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DOLOMITE AS AN ALTERNATIVE WEIGHTING AGENT IN DRILLING FLUIDS

M. J. BADRUL*, L.L. CHIOU, Z. AZLINA, Z. JULIANA
Department of Chemical Engineering, Faculty of Engineering
University of Malaya
50603 Kuala Lumpur, MALAYSIA
*Corresponding Author: badrules@um.edu.my

Abstract

A series of experimental tests have been conducted to assess the suitability of using dolomite as an alternative weighting agent in drilling fluids. Currently, barite is widely used as weighting agent in drilling fluids slurry to ensure proper weights are achieved. However, barite contains toxic materials which make it unattractive from health and environment point of views. This is especially true when drilling operations are offshore, where most of the used drilling fluids will be dumped back into the sea. In this work, rheological properties of dolomite blend drilling fluids slurry were studied. Dolomite rocks were first crushed to produce dolomite powder, before being mixed with water and bentonite at various proportions. A total of 10 samples which contains various percentages of water, bentonite and dolomite were studied. For each sample, its rheological properties were determined. Such properties include density from mud balance, viscosity from viscometer, filtrate loss from API filter press and gel strength. The effect of aging on the properties of drilling fluids was also studied. From the study, it is concluded that Sample E, which consists of 70% dolomite by weight, produces the most stable drilling fluids. It is also observed that the amount of 336 g of dolomite in the sample shows the similar physical and rheological properties to that of the 480 g barite in the sample although the density for both samples is not same.

Keywords: Drilling fluids, weighting agent, Density, Viscosity, Gel strength, Filtrate Loss.

Nomenclatures

N	Rotor Speed [rpm]
Greek Symbols	
μ_a	Apparent Viscosity [kg.m^{-1}.s^{-1}]
θ_N	Dial Reading [Degrees]

1. Introduction

Drilling fluids serve a number of purposes in drilling processes. It is crucial to ensure that the designed drilling fluids have the right rheological properties namely density, viscosity and filtrate losses [1, 3]. One of the many challenges in designing drilling fluids is to properly manage the unpredicted profile of the formation pressure. Many formations are hydrostatically pressured or overpressured, thus the pressure in the wellbore must be kept higher than that of the formation.

In general, the pressure in the wellbore must normally be higher than the hydrostatic pressure for pure water to prevent the well from blowing out [3]. Fluid pressure in the wellbore is controlled by varying the density of the drilling fluids through addition of heavy solids. An additive which has been extensively used in the upstream oil and gas industry to overcome problems related to formation pressure is barium sulfate. Barite produces mud slurry with density ranging from 898 to 1896 kg/m^3 [3, 4]. This range of mud density is appropriate for both shallow and deep wells. However, there are down sides of using barite in drilling fluids as weighting agents. First, barite is expensive considering the amount of mud/drilling fluids required to drill a single well. In addition the natural sources of barite are limited compared to the proposed weighting agent. Second, water based mud that uses barite as weighting agent seems to pose unfriendly environmental issues due to discharge of heavy materials during drilling operations [2]. This work tries to look at the suitability of using dolomite instead of barite as weighting agent in drilling fluids. It has been suggested that dolomite may be able to replace barite in a specific density range [2, 4]. The density of pure water is 8.33 Ibm/gal, which is very close to the lower limit of 9 Ibm/gal produced from barite [3, 4]. Addition of dolomite which has a specific gravity of 2.9 and bentonite (basic ingredient of slurry) is expected to increase the density of the drilling fluid to a certain degree. In addition, Malaysia is rich with natural source of dolomite rocks and it can be obtained at practically low cost. The use of dolomite blended drilling fluids will also minimise discharge of heavy metal to the environment.

2. Methodology

This project involves two major experimental tasks, namely; the preparation of the raw material and mud slurry and the rheological tests of the drilling fluids.

2.1 Preparation of raw material and mud slurry

In preparing the mud slurry, 3500 cm^3 of distilled water is added to 2-gallon (8 L) container. Then the mixture was stirred at 2400 rpm while 210 g bentonite is added slowly for 30 min. The mixture is then aged in special aging cell for about 16 hours at room temperature. After that the sample is stirred again at 4200 rpm and 40 g of lignosulfonate and 60 cm^3 of ± 0.5 NaOH is slowly added. The mixture is again stirred for 30 min. Then the mixture speed is set at 2400 rpm and the based mud is stirred for another 5 minutes. The pH of the mixture is measured and NaOH is used to adjust the pH around 11.8-11.9. Then the procedures are repeated for different composition of Bentonite, NaOH, dolomite, barite and lignosulfonate. Table 1 shows the composition of the prepared mud sample. There are a total of 11 samples of the drilling fluids including one blank sample which consists of pure bentonite without any additive.

2.2 Rheological tests of the drilling fluids

Rheological tests conducted in this study are based on the procedures recommended by the American Petroleum Institute (API). These tests include density measurement from mud balance, gel strength and apparent viscosity from rotational viscometer and fluid loss and mud cake measurement from API high-temperature filter press. The drilling fluid density measurement test consists of essentially filling the cup with a mud sample and determining the rider position required for balance. The balance is calibrated chamber in the end of the scale. Water is usually used as calibration fluid. The density of fresh water is 998 kg/m^3 or 8.33 Ibm/gal. The drilling fluid should be degassed before being placed in the mud balance to ensure an accurate measurement.

Fig. 1. API Mud Balance Used in the Test.

Table 1. Sample Composition.

Sample	Types of drilling fluids	Composition
Based mud	Blank	3500 cm^3 distill water + 210g bentonite + 60g NaOH + 40g Lignosulfonat
A	Barite	3500 cm^3 distill water + 210g bentonite + 60g NaOH + 40g Lignosulfonat + 480g Barite
B	100% Dolomite	3500 cm^3 distill water + 210g bentonite + 60g NaOH + 40g Lignosulfonat + 480g Dolomite
C	90% Dolomite	3500 cm^3 distill water + 210g bentonite + 60g NaOH + 40g Lignosulfonat + 432g Dolomite
D	80% Dolomite	3500 cm^3 distill water + 210g bentonite + 60g NaOH + 40g Lignosulfonat + 384g Dolomite
E	70% Dolomite	3500 cm^3 distill water + 210g bentonite + 60g NaOH + 40g Lignosulfonat + 336g Dolomite
F	85% Barite + 15% Dolomite	3500 cm^3 distill water + 210g bentonite + 60g NaOH + 40g Lignosulfonat + 408g Barite + 72g Dolomite
G	70% Barite + 30% Dolomite	3500 cm^3 distill water + 210g bentonite + 60g NaOH + 40g Lignosulfonat + 336g Barite + 144g Dolomite
H	50% Barite + 50% Dolomite	3500 cm^3 distill water + 210g bentonite + 60g NaOH + 40g Lignosulfonat + 240g Barite + 240g Dolomite
I	30% Barite + 70% Dolomite	3500 cm^3 distill water + 210g bentonite + 60g NaOH + 40g Lignosulfonat + 144g Barite + 336g Dolomite
J	15% Barite + 85% Dolomite	3500 cm^3 distill water + 210g bentonite + 60g NaOH + 40g Lignosulfonat + 72g Barite + 408g Dolomite

In viscosity measurement, a rotational viscometer was used. Figure 2 shows the Fann rotational viscometer employed in this study. Rotational viscometer can provide a more meaningful measurement of the rheological characteristics of the mud than marsh funnel. The mud is sheared at a constant rate between an inner bob and outer rotating sleeve. Six standard speeds plus a variable speed setting are available with the rotational viscometer. Only two standard speeds are possible with most models designed for field use. The dimensions of the bob and rotor and chosen so that the dial reading is equal to the apparent Newtonian viscosity in centipoises at a rotor speed of 300 rpm. At other rotor speeds, the apparent viscosity, μ_a, is given by;

Fig. 2. Fann Rotational Viscometer.

$$\mu_a = 300\ \theta_N / N \qquad (1)$$

Where θ_N is the dial reading in degrees and N is the rotor speed in revolutions per minute.

Another rheological parameter called the *gel strength*, measured in units of lbf/100 sq ft or 0.48 kg/ms^2, is obtained by noting the maximum dial deflection when the rotational viscometer is turned at a low rotor speed (usually 3 rpm) after the mud has remained static for some period of time. If the mud is allowed to remain static in the viscometer for a period of 10 seconds, the maximum dial deflection obtained when the viscometer is turned on is reported as the *initial gel* on the API mud report form. If the mud is allowed to remain static for 10 minutes, the maximum dial deflection is reported as the 10-*min gel*. The filter press is used to determine the following parameters;

1. Filtration rate through a standard filter paper.
2. Cake thickness build up.

The API filter press is shown in Fig. 3. API filtration test is an indication of the rate at which permeable formations are sealed by the deposition of a mud cake after being penetrated by the bit. Cake buildup during drilling is desirable as it protects the formation from being contaminated by fluid invasion. Thus it reduces formation damage during drilling operation. Thickness of the mud cake also says something about the formation. Porous rock usually produces thicker mud cake as it is easier for fluid to invade into the formation. Non porous rock such as shale will produce very thin mud cake since it is nonporous and fluid invasion is deemed impossible.

3. Results and discussion

3.1 Density

Figure 4 shows the values of density in Ibm/gal of all the blended slurry. The first sample is a blank sample i.e., sample with pure water, without bentonite and other additives. It is also shown that pure barite has a weight of about 17.4 Ibm/gal, while pure dolomite has a weight of about 15.0 Ibm/gal. It is also interesting to note that a mixture of 50 % barite and 50 % dolomite produces slurry with density around 16.4 Ibm/gal. This value is comparable to that of the density produced from 100 % barite.

Fig. 3. API filter press

It can also be seen from figure 4 that the density of the slurry remains relatively the same, when dolomite ratios are maintained at 70, 80, 90 and 100 percent. It is also obvious that the recorded densities show values higher than 15 Ibm/gal. Similar plot can also be achieved by looking at the density variation with variation of barite content. The plot is shown in **Figure 5**. The heaviest mud is 17.4 lb/gal which are produced from 100% barite, while the lightest mud is produced from blank sample, 8.7 lb/gal. Pure dolomite will produce mud with a density of 15.1 lb/gal. **Figure 6** shows that a denser mud could be produced with the addition of barite to the mud mixture consisting of barite and dolomite. Mud with pure barite as weighting agent produce the heaviest mixture of 17.4 lb/gal.

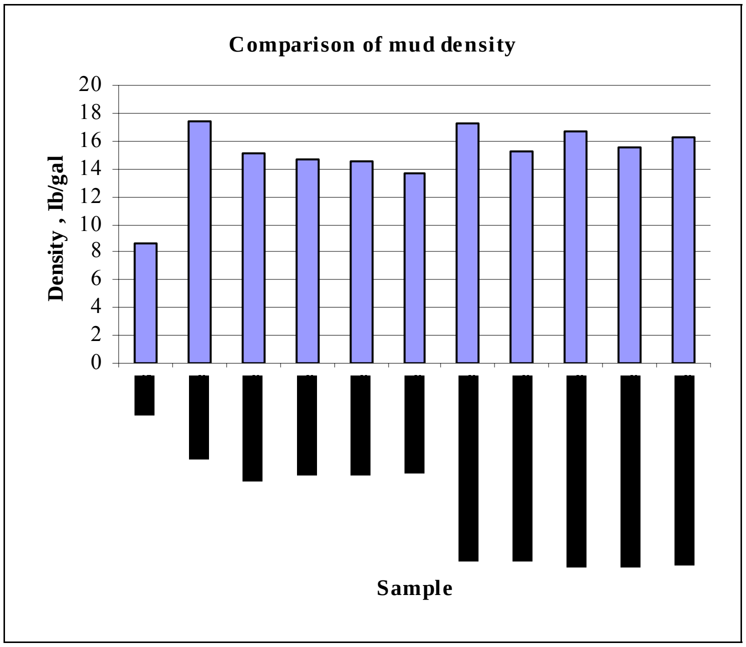

Fig. 4. Mud Slurry Density at Various Compositions.

3.2 Viscosity and Aging Effect

Table 2 summarises the experimental results showing the measured viscosity of the slurry before and after aging. Aging process was used to mimic the down hole condition. Figure shows schematic of the high pressure and high temperature rolling oven. Initial measurements were made at 2 different speeds namely 100 and 200 rpm. The results indicate that regardless of aging, all samples shows significant difference in viscosity value. For instance, sample with 100% barite and 100% dolomite show viscosities magnitude of 20 and 28 cP respectively. However, after aging, the measured viscosities increase to 50 and 142 cP. This trend is maintained for all other samples.

In addition it is also observed that an increase of mixing speeds during mixing also changes the values of the measured viscosity. For instance, under 100 rpm, sample with 50% bentonite and 50 % barite shows a viscosity value of 22 Cp and 44 Cp before and after aging. However, when the speed of the blender is changed to 200 rpm, the measured viscosity seems to increase from 41 to 103 Cp respectively. This shows significant effect of mixing speed on the slurry viscosity. This observation also holds for all other samples. Further tests at higher speeds, i.e., 500 and 600 rpm, show similar behaviour. These data are tabulated in Table 3. It is expected that there is a critical speed at which the viscosity of the slurry will relatively remain the same. Due to the limitation of the apparatus, the highest speed that could be achieved is 600 rpm.

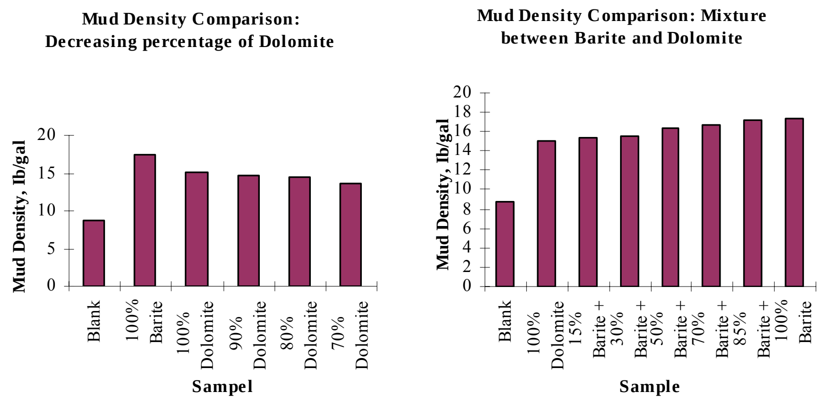

Fig. 5. Slurry Density at Various Dolomite and Barite Content.

Figure 6 shows the Fann dial reading for all of the samples tested. Slurry with 100% dolomite gives the highest Fann reading while sample without weighting agent neither barite nor dolomite gives the lowest reading. Mud with barite as weighting agent produced reading between the blank and 100% dolomite sample for both cases, before and after aging. It can also be observed from figure 4 that sample with 70% dolomite produces similar curve as barite for both cases before and after aging. The reduction of dolomite content in the slurry seems to reduce the Fann reading

3.3. Gel Strength

Figure 7 shows the values of gel strength of all of the tested samples, both before and after aging. It can be seen that sample with 85, 90 and 100 % dolomite behave like a progressive gel. This behavior is can be detected when the recorded gel strength is practically very low for the first 10 second and it increases slightly after 10 minutes. It also observed that the blank sample seems to behave like a fragile gel where the gel strength is very low at first 10 seconds and it remains constant after 10 minutes. Other samples seem to behave like a good gel where the value of gel strength is low for the first 10 seconds. After aging, at 107°C, the blank and barite samples behave like a good gel. Other samples show high values of gel strength. Since the applied mixer used was well below the recommended RPM of 4000, thus the sample may not mix very well. However, it was acceptable since the solid content can be considered low.

Table 2: Viscosity at 100 and 200 rpm before and after aging

Sample	100 RPM		200 RPM	
	Before aging (cP)	After aging(cP)	Before aging (cP)	After aging(cP)
Blank	6	25	10	35
100% Barite	20	50	32	77
100% Dolomite	28	142	50	150
90% Dolomite	30	108	48	137
80% Dolomite	24	75	40	100
70% Dolomite	20	72	31	91
85% Barite + 15% Dolomite	21	55	36	71
15% Barite + 85% Dolomite	34	95	56	123
70% Barite + 30% Dolomite	21	53	38	70
30% Barite + 70% Dolomite	29	77	47	103
50% Barite + 50% Dolomite	22	72	41	103

Table 3. Viscosity at 500 and 600 rpm before and after Aging.

Sample	500 RPM		600 RPM	
	Before aging (cP)	After aging(cP)	Before aging (cP)	After aging(cP)
Blank	19	55	20	65
100% Barite	67	151	80	175
100% Dolomite	100	264	120	285
90% Dolomite	97	210	115	233
80% Dolomite	82	180	100	185
70% Dolomite	62	166	73	167
85% Barite + 15% Dolomite	71	118	84	134
15% Barite + 85% Dolomite	120	198	138	202
70% Barite + 30% Dolomite	76	116	88	130
30% Barite + 70% Dolomite	98	182	118	191
50% Barite + 50% Dolomite	83	186	98	242

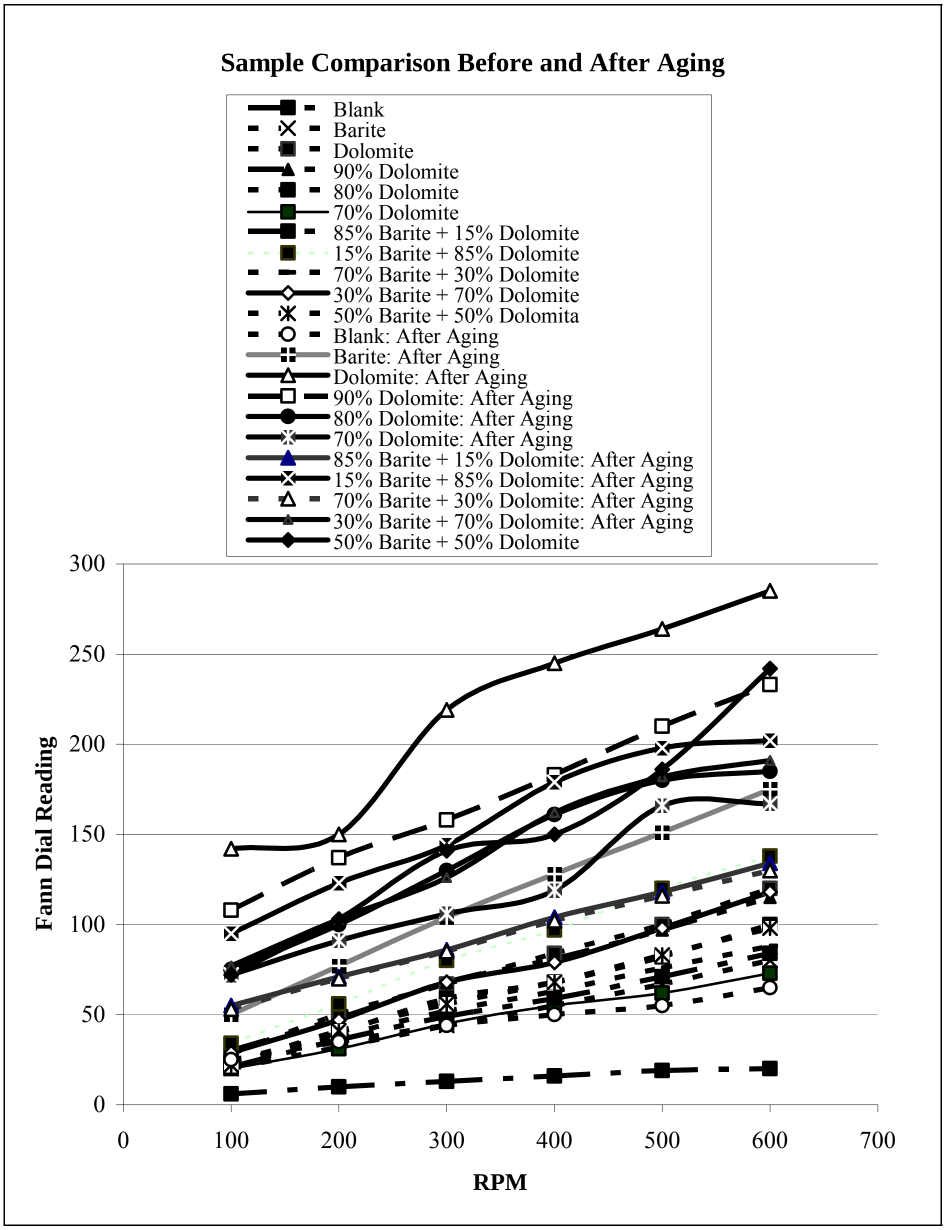

Fig. 6. Fan Samples Reading on the Viscometer Fan Cylinder before and after Aging.

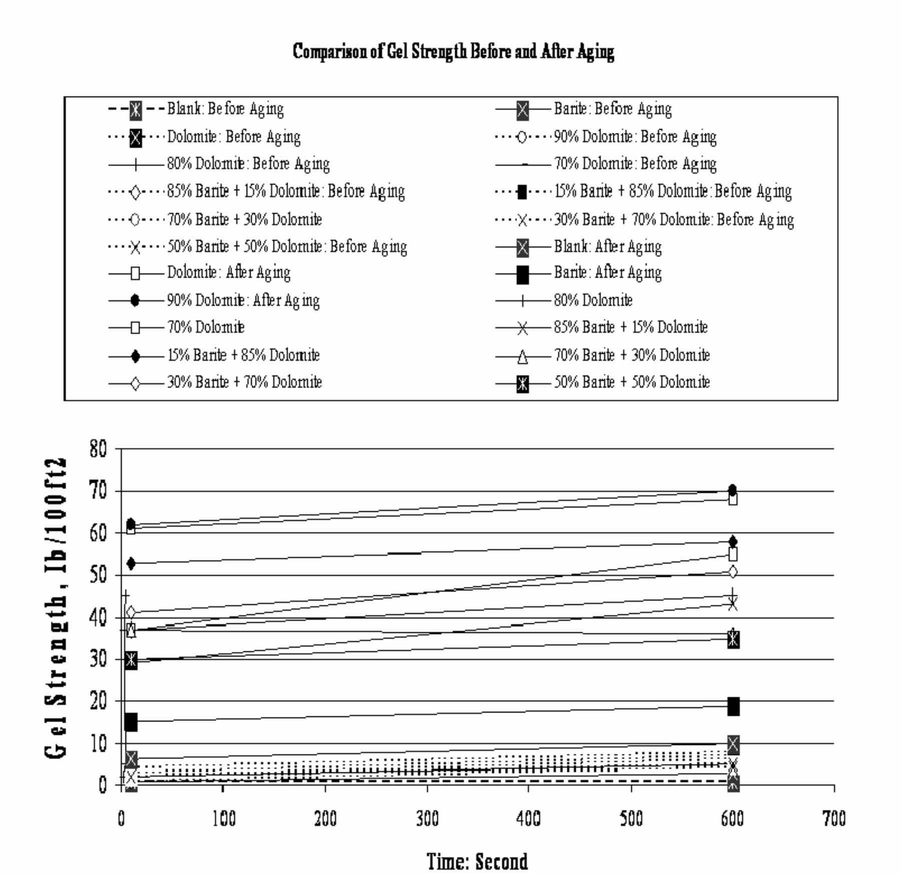

Fig. 7. Gel Strength before and after Aging

3.4 Mud cake and filtrate loss

Figures 8 and 9 show the thickness of mud cake and the volume of the collected mud filtrate from all tested samples. The blank sample produces the thinness cake which is about 0.22 cm. Sample with 100 % dolomites produces a 1.14 cm thick cake. It is also noted that the cake thickness seems to reduce with the reduction of dolomite content. In general, the filtrate loss for all tested samples can be considered small. It is also obvious from Figure 8 that the filtration volume is directly proportional with time. Sample with no weighting agent produces the smallest filtrate loss. This is because bentonite shows low permeability and porosity when compressed compared to that of dolomite and barite. Sample with 90 % dolomite content show the highest filtrate loss of 18.33 ml. Sample with 100 % dolomite produces the smallest filtrate loss. This is due to the reduction the porosity of the sample.

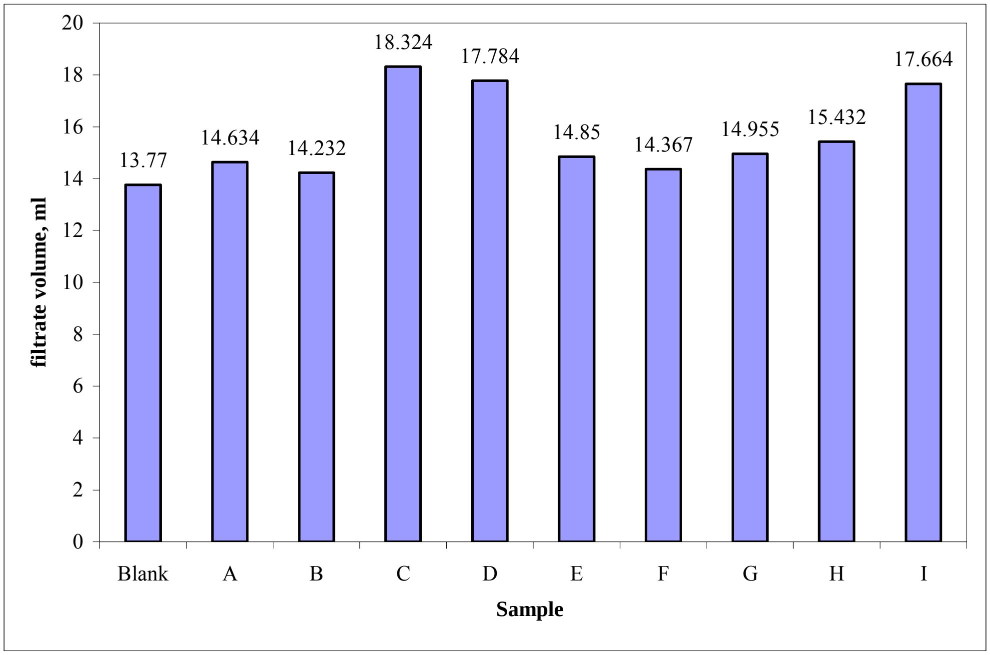

Fig. 9. Filtrate Loss from HTHP Filter Press.

4. Conclusions

From the experimental study, the following conclusions can be drawn;

1. Addition of barite and dolomite increase the density of the drilling fluids. Thus, both materials may be used as weighting agents in drilling fluids.
2. Addition of dolomite to mud slurry, prior to aging, tends to increase its plastic viscosity.
3. Slurry with barite mixture seems to exhibit higher plastic viscosity compared to slurry with dolomite mixture.
4. The amount of filtrate loss is a function of dolomite content in the slurry. Large amount of dolomite content gives the lowest filtrate volume. This is due to lower porosity of the mixture.
5. Viscosity of drilling fluid is a function of the rotational speed during mixing. Higher speed gives higher viscosity values.
6. Slurry with 30% dolomite content exhibits similar rheological properties to that of 100% barite.
7. The best dolomite drilling fluids mixture was obtained from Sample E, which composed of 70% dolomite by weight.

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