, brittle, and very heavy. About 7.4 times as heavy as water. Galena most commonly forms cubic crystals, and breaks with perfect cubic cleavage [© Halliburton energy services company, US6548452] 7.

Galena is useful because it is soft, dense, and workable, melts at a relatively low temperature, and bonds readily with other metals. It was once extensively used in the petroleum industry in formation of drilling fluid.

2.2.3. Hematite

Possible substitutes for barite, especially in the oil drilling industry, include other similar minerals, such as HEMATITE which is a synthetic iron ore which provide a good substitute for barite. [once widely used by a German company].However, these alternative have yet to be widely used in the oil industry, and barite continues to be the preferred commodity for this application as long as barite production remains strong [Thane K. stinson, East st, lois,andlorena Ayers].6 .

2.2.4. Ilmenite [Fetio3]

Ilmenite, mineral also regarded as an iron titanate, [FeTiO3]. It is massive, that is, without a regular form; occurring as rhombohedral tabular crystals (see Crystal), frequently enveloped in crystalline metamorphic rocks; as an accessory mineral in igneous rocks; and loosely in sand. Ilmenite is an opaque mineral, black to brownish-red, with a metallic or sub metallic luster. It has hardness from 5 to 6 and a specific gravity of 4.5 to 5.0. The mineral is readily distinguished by a slight magnetic character. It is the chief source of titanium dioxide, TiO 2, which is used as a weighting material in drilling fluid. Ilmenite is found in large quantities in the Il'men' Range in the Ural Mountains, in Russia, from which the name is derived; in parts of Nigeria, Norway, Finland, Malaysia, and Australia; and, in the United States.[Haaland, Ellen, Pettersengier, &Tuntland]9.

2.3. Viscosity Control

2.3.1.Viscosifiers
Many different products are classified as viscosifiers; - Bentonite, attapulgite clays, subbentonites and polymers are most widely used viscosity builders. Bentonite, attapulgite clays and sub-bentonites all form colloidal suspensions in water. They increase viscosity, yield point and gel-strength by inter surface friction and by chemically binding-water..Polymers are multi-purpose additives that may simultaneously modify viscosity, control filtration properties, stabilize shale and create or prevent clay flocculation

2.3.2.Thinners
Mud thinners or dispersants reduce viscosity by breaking the attachment of clay plates through the edges and faces. The thinners absorb to the clay plates, thus disturbing attractive forces between the sheets. Thinners are added to a mud to reduce viscosity, gel strength and yield point. Most thinners can be classified as; - organic materials or as inorganic complex phosphates. Organic thinners include lignosulfonates, lignins and tannins. Inorganic thinners include Sodium acid pyrophosphate, tetra sodium pyrophosphate, sodium tetra phosphate and sodium hexametaphosphate. Organic thinners are good for higher temperature

2.4. Fluid Loss Additives
The reasons for fluid loss control are:
- To maintain hole integrity,
- To protect water sensitive shales,
- To minimize hole washout to achieve better casing cement jobs,
- To reduce fluid loss to productive formation and to minimize formation damage,
- To reduce log analysis problems,

2.4.1. Bentonite
- A multipurpose additive that aids in fluid loss control, barite suspension, viscosity generator for hole cleaning purposes,
- It is not suitable for use in environments high in concentration of sodium, calcium or potassium without pre-hydration,
- It may contaminate formations such as salt or anhydrite,
- Slurries are susceptible to the effect of high temperature gelation which could cause an increase in the fluid loss,

2.4.2. Starch
- They work well as fluid-loss agents in the presence of low soluble calcium or sodium ions,
- They are suitable for salt-water or gyp muds,
- An increase in viscosity is observed when it is used,
- A bactericide must be used to prevent degradation and fermentation,
- It degrades at temperatures over 200°F,

2.4.3. CMC
- It is active in low to moderate contaminating-concentrations, which makes it suitable for use in inhibited mud.
- It has temperature stability up to 400°F,
- A thinner may be necessary to counteract the viscosity effects of the additive,
- It may cause a thinning effect in some salt mud.

2.4.4. Cypan
- It can be used successfully in high-temperature regions due to its stability up to 400°F,
- It is highly sensitive of calcium ion contamination,
- It may cause dynamic filtration

2.4.5. XC Polymer
- It builds viscosity,
- It increases gel structure,
- It has low viscosity at high shear rates,

2.5. Selection of Drilling Fluids
Selection of the best fluid to meet anticipated conditions will minimize well
Costs and reduce the risk of catastrophes such as stuck drill pipe, loss of
Circulation, gas-kick, etc. Consideration must also be given to obtain adequate formation evaluation and maximum productivity. Some important considerations affecting the choice of mud to meet specific conditions are presented as follows [© Halliburton energy services company, US6548452, April, 2013]8.

-Location: The availability of supplies must be considered, i.e., in an offshore .well, the possibility of using salt water should be considered.
-Mud-making shale: Thick shale sections containing dispersible clays cause a rapid rise in viscosity as cuttings become incorporated in the mud. When the mud is unweighted, it is easy to reduce the excessive viscosity, however, when the mud is weighted, costly chemicals such as barite should be used to restore the mud properties
-Pressured formations: The density of the mud should be adjusted as pressurized formations are to be drilled. However, high density muds increase the cost of drilling and have risks of stuck pipe, loss circulation,
.-High temperature: Most of the mud additives degrade with time and elevated temperatures, which are higher than degradation temperature. Special additives must be used to make mud resistive to high temperatures
-Hole instability: Two basic forms of hole instability are hole contraction and hole enlargement. If the lateral earth stresses bearing on the walls of the hole exceed the yield strength of the formation, hole slowly contracts. The density of the mud should be high enough to resist contracting. Hole enlargement occurs at water sensitive shale zones. Shale stabilizers should be used to prevent hole enlargement
-Rock salt: To prevent the salt from dissolving and consequently enlarging the hole, either an oil base mud or saturated brine must be used.-Hole inclination: In highly deviated holes, torque and drag are a problem because the pipe lies against the low side of the hole and the risk of pipe stuck is high. Proper mud should be selected to prevent such problems, and keep cutting to be removed from the well properly.
Formation evaluation: The selected mud should be suitable for logging tools, MWD, Productivity impairment: Solids control or density adjustments should be considered properly to keep the formations non-damaged or blocked.

2.6. Functions of Drilling Fluids
In the early days of rotary drilling, the primary function of drilling fluids was
to bring the cuttings from the bottom of the hole to the surface [Jay P. simpson, O-Brien, Goins-Simpson, and assoccs, Inc] 10. Today, it has at least ten important functions.
Assists in making hole by:
1. Removal of cuttings
2. Cooling and lubrication of bit and drill string
3. Power transmission to bit nozzles or turbines
B- Assists in hole preservation by:
4. Support of bore hole wall
5. Containment of formation fluids
C-It also:
6. Supports the weight of pipe and casing
7. Serves as a medium for formation logging
D-It must not:
8. Corrode bit, drill string and casing and surface facilities
9. Impair productivity of producing horizon

3. Methodology
Five different locally available ore minerals[minerals found within Nigeria] that has almost the same property with barite ($BaSO_4$) in terms of its specific gravity, hardness, solubility in water, cost effectiveness etc or even better were used as weighting agents during the formation of the drilling fluids. namely:-Barite[$BaSO_4$],Hematite[Fe_2O_3],Galena[PbS], Calcite($CaCO_3$), and Illmenite[$FeTiO_3$].

3.1 Milling of Acquired Samples
Before a material is fit to be used in drilling fluid, it has to be in liquid or powder form. Hence, the local weighting materials namely; - hematite, barite, Calcite, ilmenite& galena were grinded into powder form using pestle and mortar.

3.2 Sieving of the Milled Weight Materials
This is done so as to prevent the abrasion of casing during its potential usage (while drilling) by coarser grain particles. It was done with the aid of an electric device called SIEVE (see fig.1) . This device comprises up of an agitator coupled with a mesh of various sizes [720-63] micro meter (see fig.2). The samples were poured gently into the upper sieve while the agitator vibrate thereby lowering the samples across the various mesh, hence, collecting the finest samples at the receiver plate.

3.3 Acquisition of Various Mud Additives such as C.M.C, bentonite, caustic-soda [NaOH], and subsequently, weighting them to the required quantity using a weighting balance as stated below;

3.4 Formulation of the Drilling Mud
Five [5] equal volume of;-
- Distilled water [1 quart each] - 20g of weighting agent [each]

- 20g of C.M.C - 20g of caustic soda [NAOH]
- 160g of bentonite

The following composition of the mud stated above were poured gently into a vessel containing one [1] quart of water and stirred continuously.

3.5 Finally, Measurement of Individual

3.5.1. mud weight

the weight of individual mud was weighed using mud balance(see ftg.3). This balance comprises up of a small vessel which was filled with the mud and a metering section which was adjusted gently to account for the mud weight. This balance has two [2] calibration on it, the upper calibration gives the mud weight in [g/cm3] while the lower calibration gives the mud weight in [lb/gal]. For this project, the mud weight was measured in lb/gal.

3.5.2. PH

The PH of each mud was measured using a PH-METER, it consist of a stirrer and a sensitive scale which were immersed into the mud and stirred gently with the stirrer. This meter gives the PH of the mud and the room temperature at which the PH was measured

3.5.3. Hardness

the hardness of each weighting agent was determined using a Mohr scale of hardness.Here, the samples were scratched against either a knife, Coin, glass etc and the corresponding hardness was determined from the scale .as shown in fig.4.

Finally, the Viscosity of the mudwere measured using NDJ 85N rotational viscometer. The mud was fed into a small cylindrical vessel and placed at the environmental chamber of the viscometer and the spindle lowered into the mud. As the spindle is being lowered into the mud, it's rotation and the corresponding viscosities were measured at 60, 30, 12, 6, and 3 rotations per minute using spindle 3(see fig.5).

3.5.4. Gel Strenght

The Gel strength is the shear stress measured at low shear rate. It was measured after the mud has set quiescently for a period of ten[10] seconds and ten[10] minute as in the standard API procedure. Although, measurement after 30 minute and 16 hours can be made[Marsh H]12.Subsequently, analysis of the five(5) different muds on their potential as drilling fluid economic standpoint (the price of each weighting agent used was determined using mines journal which contains price quotations of each of the pure samples used)(see table 3).

3.5.5. Discussion of Result

NAME: Barite
Chemical Formular: $BaSo_4$
Composition:

3.5.6. Observations

- Both weighting agents were insoluble in water.
- Both drilling muds were alkaline solutions [with PH > 8].
- Mud weight is dependent on the specific gravity of the weighting agents
- [mud weight increases with increasing specific gravity and vice versa].
- Muds with lower plastic viscosities are characterized with a higher yield point values.

3.5.7. Criteria for Selection of Alternative Weight Material to Barite

The choice of weighting agent to be used in drilling fluids is determined by the Need to [Wayne Matlock, Lee Com, M-I SWACO] 11.

- Provide low rheology (low plastic viscosity) particularly in high density fluids
- Show low settling tendency, providing low sag.
- To be easily removable from the reservoir by mechanical or chemical means
- To be hard enough not to create fines during drilling which may cause formation damage or high gel values. Should contain a minimum of coarse particles to prevent abrasion.
- To be sustainable and readily available and in large quantities
- To have a good HSE profile.
- To be cost effective

3.5.8. Conclusion

From the topic of this project research work "POTENTIAL USAGE OF LOCAL WEIGHTING MATERIALS IN DRILLING FLUID AS A SUBSTITUTE TO BARITE", five[5] different locally available mineral namely; ilmenite, hematite, calcite, and galena were obtained. Five [5] equal volume of water-base mud were prepared using each of this samples as a weighting Agent. The rheological properties of the muds as well as other properties were evaluated such as specific gravity, hardness, solubility in water, viscosity[plastic and apparent], yields point, PH, gel-strength and cost effectiveness are compared to the mud formulated using barite as a weighting agent as shown in the table above. After careful observation and comparison of these mud properties to that of mud formulated using barite as weighting agent, possible substitute for barite, especially in the oil drilling industries include ILMENITE. This provide a good substitute for barite especially considering the mud properties obtained when it wasused as a weight material, [with 4.6 specific gravity, characterized with lower plastic viscosity, moderate yield point, moderate gel value, relatively harder[4.0 0n Mohr scale of hardness], available in significant quantity ,exhibiting higher mud weight and competitively priced when compared to barite as shown in the table above.

4. Recommendation

4.1. Substitute and Alternative Source of Barite

Possible substitute for barite, especially in the oil drilling industries, include other similar minerals, such as; ILMENITE. These provide a good substitute for barite especially considering the mud properties obtained when it is used as a weight material, [with 4.6 specific gravity] characterized with lower plastic viscosity[its ability to drill faster due to low viscosity of fluid exiting at the bit nozzle], higher yield point[ability of the mud to transport cuttings out of the annulus], higher gel strength value[ability of the mud to suspend cuttings], relatively harder[4.0 0n mohr scale of hardness], available in significant quantity ,exhibiting higher mud weight and competitively priced when compared to barite as shown in the table above.

Drilling Engineering – Fall 2012

NEW MEXICO TECH

Drilling Fluid Components

Soluble Salts

Potassium chloride (KCl)	Weights up to 9.7 ppg
Sodium chloride (NaCl)	Weights up to 10.0 ppg
Potassium bromide (KBr)	Weights up to 11.6 ppg
Calcium chloride ($CaCl_2$)	Weights up to 11.6 ppg
Calcium chloride ($CaBr_2$)	Weights up to 15.3 ppg
Zinc bromide ($ZnBr_2$)	Weights up to 21.5 ppg

Prepared by: Tan Nguyen

Table 1: Single-Salt System at a Temperature of 70°F

Drilling Engineering – Fall 2012

NEW MEXICO TECH

Weighting Materials

Material	Principal Component	Specific Gravity	Hardness (Moh's Scale)
Galena	PbS	7.4-7.7	2.5-2.7
Hematite	Fe_2O_3	4.9-5.3	5.5-6.5
Magnetite	Fe_3O_4	5.0-5.2	5.5-6.5
Iron Oxide (manufactured)	Fe_2O_3	4.7	---
Iilmenite	$FeO \cdot TiO_2$	4.5-5.1	5.0-6.0
Barite	$BaSO_4$	4.2-4.5	2.5-3.5
Siderite	$FeCO_3$	3.7-3.9	3.5-4.0
Celesite	$SrSO_4$	3.7-3.9	3.0-3.5
Dolomite	$CaCO_3 \cdot MgCO_3$	2.8-2.9	3.5-4.0
Calcite	$CaCO_3$	2.6-2.8	3.0

Prepared by: Tan Nguyen

Table 2: Weighting Materials

Meassured Properties	Barite [Baso4]	Hematite [Fe203]	Ilmenite [Fetio3]	Galena [Pbs]	Calcite [Caco3]
Specific gravity	4.31	5.11	4.6	7.4	2.8
Hardness [Mohr scale]	3.0	5.0	4.0	2.5	3.0
Mud weight [lb/gal]	12.20	12.80	12.55	14.34	8.15
Plastic viscosity[pa. s]	6.36	4.17	1.62	-2.55	3.60
Apparent viscosity[pa. s]	3.191	2.399	0.955	-0.667	1.927
Yield point [lb/100 ft2]	0.0217	0.6275	0.2901	1.2152	0.254
Solubility [in water]	Insoluble	Insoluble	Insoluble	Insoluble	Insoluble
PH	12.4@ 30.4oc	12.6@ 30.5oc	12.8@ 33.4oc	12.8@ 32.8oc	12.5 @ 32.2oc
Cost effectiveness [US$/metric ton]FOB price	1500-2500		18 00-3000	1050-1100	

Table 3: comparism of rheological properties of the muds

Figure 1: Sieve Arrangement

Figure 2: Sieves Of Various Mesh Sizes (63-720) µM

Figure 3: Mud Balance

Figure 4: Mohr scale of mineral hardness' © 1998-2013

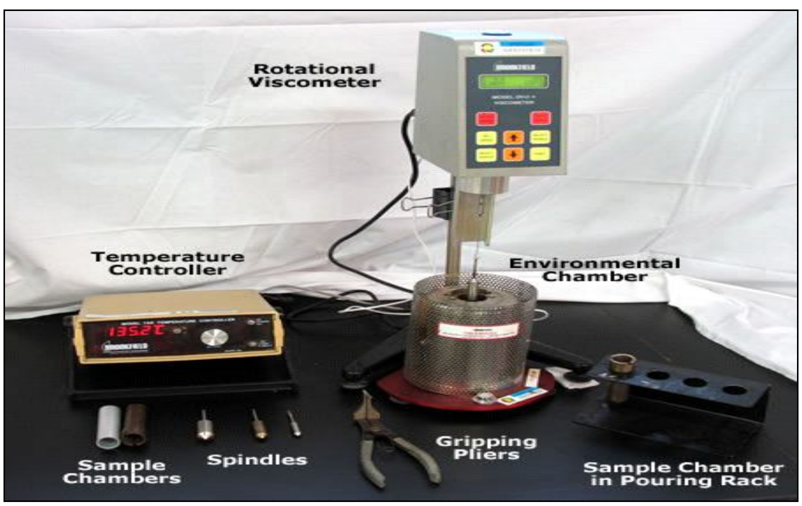

Figure 5: NDJ 85n Rotational Viscometer

5. References

1. Menzel, Dieter, SachtlebenChemie GmbH ‘ A New Weight Material for Drilling Fluids Based on Synthetic Iron Oxide’ ‘Fall Meeting of the Society of Petroleum Engineers of AIME, 30 September-3 October 1973, Las Vegas, Nevada. ISBN 978-1-55563-773-6
2. Mohamed Al-Bagoury, and Chris Steele ‘ A New Alternative Weight Material for Drilling Fluids’IADC/SPE Drilling Conference and Exhibition, 6-8 March 2012, San Diego, California, USA
3. Gatlin, C.: Petroleum Engineering Drilling and Completion hand book, 1960, by Prentice-Hall, W.C. Eaglewood Cliffins, N.J.
4. Arcos, D., Zhu, D. and Bickel, E., “Technical Economics and Risk Analysis for a Multilateral Well”, SPE Russian oil and Gas Technician Conference and Exhibition, Moscow, Russia, pp 28 – 30 October 2008.
5. Mclean. HR and Addis MA “Wellbore Stability: The Effect of Strength Criteria on Mud Weight” SPE Annual Conference, September, 1990.
6. Thane K. stinson, East st, lois,andlorena Ayers “ Iron oxide Weighting Materials For Drilling mud”, patented oct, 13, 1942. [US2298984].
7. 7. “Weight Materials for drilling fluid and method of creating and maintaining the desired weight” © Halliburton energy services company, US6548452, April, 2001
8. Haaland, Ellen, Pettersengier, &Tuntland “Testing of iron oxide as weight material for drilling fluid’ journal of petroleum engineering (6280-Ms] 1976.
9. Jay P. simpson, O-Brien, Goins-Simpson, and assoccs, Inc “The drilling mud Dilemma’ journal of petroleum engineering Technology (13927-PE) volume 37, number 2 February 1985
10. Wayne Matlock, Lee Com, M-I SWACO “Micronized weight material optimizes ERD drilling” February 2008.
11. H.A. nasr- el-Din, S.H, Al mutairi, H.H al hajj, J D. lynn, core laboratories. ‘Evaluation of new barite dissolver; lab studies’ SPE International symposium and exhibition on formation damage control, 18-20 February 2004, Lafayette, Louisiana.
12. Marsh H. ’properties and treatment of rotary mud’ petroleum development and technology, transaction of the AIME [1931]; 234-251.
13. Christopher G, struchtemaver, james P, and Mustapha s. el-shahed. ‘Influence of the drilling mud formulation process on the bacterial communities in thermogenic natural gas wells of the bernett shale’ Environ microbial> v.77 [14], jul. 2011.
14. Mohr scale of mineral hardness’ © 1998-2013. American federation of mineralogical societies, Inc.
15. Tor H. Omland,HelgeHodne, ArildSaasen and Per A. Amundsen.; Rig-Site Equipment Determines drilling fluid weight material sag;, Error! Hyperlink reference not valid. and product> drilling fluid system and product

Annexure

Rotations Per Minute [Rpm]	Readings [Pa.S]
60	1.010
30	1.369
12	0.000
6	0.000

Table 4: Dynamic viscosity of barite

Rotations Per Minute [Rpm]	Readings [Pa.S]
60	1.262
30	1.334
12	1.412
6	0.000

Table 5: Dynamic viscosity of hematite

Rotation Per Minute [Rpm]	Readings [Pa.S]
60	0.430
30	0.801
12	0.440
6	0.375
3	0.000

Table 6: Dynamic viscosity of ilmenite

Rotation per minute [RPM]	Readings [pa.s]
60	0.603
30	0.949
12	1.480
6	2.1oo
3	0.000

Table 7: Dynamic viscosity of galena

Rotation Per Minute [Rpm]	Readings [Pa.S]
60	0.987
30	0.543
12	o.673
6	0.000
3	0.000

Table 8: Dynamic viscosity of calcite

List of Terms
ERD= Extended Reach Drilling
HPHT=High Pressure High Temperature
ECD=Equivalent Circulating Density
HSE=Health Safety, and Environment