Petroleum Res. J. Vol. 12 (2000); P. 1-8, 5 Figs.

Evaluation of Itabirite as a Barite Substitute for Weighting Material in Water-based Muds

Mohamed Bizanti*

تقييم إمكانية استخدام إيتابرايت كمادة سائل حفر بديلة عن البارايت في سوائل الحفر المائية

محمد البزنطي

يُستَغَلّ أكثر من 90% من خام البارايت المعروف حالياً كمادة إضافة تزيد من كثافة سوائل الحفر أثناء عمليات التنقيب عن النفط والغاز، ونظراً لزيادة الطلب على هذا الخام ولوجود شوائب به، في بعض الأحيان، تؤثر على كفاءته كسائل حفر فإن الحاجة أصبحت ملحة للبحث عن مادة بديلة تزيد من كثافة سائل الحفر.

يتناول هذا البحث الفوائد والمشاكل الناجمة عن استخدام خام الإيتابرايت (الهيماتيت الغني بمعدن الميكا) كمادة بديلة تضاف إلى سائل الحفر. ولإيجاد كمية التآكل الناجمة عن استخدام هذه المادة تم اختيار ثلاثة أحجام تتراوح مجالاتها ما بين 74 إلى 125 و44 إلى 74 وأقل من 44 مايكرون. أجريت التجارب المعملية بواسطة جهاز خلط ولمدة 30 دقيقة وعند سرعات 9800 و11200 و12570 و14350 دورة في الدقيقة وتم تحليل ودراسة خواص اللزوجة والمرونة واللدونة والترشيح والتآكل الناتج عن استعمال هذه الأحجام المختلفة من مادة الإيتابرايت.

وللتغلب على مشاكل التآكل ونقص في الترشيح فإن هذه الدراسة تشير بأنه بالإمكان استخدام خام الإيتابرايت كمادة سائل حفر بديلة عندما تكون أحجام جزئياته 44 مايكرون وفي حالة إضافة البوليجير كمادة إضافية محسنة.

Abstract: *A laboratory investigation evaluates the benefits and problems associated with the use of itabirite (micaceous hematite) as a weighting material in water-based mud.*

Three different ranges of particle sizes itabirite were selected for the test: (1) particle sizes between 74 and 125 microns, (2) particle sizes between 44 and 74 microns, (3) particle sizes smaller than 44 microns. Thirty-minute abrasion tests were conducted with a modified Hamilton Beach Blender at 9,800, 11,200, 12,570, and 14,350 rpm. Rheological properties, filtration properties, and abrasiveness were studied and analyzed.

Itabirite exhibited better rheological characteristics than barite and could increase the penetration rate since a lower solids content can be used to obtain proper weight. However, it did not exhibit good filtration properties and was found to be more abrasive. The feasibility of using itabirite as a weighting material was enhanced with a finer particle size distribution and by using a determined amount of Drispac Superlo polymer, which controlled filtration and acted as a coating agent to lower abrasiveness.

* Petroleum Engineering Dept. Chairman , Al Fateh University, Tripoli Libya. E-mail: mbizanti@yahoo.com

INTRODUCTION

Over the past few years, increases in the cost of drilling fluids, a shortage of high-quality barite, and growing dissatisfaction with using barite as a weighting material have forced the petroleum industry to seek a new weighting material which will meet the standards set for barite. The alternative weighting material can be found among the iron oxide materials. Ilmenite and itabirite (a mixture of iron oxide and silica) have been reported to be superior barite alternatives. Itabirite is micaceous hematite (Fe0) and has a hardness of 5.0 to 6.0 Mohs and a specific gravity of 5.1.

This study describes laboratory tests and measurements on itabirite and barite in water-based muds. Comparison of the rheological and filtration properties and abrasiveness provides a basis for evaluating itabirite for use as a weighting material in drilling fluids[1].

The deeper the hole, the greater the amount of barite, as a percentage of the total mud mix, is needed to suppress high formation pressures and prevent blowouts. Recent discoveries in frontier areas have generally been deeper than the discovery depths in existing oil and gas producing areas. The trend is expected to continue, resulting in more barite being consumed[2].

Previous field and laboratory studies have concluded that improved rheological properties and a lower attrition rate are attained with fine particles of ilmenite[3]. However, excessive wear will occur in high-velocity parts of the mud system, such as the mud mixer, storage system, and centrifuge pumps. Little abrasion occurs at low velocity because of elastic impacts, whereas plastic deformation causes severe abrasion at a higher velocity. It is suggested that the dilemma of ilmenite hardness can be resolved by processing the ilmenite to a particle size of no more than 3 wt percent larger than 45 microns as compared to API barite, which has 3 wt percent larger than 74 microns.

Drispac Superlo

Drispac Superlo is a chain polymer, shorter than regular Drispac, which is a polyionic cellulose derivative. This polymer is manufactured and marketed by the Drilling Specialties Company.

Drispac Superlo is dispersible in water-based mud and functions in both fresh and salt-water muds. It controls water loss with only a small viscosity increase, compared to regular Drispac. In addition, it works with all of the thinners now in use in water-based muds and performs well with inhibiting salts such as NaC1, KC1, and $CaSO_4$. It also mixes with unweighted muds and weighted muds. Drispac Superlo is resistant to microorganism, (Drilling Specialties Company, 1985) and is an effective coating agent that protects hydratable solids from disintegration and does not alter mud viscosity appreciably[4,5].

Equipment

Test equipment used includes the following:

1- Aroid Mud Balance
2- Standard Filter Press
3- Hamilton Beach 14 Speed Blender

Presently, there is no API approved method for determining the abrasiveness of a fluid or oil field material. A modified Hamilton Beach 14 speed blender was used to conduct the abrasion tests. It consists of: (1) a two-piece cover, (2) an open container, (3) a cutting unit assembly, (4) a high/low selector switch, (5) a control panel, and (6) a blender base.

Other Equipment

A portable sieve shaker, thermometer, mixer, Mettler macro balance, and a Beckman Zeromatic IV pH Meter were also used[6].

Abrasion Test

The abrasion test was conducted as follows:

1- The blade to be tested was weighed to 0.0001 gram.
2- After the blade was installed in the blender, 500 cc of the mud sample was poured into the blender.
3- The mud with test material was stirred for 30 minutes at 9800 rpm.
4- The blade was removed, cleaned, dried, and reweighed to 0.0001 gram.

5- Steps 1 through 4 were repeated for speeds of 11,200, 12,750, and 14,350 rpm.
6- The weight loss of the blade in grams and percent weight loss at each rpm was determined.

Interpretation and Discussion of Experimental Results

Sixteen mud types were investigated during this research (Table 1). The nomenclature for this study is listed at the end of this paper. All the mud types contained the same amount of bentonite 14 lbm/bbl. (14 g/350 ml). This is 1.54 percent of bentonite by total volume for each mud type. Using a small amount of bentonite in high weight water-based muds was essential for proper suspension of weighting materials in the continuous phase.

It was determined that in the itabirite mud system, 16 percent inert solids by total volume were required to obtain the desired mud density of 14 ppg. Table 2 lists the properties of itabirite used in this study. In the barite mud system, 20.5 percent inert solids by total volume were required to obtain the same mud density. The difference in the solid percent of these two muds was due mainly to the difference in specific gravities.

With the exception of mud types B, IL, IM, and IS (untreated muds, Table 1) 0.5 lbm. (0.5 g./350 ml) Desco thinner was used to (a): minimize the effect of viscosity (the selected polymer Drispac Superlo was used in concentrations of 0.25, 0.5, and 0.75 lbm/bbl. as a coating agent to lower mud abrasiveness), and (b) to reduce the yield point, because Desco thinner has a tendency to decrease the attraction of the active clay particles through adsorption on the clay surfaces.

Analysis of the Abrasion Tests

Abrasion is measured as weight loss (in grams) of a modified Hamilton Beach 14-speed blender blade. It was assumed that the greater the weight loss, the greater the abrasiveness of the mud.

It is believed that in a drilling system, shear rate varies from 170-10,000 sec.$^{-1}$ at the solids removal equipment and drill pipe, and from 10,000 to 1,000,000 sec.$^{-1}$ at the bit and bit nozzle[7]. Thirty-minute abrasion tests were conducted at 9800, 11,200, 12,750, and 14,350 rpm. Spanning the rpm range of the Hamilton Beach 14-speed blender. Four different speeds were selected to investigate the correlation between shear rate, abrasion, and polymer concentration.

Table 1. Drilling mud types

Mud type	Mud composition	Size distribution
B	(1.54% Ben + 20.5 % Bar + 77.96% Dis W	API
B1	(Type B) + .5 ppb D + .25 ppb NaOH + .25 ppb DS Pol	API
B2	(Type B) + .5 ppb D + .25 ppb NaOH + .5 ppb DS Pol	API
B3	(Type B) + .5 ppb D + .25 ppb NaOH + .75 ppb DS Pol	API
IL	(1.54 % Ben + 16.0 % Itab + 82.46% Dis W	74-125 microns
IL1	(Type IL) + .5 ppb D + .25 ppb NaOH + .25 ppb DS Pol	74-125 microns
IL2	(Type IL) + .5 ppb D + .25 ppb NaOH + .5 ppb DS Pol	74-125 microns
IL3	(Type IL) + .5 ppb D + .25 ppb NaOH + .75 ppb DS Pol	74-125 microns
IM	(1.54% Ben + 16.0% Itab + 2.46% Dis W	44-74 microns
IM1	(Type IM) + .5 ppb D + .25 ppb NaOH + .25 ppb DS Pol	44-74 microns
IM2	(Type IM) + .5 ppb D + .25 ppb NaOH + .5 ppb DS Pol	44-74 microns
IM3	(Type IM) + .5 ppb D + .25 ppb NaOH + .75 ppb DS Pol	44-74 microns
IS	(1.54% Ben + 16.0% Itab + 2.46% Dis W	37-44 microns
IS1	(Type IS) + .5 ppb D + .25 ppb NaOH + .25 ppb DS Pol	37-44 microns
IS2	(Type IS) + .5 ppb D + .25 ppb NaOH + .5 ppb DS Pol	37-44 microns
IS3	(Type IS) + .5 ppb D + .25 ppb NaOH + .75 ppb DS Pol	37-44 microns

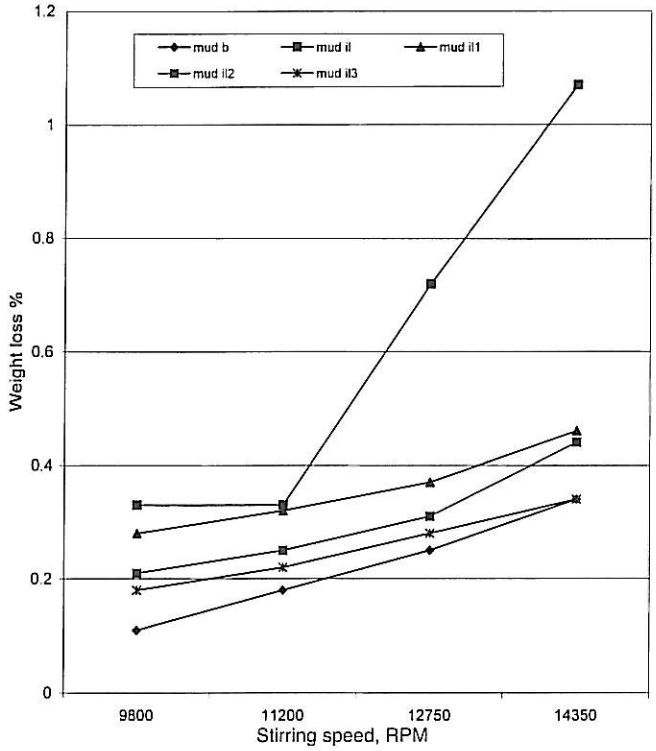

Fig. 1. Weight loss % *vs* rpm.

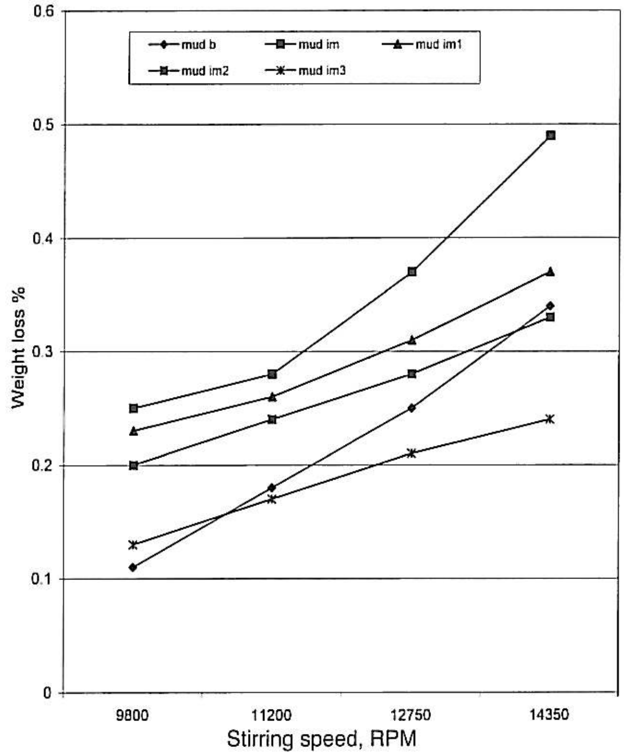

Fig. 2. Weight loss % *vs* rpm.

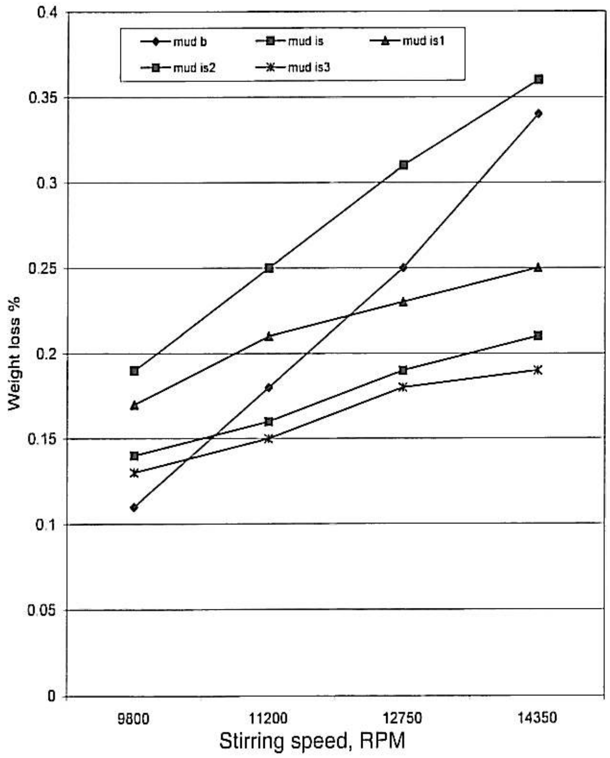

Fig. 3. Weight loss % *vs* rpm.

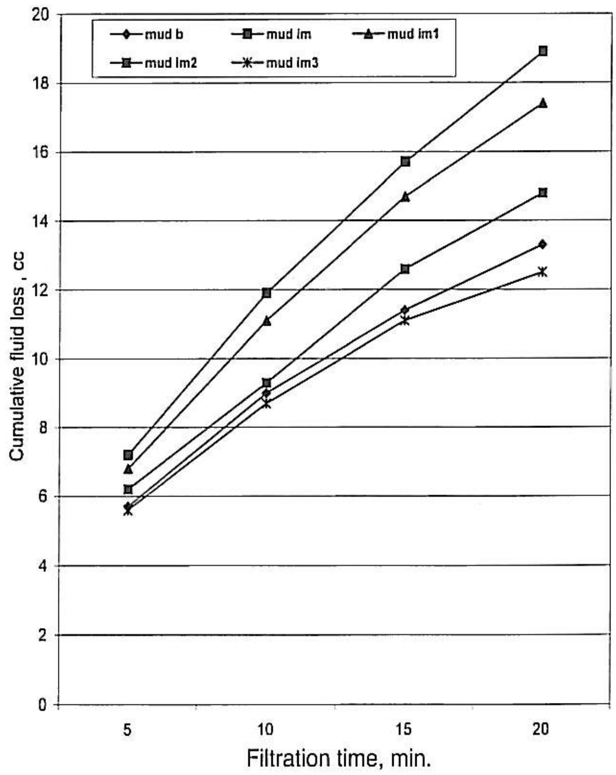

Fig. 4. Cumulative fluid loss *vs* time.

Resulting weight losses (percentage) as a function of stirring speed are plotted (Figs. 1-4). The figures show the relation between the relative abrasiveness of barite and itabirite with varying ranges of particle size at each polymer concentration of Drispac Superlo (DS).

In this paper, Drispac Superlo polymer concentrations of 0.25, 0.5, and 0.75 lbm/bbl were used as coating agents for the purpose of lowering the abrasiveness. It was experimentally verified that the use of polymers greatly reduced the abrasivity of the mud system and rendered it more efficient.

It can be seen in figures 1 through 3 that 0.75 lbm/bbl. concentration of DS for large particle sizes (between 74-125 microns) and 0.5 lbm/bbl. for small particle sizes (between 37-44) were adequate for lowering the abrasivity of the itabirite mud system to the barite level.

Table 2. Properties of itabirite used in the study (Densimix Technical Data, 1983)

Typical itabirite physical analysis	
Minus 100 mesh	100%
Minus 200 mesh	98.5% - 99.8%
Minus 325 mesh	92.0% - 96.0%
Free moisture @ 105° C	Less than 0.15%
Colour	Brown to red brown
Specific gravity	5.1
Magnetite content	Trace
pH	6.5-7.5
Plaine surface area	1900 – 2100 cm^{-2}/gm
Typical itabirite chemical analysis	
Fe	68.0–68.5% (97.2–97.9% Fe_2O_3)
SiO_2	0.5–1.0%
Al_2O_3	0.5–1.0%
CaO + MgO	0.15%
S	0.01%
P	0.03%
Cu	0.01%
Na_2O	0.02%
K_2O	0.005%
Ca^{++}	10.0–15.0 ppm
Mg^{++}	0.5–2.0 ppm

It was postulated in this study that abrasion in a mud system could be demonstrated as a function of mud density, shear rate (in the lab, stirring speed of the blender blade in rpm; in the field, velocity of the mud circulation, $sec.^{-1}$), polymer concentration (PC, lbm/bbl), stirring time (in the field, time of mud circulation), and particle size (S) associated within the mud system. In this study, some of the independent variables were constant for the itabirite mud system, such as the mud density (14 ppg) and stirring time for the abrasion tests (30 minutes).

To further assess the abrasion tests for the itabirite mud system, regression analyses were used to study the predictive models that exist between abrasion (AB) as the dependent variable and regressor independent variables chosen from the set (S. PC, rpm) studied in this paper. The results of the regression analyses of three different models: linear, semi-log, and log-log are presented in Table 3. It is believed that the log-log model is best suited for describing the laboratory data.

It was observed that 0.75 lbm/bbl concentration of Drispac Superlo for large particles of itabirite (between 74 and 125 microns), and 0.5 lbm/bbl for small particle sizes of itabirite (between 37 and 44 microns) was adequate to improve the filtration properties. Figure 4 shows that there is an increase in cumulative fluid loss as the itabirite weighting material is introduced in the base mud (bentonite plus water). This was a result of the inert solid particles changing and disturbing the texture of the filter cake. These particles would not allow the bentonite clay particles to lie on top of each other, therefore, preventing the formation of an impermeable filter cake. This increase in cumulative fluid is improved by the addition of Drispac Superlo.

Polymer concentration-plastic viscosity relationships for barite and itabirite mud types are presented graphically in figure 5 for the Drispac Superlo polymer.. This figure shows that with the addition of polymer at each concentration, lower plastic viscosity can be obtained with the itabirite mud system than with barite. Therefore, the use of polymers was more beneficial in the itabirite mud system. Because of this advantage, the abrasion problem in the mud system could be overcome by increasing the polymer concentration.

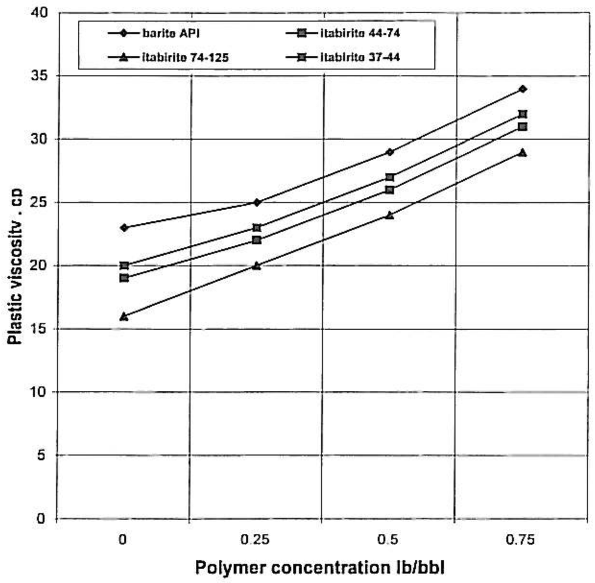

Fig. 5. Polymer concentration *vs* plastic viscosity.

Impact of the Study

Previous work[8,9], using drilling mud weighted with itabirite has reduced the cost of oil mud to three hundred and fifty thousand dollars a saving of 70 to 100 thousand dollars compared to other offset wells using mud weighted with barite.

The rate of penetration in the test well should almost twice the ROP obtained using itabirite mud system compared to barite mud system.

CONCLUSIONS

In this study the feasibility of using itabirite has been demonstrated. Based on the results obtained in this study, the following conclusions can be drawn:

1- Itabirite can be an acceptable weighting material as a barite substitute in water base muds.
2- Abrasion is dependent on the particle size distribution in a mud system. The smaller the solid particle sizes contained within the mud of the same density, the less abrasive it is.
3- Itabirite is more abrasive than barite.
4- The feasibility of using itabirite as a weighting material in water-base mud can be improved by selecting the particle size distribution between 37 and 44 microns and by using Drispac Superlo or Kelzan XCD polymer as a coating agent to lower the abrasivity of the itabirite mud to the barite level. The use of a polymer also helps control the filtration properties while maintaining reasonable rheological properties.
5- Regression analysis was applied to the experimental results to predict the abrasion equations for the mud system. Results indicate that there is a good predictive linear regression existing between abrasion (AB) as a dependent variable and regressors chosen from the set {S,PC,rpm} studied in this research. The log-log model was found to be the best in predicting abrasion.
6- From regression analysis, abrasion rates were found to be dependent on particle size and polymer concentration, and they were strongly dependent on shear rate.

Recommendations for Future Research

The feasibility of using itabirite, as an alternative weighting material in water-base muds can be best determined through laboratory testing. The following additional laboratory research is required before selecting itabirite for actual applications:

1- Effect of high pressure & temperature on rheological and filtration properties.
2- Effect of dynamic filtration properties.
3- Effect of additional particle sizes and shapes.

Table3. Prediction of abrasion equations (AB=f(S, PC,rpm))

Model	Polymer	Prediction equation	R^2-value	F	standard error
Linear	DS	AB=0.32304979+2.94808731(S)-0.27266667(PC)+0.000043049(rpm)	0.6727	30.157	0.0343
Semi-log	DS	$AB=0.04059807e^{8.80979373(S)}e^{-0.83701060(PC)}e^{0.000132340(rpm)}$	0.9027	136.059	0.0942
Log-log	DS	$AB=0.00000249(S)^{0.53060128}(PC)^{-0.31992027}(rpm)^{1.35026810}$	0.9350	153.323	0.0362

REFERENCES

[1] El Bokle, F.M., 1982. *Technique for Evaluation and Improving the Performance of the Iron Oxides Used as Barite Substitutes in Oil Well Drilling Fluids*. Ph.D. dissertation, University of Oklahoma, Norman, Oklahoma.

[2] Sarkis, G. Amapin, 1985. Barite, mineral facts and problems. *Bureau Mines, Bull.* **675**, 56–73.

[3] Blomberg, N.E., *et al.*, 1984 (June). Evaluation of ilmenite as weight material in drilling fluids. *J. Petrol. Tech*, 969–974.

[4] Drilling Specialties Company,1985. Product Literature, "Drispac Superlo Additive," "Desco,",Technical Services Division, Drilling specialties company, Bartlesville, Oklahoma, P. 7.

[5] Densimix Technical Data, June 1983. Houston, Texas.

[6] Moonesan, A., 1987 (March). *Itabirite Evaluation*. M.Sc. thesis, Louisiana Tech. University, Ruston, Louisiana.

[7] Chilingarian, G.V., and Vorabutr, 1981. *Drilling and Drilling Fluids*, Elsevier Scientific Publishing Co.

[8] Binder, G.G., Jr. *et al.*, 1981 (Dec.). Evaluating barite as a source of soluble carbonate and sulfide contamination in drilling fluids. *J. Petrol. Tech.* 2371–2375.

[9] Scharf , A.D. and Watts, R. D., 1988. Itabirite : an alternative weighted material for heavy oil – base muds. Paper *SPE* 13159, Exhibition, Houston.

NOMENCLATURE

AB	=	Abrasion
B = BAR	=	Barite
Ben	=	Bentonite
Conc	=	Concentration
cp	=	Centipoise
Cumu	=	Cumulative
Dis W	=	Distilled water
D	=	Desco
DS	=	Drispac superlo
IL	=	Itabirite large particle sizes (between 74 and 125 microns)
IM	=	Itabirite medium particle sizes (between 44 and 74 microns)
IS	=	Itabirite small particle sizes (between 37 and 44 microns)
Itab	=	Itabirite
ml	=	Milliliters
PC	=	Polymer concentration
Pol	=	Polymer
lbm/bbl	=	Pound mass per barrel
ppg	=	Pounds per gallon
PV	=	Plastic viscosity
rpm	=	Revolution per minute
S	=	Particle size
Yp	=	Yield point