STUDY ON CASTOR OIL AS OIL BASED FLUID IN DRILLING OPERATION

By

PREVEEN KUMAR RAJAN

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CERTIFICATION OF APPROVAL

STUDY OF CASTOR OIL AS OIL BASED FLUID IN DRILLING OPERATION

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A project dissertation submitted to the

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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 undertaken or done by unspecified sources or persons.

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PREVEEN KUMAR RAJAN

ABSTRACT

Drilling fluid is a critical component in the drilling process, where it provides the gel to efficiently lift cuttings, maintain stable wellbore and produce sufficient hydrostatic pressure that could prevent the influx of formation fluids into the wellbore. The usage of diesel oil as the continuous phase of drilling fluid is harmful to the environment especially marine environment in offshore drilling operation. Therefore, various bio-diesel oils had been introduced to replace the diesel oil.

Types of drilling fluid used in this project are oil based mud and synthetic based mud. The biodiesel oils (Castor oil and Palm Oil) are used as oil phase in oil based mud and mineral oil (Saraline) is used as synthetic fluid in synthetic based mud. This project is mainly to identify whether Castor oil can be used as an alternative for biodiesel oil to replace diesel oil in oil based mud by examining the rheological properties and elastomeric effect of the muds.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

The use of oil based mud (OBM) has increased significantly in drilling operation. OBM is known to provide excellent shale inhibition, borehole stability, lubricity, thermal stability, corrosion inhibition, tolerance of contamination and ease of maintenance. Diesel oil had been widely used as the base oil since the introduction of OBM as drilling fluid. In early 1980’s many researches on diesel oil as the base oil for drilling fluid. From these researches output showed that diesel oil not suitable to be used as base oil due to high toxicity and aromatic contents exposure to the people and environment.

Therefore, vegetable oil based drilling fluids and synthetic based muds were introduced as environmental friendly alternatives. Normally, vegetable oil based drilling fluid is actually vegetable oil which already converted to biodiesel and is used as continuous oil phase in OBM, but in this study we will use Straight Vegetable Oil(SWO) as the oil phase by blending it with Linear Alkyl Benzene(LAB). The vegetable oils that are used in this project are the Castor oil and Palm oil. These oils have comparable physical and chemical properties with those of diesel oil that can be surely replaced the diesel oil in OBM. These vegetable oils are harmless to the environment since it has low aromatic content and less toxic.

The synthetic based mud (SBM) is also harmless to the environment and less toxic. It provides environmental superiority, technical acceptability and human health advantages. SBM is same with OBM. The oil phase is replaced with synthetic fluid which is mineral oil (Saraline). Oil based drilling fluid has synthetic oil as its base fluid. In this project, the properties of Castor oil is to be measured and characterized in its use as a substitute base oil. The compatibility of castor oil with the drilling tools will also be determined through experiments.

1.2 Problems Statement

Diesel oil has been use commercially in drilling operation but it is harmful to the environment. The usage of vegetable oil and mineral oil can be an alternative based drilling fluid. Therefore, Castor Oil or Palm Oil or Saraline Oil might be a candidate solution as an alternative energy resource and it is comparable with diesel oil.

Castor oil will be a potential bio-diesel oil to replace the oil phase in oil based mud because of:

- Developed locally
- Environmentally friendly
- High viscosity
- High density

In order to develop a reliable, environmentally friendly, economical alternative to mineral oil, the chemical properties of Castor oil and also its compatibility as oil based mud with the drilling tools will be tested by conducting elastomer test. Besides that, physical properties of Castor oil will also be determined by various tests.

1.3 Objectives

The objectives of this study are:

- To experimentally study and compare the rheology properties of the Castor oil, Palm Oil and Saraline Oil based drilling fluid.
- To identify whether Castor oil can be an alternative base fluid for oil based mud
- To measure the compatibility of Castor oil based drilling fluid O-ring, blowout preventers (BOPs), pulsation dampeners, downhole mud motors and drilling bits by conducting elastomer test.

1.4 Scope of Study

The research will involve in the understanding of oil based mud. The study of this project can be broken down to the identification of the most suitable base oil to be used for drilling fluid by evaluating the rheology and elastomeric effect of the formulated mud. Main tasks for the author in this project is:

- Reducing the viscosity of Straight-Vegetable Oil by blending with Alkyl Benzene
- Conducting research on the theory and definition of terms related to the study.
- Conducting experiments to see the effectiveness of Castor oil, Palm Oil and Saraline Oil used as oil base fluid in drilling operation.

1.5 Relevancy and Feasibility of Study

This study will produce a quantitative correlation of the rheology study of Alkyl Benzene Blended SWO (Castor oil and Palm Oil) and Saraline Oil. This correlation will give an idea in choosing the suitable drilling fluid to be use in drilling operation. The study focuses on experimental work particularly rheology and elastomer test in the lab, using the three base fluids with particular attention given to the characteristics of Castor oil and its compatibility with the drilling tools and logging tools. A limited amount of formulations is prepared, in order to fit within the time frame, hence proper research must be done into the formulation calculations beforehand. Result collected from experiments is analyzed and discussed.

CHAPTER 2

LITERATURE REVIEW AND THEORY

2.1 Castor Oil

Castor oil, which is extracted from the Ricinus communis seeds plant, is a new alternative for vegetable-oil based mud that is potential to be developed locally, environmentally friendly, and able to meet the standard requirement of OBM. It has density and viscosity higher than any other vegetable oils. Castor oil has SG of 0.958-0.968 (diesel oil has SG of 0.84 in 60° F (API, 1998) and viscosity of 9.5-11 poise in 68°F (Jamieson, 1943). In some tropical countries, castor oil has been used as a lubricant for heavy machines such as locomotives (Jamieson, 1943).

Castor oil can possess different physical and chemical properties. However, regardless of its country of origin or season in which it was grown, its chemical composition remains relatively constant (Table 1). Like other vegetable oils, castor oil is a triacylglycerol composed of various fatty acids and glycerol. The fatty acids consist of up to 90% ricinoleic acid and varying small amounts of saturated and unsaturated fatty acids. The high content of ricinoleic acid is the reason for the high value of castor oil and its versatile application possibilities in the chemical industry.

Figure 1: Crude Castor Oil

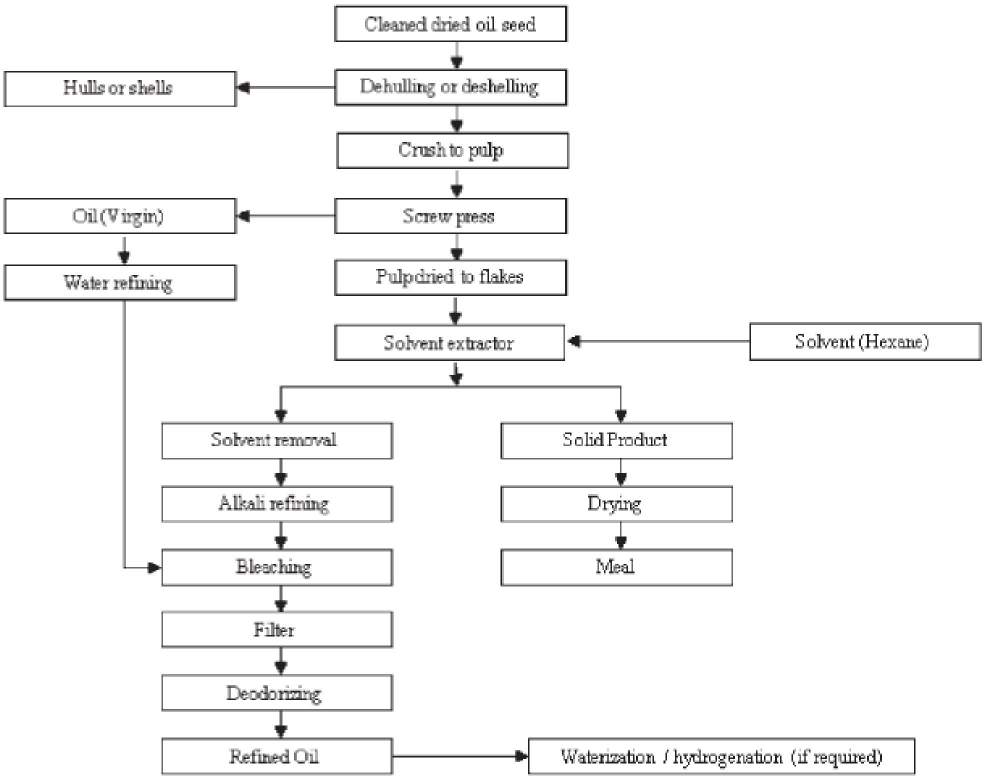

Figure 2. Typical procedure for the extraction and preparation of castor oil for further modifications [7–9].

Fatty acid	Molecular formula	Percentage [%]
Palmitic	C16H32O2	0.8– 1.1
Stearic	C18H36O2	0.7– 1.0
Oleic	C18H34O2	2.2– 3.3
Linoleic	C18H32O2	4.1– 4.7
Linolenic	C18H30O2	0.5– 0.7
Ricinoleic	C18H34O3	87.7–90.4

Table 1. Castor oil composition.

TEST	METHOD	RANGE
Iodine value	USP	83 - 88
Saponification value	USP	176 - 184
Acid value	USP	2.0 max
Hydroxyl value	USP	160 - 168
Moisture & volatile	AOCS Ca 2b-38	0.355% max
Density		$9.61 \times 10^{-1} g/cm^3$
Boiling point		313°C
Viscosity, St	ASTM D1545	6.3 - 8.9
Color Gardner	AOCS Td la-64	4 max
Appearance	Characteristically clear and free from suspended matter	
Odor	Slight, characteristic	

Table 2: Physical and chemical properties of Castor oil

2.2 Methyl Ester Palm Oil

Palm oil, is an edible plant oil derived from the mesocarp of the fruit of the oil palm (Elaeis guineensis).The used of palm oil derivatives could be considered as an alternative based fluid which is harmless to the environment. Methyl ester palm oil is a clear yellow of vegetable oil origin obtained by pressing or boiling the flesh of the fruit of the oil palm. Palm oil differs from palm kernel oil, the latter being obtained from the kernels of the oil palm. Crude palm oil has complex process to change to methyl ester palm oil. The test results showed that palm oil derivative is suitable alternative to formulate oil based drilling mud with necessary rheological properties, compatible with existing mud additives and non-toxic to the marine life.

Table II Chemical composition of palm oil methyl ester (POME)

No.	Component	Percentage	Chemical formula	Remarks
1	Myristic	1.1-2.5	$CH_3(CH_2)_{12}COOH$	Saturated fatty acid
2	Palmitic acid	40.0-46.0	$CH_3(CH_2)_{14}$ COOH	MP[a] 65°C; saturated fatty acid
3	Stearic acid	3.6-4.6	$CH_3(CH_2)_{16}$ COOH	MP 80°C; saturated fatty acid
4	Oleic acid	39.0-45.0	$CH_3(CH_2)_7$ CH = $CH(CH_2)_7COOH$	MP 13°C; mono-saturated fatty acid
5	Linoleic	7.0-11.00	$CH_3(CH_2)_4$ CH = $CHCH_2$ CH = $CH(CH_2)_7COOH$	MP −5°C; poly-unsaturated fatty acid

Note: [a]MP = melting point

Table 3: Physical and chemical properties of Palm oil Methyl Ester

2.3 Saraline Oil

Saraline 185V is a quality drilling fluid sourced from clean natural gas, it contains virtually no aromatics and contaminants such as sulphur and amines. Saraline 185V is classified as a synthetic base drilling fluid. Saraline 185V readily biodegrades, is non-toxic in the water column and has low sediment toxicity. It has a low viscosity, a low pour point and relatively high flash point making it ideal for deepwater exploration. It is widely used as a non-aqueous base fluid in an invert emulsion drilling mud. SARALINE **1**85V is manufactured by Shell MDS

2.4 Base Fluid Properties

There are certain requirements to identify whether the oil can be use as base fluid in drilling fluid. The requirements are as follows;

2.4.1 Kinematic Viscosity

It should be as low as possible. This allows the oil based mud to be formulated at lower oil/water ratio and gives better rheology (lower plastic viscosity) especially at lower mud temperature.

2.4.2 Flash Point

It should be greater than 100°F. Higher flash point will minimize fire hazards as less hydrocarbonvapours is expected to generate above the mud.

2.4.3 Pour Point

It should be lower than the ambient temperature to allow pumpability of mud from storage tanks.

2.4.4 Non-toxic and low aromatic content

Base oil should have total aromatic hydrocarbon content of less than 5%. It should be non-acutely toxic in a standard 96 hr LC 50 toxicity test, performed using 100% water soluble fraction of the base.

Table 4 below shows the base fluid properties of Castor Oil, Palm Oil and Saraline Oil.

Base Oil / Base Oil Properties	Base Oil Required Properties	Castor Oil	Palm Oil	Saraline Oil	Test Method
Specific Gravity		0.96	0.87	0.77	ASTM D1250
Kinematic Viscosity@40°C mm²/sec	2.3 – 3.5	6.7	4.3	2.66	ASTM D445
Flash Point °C	> 66°C	229	168	89	ASTM D93
Pour Point °C	< Ambient temp.	3	2	-27	ASTM D97
Aromatic Content %	4 - 8	-	-	0.1	ASTM D1319

Table 4: Base Oil Physical Properties

2.5 Rheological Study

Rheology of fluids in the well is the relationship between the flow rate and the pressure required to maintain the flow rate (either in pipe or annulus). The relationships between these properties will affect circulating pressures, surge and swab pressures and hole cleaning ability. In this project, the rheological study comprises of plastic viscosity, yield point, electric stability and gel strength. Each study is so significant to choose a better base fluid.

2.5.1 Plastic Viscosity

Plastic viscosity relates to the resistance to flow due to interparticle friction. The friction is affected by the amount of solids in the mud, the size and shape of those solids and the viscosity of the continuous liquid phase.

Plastic Viscosity, PV= [600rpm Reading] – [300 rpm Reading]

Unit: **centipoise,cp**
Specification value: **25 - 45 cp**

2.5.2 Yield Point

Yield point estimates the portion of the total viscosity that comes from attractive forces between particles suspended in the mud.

$$\boldsymbol{Yield\ Point, YP} = [\mathbf{300}\boldsymbol{rpm\ Reading}] - [\boldsymbol{Plastic\ Viscosity, PV}]$$

Unit: **lb/100 ft^2**
Specification value: **10 – 20 lb/100ft^2**

2.5.3 Electric Stability

The electric stability (ES) of an oil-based drilling fluid mud is a property related to its emulsion stability and oil-wetting capability. ES is determined by applying a voltage ramped sinusoidal electrical signal across a pair of parallel flat-plate electrodes immersed in the mud. The resulting current remains low until a threshold voltage is reached, whereupon the current rises very rapidly. This threshold voltage is referred to as the ES of the mud and is defined as the voltage. Specification value: > 600volts

2.5.4 Gel Strength

Gel strength are determined in two-speed direct-indicating viscometer by slowly turning the driving wheel on top of the instrument by hand and observing the maximum deflection before the gel breaks. Gel strength may be measured after allowing the mud to stand quiescent for any time interval of interest, but they routinely measured after 10 seconds (initial gel strength) and 10 minutes.

Specification value;
Gel 10sec: **10 – 20 lb/100ft^2**
Gel 10min: **20 – 40 lb/100ft^2**

2.5.5 ***Viscosity***

Viscosity of fluids defined as the resistance of fluids to flow. Viscosity measured in the unit of poise which is equivalent to dyne-sec/cm2. One poise represents a high viscosity, therefore the generally unit that represents the fluids is centipoises. A centipoise is equivalent to 1/100 poise or 1 millipascal-second. This property of fluids is significant in hole cleaning to control the settling rate of drill cuttings generated by the drill bit through moving fluid and bring them up to the surface.

There are two main apparatus that the author has utilized in the laboratory which are marsh funnel and direct indicating viscometer. Marsh funnel is a simple device for routine measurement of drilling fluids viscosity. The viscosity measured through this apparatus is known as funnel viscosity. The Marsh funnel is dimensioned so that the outflow time of one quart freshwater (946 cm3) at a temperature of 70° ± 5°F (21° ± 3°C) is 26 ± 0.5 seconds. Thus, fluid which records a time more than 26 ± 0.5 seconds using the marsh funnel is more viscous compared to freshwater and vice versa.

2.5.6 ***Filtration***

Filtration control is one of the main factors considered essential in drilling. Filtration measures the relative amount of fluid lost through permeable formations or membranes when subjected to pressure. Thus, it is important to minimize the filtrate invasion to the formations. When drilling permeable formations, filtration rate is often the most important property where the hydrostatic pressure exceeds the formation pressure. Proper control of filtration improves the borehole stability chemically. This is because controlling the fluid loss minimizes the potentially detrimental interaction between the filtrate and the formation. Filtrate invasion may be controlled by the type and quantity of colloidal material and by filtration control materials.

Besides that, controlling fluid loss helps to put off or reduce wall sticking and drag. Filtration control is also significant in formation evaluation as invasion of mud filtrate may influence the readings taken. The readings may represent the mud filtrate rather than the formation fluid properties. Besides that, quality of filter cake which is the suspended solids of a drilling fluid that deposited on a porous medium during the process of filtration is also important. The fluid loss amount is inversed to the thickness of filter cake deposited. The physical property of a cake is stated in notations like “hard”, “soft,” “tough,” rubbery” and “firm”.

The high temperature/high pressure (HTHP) test is conducted using the HTHP filter press shown in the picture below at a temperature greater than ambient and it requires differential pressure of 500 psi. The top and bottom pressure to be applied on the HTHP filter press depends on the temperature to run the test and this can be referred to the table in appendix 1. The HTHP filtrate is collected for a period of 30 minutes in cubic centimetres and the filtrate volume is doubled to correct it to the filter area of the API filtration test. The permeable medium used is the same as that used for the low temperature test. The filter cake should also be assessed for thickness and consistency after the filtrate loss has been tested.

2.6 Process of mixing and testing drilling fluids

First and foremost, the mud formulation for water and oil/synthetic based muds is created using the mud formulator shown in figure 1. The mud formulator is an excel spreadsheet utilized to calculate the appropriate amount of products to be used to mix one lab barrel of mud which is almost 350ml in the laboratory. The final weight, type of mud, products such as weighting material, emulsifiers, viscosifiers, fluid loss agent and others are keyed into this spreadsheet and calculated. As the test oil of this experiment (Castor oil) is too viscous, small amount of diluter will be used in this experiment which is Toluene.

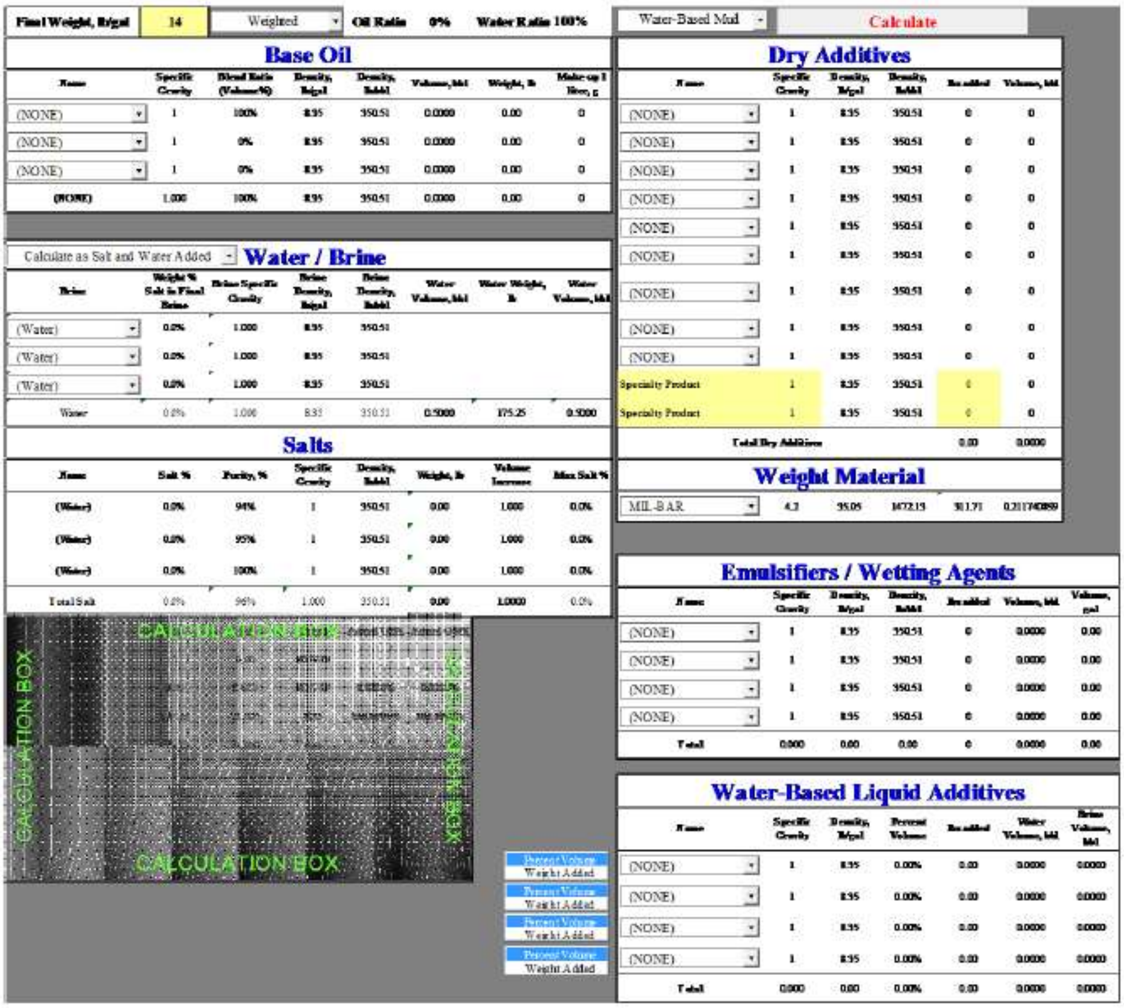

Figure 3 : Mud Formulator Spreadsheet

Next, the base fluids and products are weighed according to the formulation calculated. The chemicals are then mixed according to the mixing time and order. In water based mud, the viscosifiers are generally added first into the base fluid which is water followed by the fluid loss agent and then the weighting material. Whereas, in oil/synthetic based mud, the emulsifiers are commonly added first into the base fluid such as base oil, followed by the viscosifiers, fluid loss agent and finally the weighting material. The following mixture of mud will have Toluene added before the emulsifier is mixed. The amount of Toluene added will be varied to see the difference in the rheology that it produces. In the laboratory, generally, the mixing time for water based mud is 45 minutes and for oil based mud is one hour. Once the mud is mixed, the initial properties of the mud are tested.

2.7 Elastomers

Oil based drilling fluids can chemically alter the properties of elastomers used in drilling equipment, severely affecting life and function. The products affected include O-ring, blowout preventers (BOPs), pulsation dampeners, downhole mud motors and drilling bits. This study centers on the effects of selected environmentally safe Castor oil based mud on elastomers and logging tools.

The performance of elastomers in Castor oil drilling fluid is strongly dependent upon drilling fluid chemistry, operating temperature and the type of elastomer chosen for service. Caution and testing have to be done when selecting environmentally safe drilling fluids and compatible elastomers.

CHAPTER 3

METHODOLOGY

3.1 Methodology Flowchart

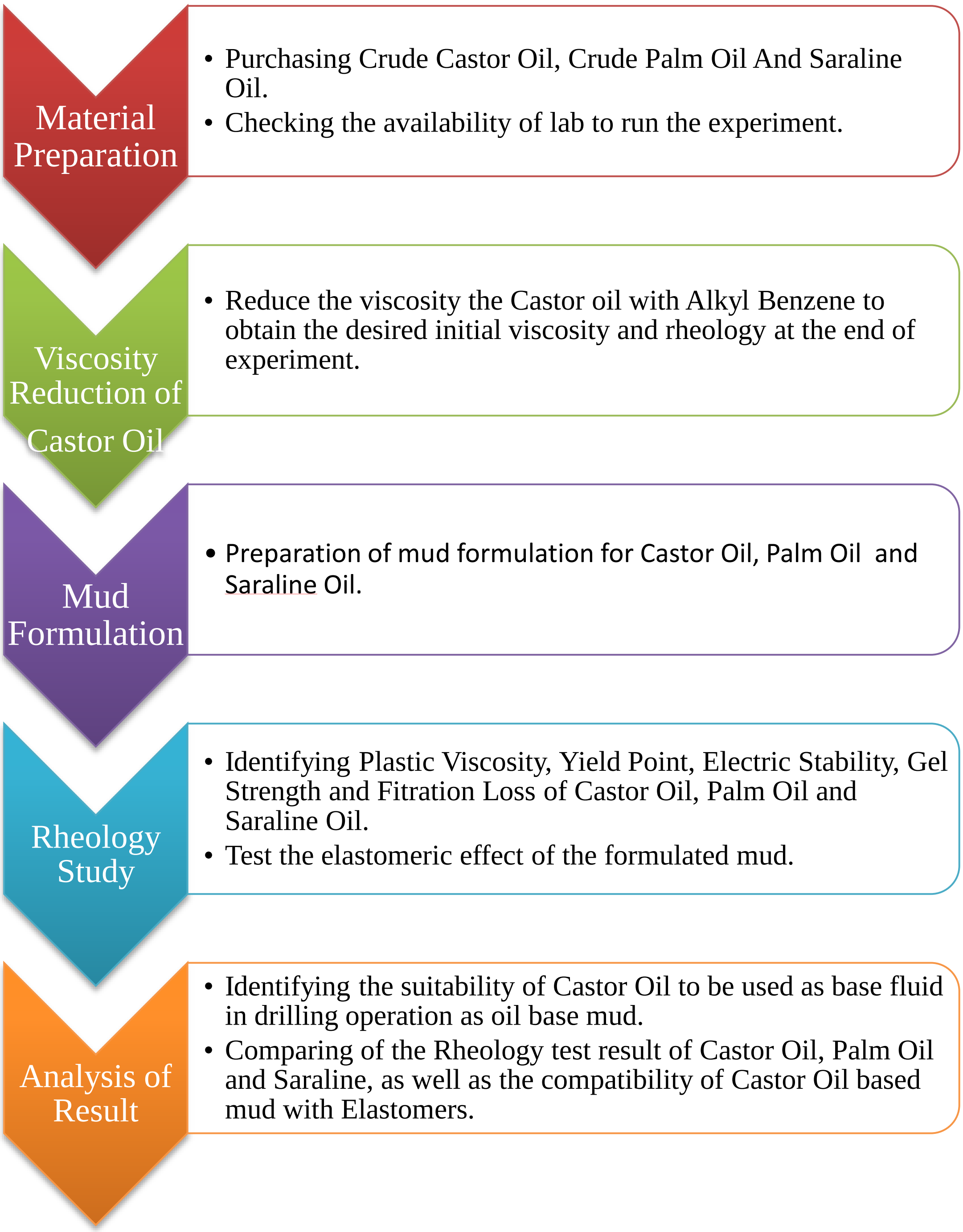

Figure 4: Methodology Flowchart

3.2 Addition of Methyl-benzene to Castor oil

The most common methods used to reduce oil viscosity in the Biodiesel industry is called transesterification. The problem with the transestrification refining method is that it is relatively expensive and produces a quantity of glycerin byproduct that has to be processed again before it has any value. The final fuel product has detergent qualities that can clean out existing fuel tanks and the resulting debris is prone to clog fuel filters for a while.

So, to reduce oil viscosity in a less expensive and much lesser time consuming way, addition of solvent preferably Alkyl-benzene is done by the author. This is because addition of Alkyl-benzene reduces the density of the oil and thus decreases the oil viscosity. The purpose of making a solvent blended biofuel is to thin the resulting blended oil to near the viscosity of diesel oil and reduce its gel-point. The resulting solution should be a uniform solution without precipitates.

Vegetable oils are an attractive renewable source for alternative diesel fuels. However, the relatively high kinematic viscosity of vegetable oils must be reduced to make them more compatible with conventional compression-ignition engines and fuel systems. Cosolvent blending is a low-cost and easy-to-adapt technology that reduces viscosity (and gel point) by diluting the vegetable oil with a low-(molecular weight solvent), which is in our case is Methyl-benzene(Toluene).

Blending methods vary; however, the most common method of making Blended Biofuels Diesel (BBD) is to blend the solvent with the source vegetable oil because blending solvents with vegetable oils has three basic functions. Blending reduces the viscosity of the source oil, reduces its gel-point, and tends to force water, and other contaminants, out of solution. This means that thinned oil will drop its contaminant load much more quickly than the more viscous source oil.

3.3 Mud Formulation of Base Fluid

Before rheology test commence, mud formulation should be done for each base fluid that going to be tested. Table 3.1 shows the mud formulation of Castor Oil, Methyl Ester Palm Oil and Saraline Oil.

Composition	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7
Saraline 185V, lb/bbl	183.6		-	-	-	-	-
Methyl Esther Palm Oil		215.6					
Castor Oil	-		241.18	230.14	230.14	230.14	230.14
Toluene	-		-	10	15	20	25
VERSAPRO lb/bbl	8		8	8	8	8	8
VERSAGEL®, lb/bbl	7		7	7	7	7	7
LIME®, lb/bbl	4		4	4	4	4	4
VERSATROL® HT, lb/bbl	8		8	8	8	8	8
Water, bbl	59		67.31	67.31	67.31	67.31	67.31
$CaCl_2$, lb/bbl	20.9		12.64	12.64	12.64	12.64	12.64
MIL-BAR®, lb/bbl	129.46		1.88	1.88	1.88	1.88	1.88

Table 5: Mud Composition

3.4 *ASTM Standards:* D471 Test Methods for Rubber Property Effect of Liquids

Besides that, the compatibility of Castor oil with elastomers will also be tested. Elastomers are developed and selected for mechanical performance with environmental interactions secondary. The properties of elastomers are presented before and after Castor oil based mud exposure. The property changes were evaluated with respect to equipment function and performance and exposure time. This test procedure measures the ability of rubber to withstand the effect of liquids. It is designed for testing specimens of elastomeric vulcanizates cut from standard sheets.

3.5 Required Tools

Equipments:

1) Multi Mixer, 2) FANN Model 35 3) HTHP filter press, 4) Electric Stability Meter, 5) Basic equipments in lab such as beaker,heater,3 neck flask, separator funnel, and termometer

Consumables:

1) Crude Castor Oil, Methyl Ester Palm Oil, Saraline Oil, Methyl-benzene.

CHAPTER 4

RESULTS AND DISCUSSION

4.1.1 RHEOLOGICAL TEST RESULTS

Table 4.1 shows the mud properties results after rheology test were applied to Castor Oil, Methyl Ester Palm Oil and Saraline.

Test 1 = Saraline Oil

Test 2 = Methyl Ester Palm Oil

Test 3 = Castor Oil

Test 4 = Castor Oil with 10g Toluene

Test 5 = Castor Oil with 15g Toluene

Test 6 = Castor Oil with 20g Toluene

Test 7 = Castor Oil with 25g Toluene

Formulation	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7
Mud weight (ppg)	10	10	10	10	10	10	10
Rheology Temperature(◦F)	75	75	75	75	75	75	75
600 rpm	54	79	300+	232	183	85	32
300 rpm	37	54	300+	186	147	57	28
200 rpm	21	28	239	121	98	39	15
100 rpm	16	19	178	86	59	21	9
6 rpm	8	7	76	43	15	6	3
3 rpm	7	5	54	39	10	3	2
Plastic Viscosity, cP (ALAP)	17	25	-	46	36	28	4
Yield Point, lb/100 ft^2	20	29	-	140	111	29	24
Gels, 10 sec	10	14	55	39	20	14	5
Gels, 10 min	13	16	71	45	27	18	8
Electrical Stability	652	1380	671	601	521	499	401
HPHT at 250°F and 500psi, mL	3.2	2.8	1.2	2.4	2.8	3.4	6.4

Table 6: Rheology Test Result

When, Castor Oil and Methyl Ester Palm Oil is compared with Saraline Oil, Saraline Oil has lower PV and YP and also preferable ES and Gel Strength value that shows that it has a better and more preferable characteristics to be used as base fluid. This is because Saraline Oil is commercially used base fluid in oil and gas industry these days. Therefore, Saraline oil being a comparison factor in this project shows more preferable rheology properties of a base fluid. Figure 7.1, Figure 7.2, figure 7.3, Figure 7.4, Table 7.2, table 7.2 below shows the rheology study parameters of the base fluid using tables and graphs.

4.1.1 Plastic Viscosity

Base Fluid	**Castor Oil with 20g Toluene**	**Methyl Ester Palm Oil**	**Saraline Oil**
Plastic Viscosity, cp	28	25	17

Table 6.1: Plastic Viscosity

4.1.2 Yield Point

Base Fluid	**Castor Oil with 20g Toluene**	**Methyl Ester Palm Oil**	**Saraline Oil**
Yield Point, cp	29	29	20

Table 6.2: Yield Point

Graph I: Plastic Viscosity and Yield Point

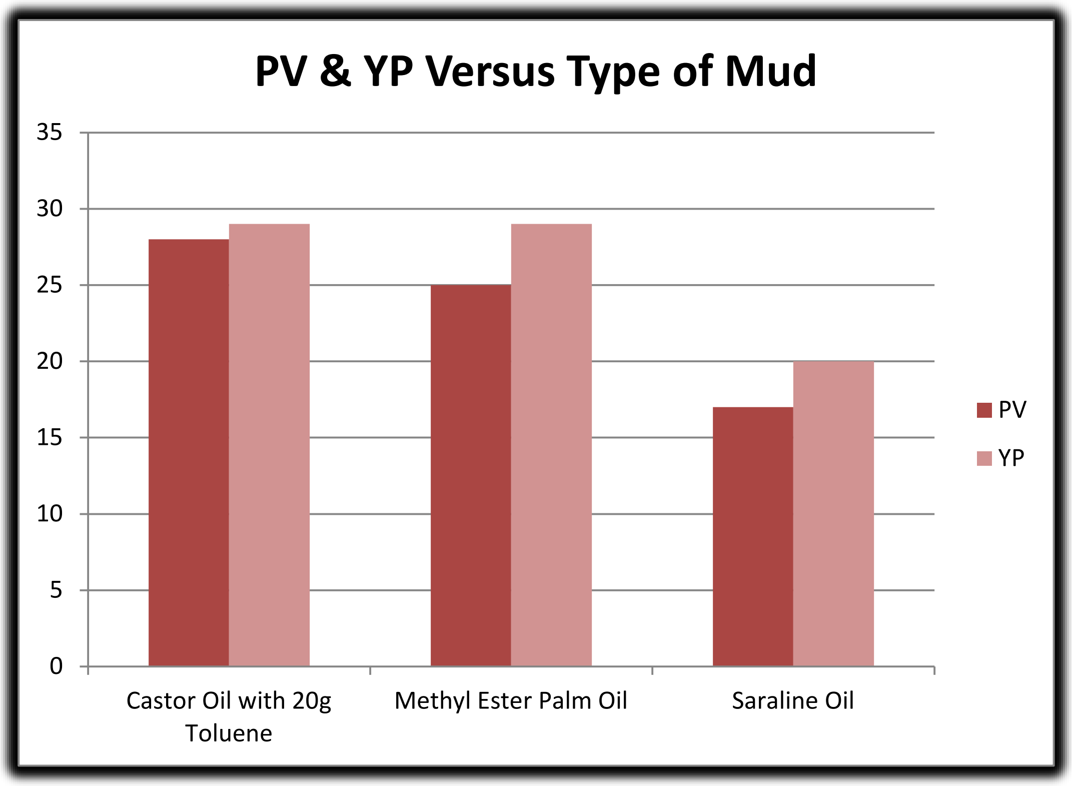

Figure 5.1: Graph of Plastic Viscosity of Base Fluid

Graph II: Gel Strength

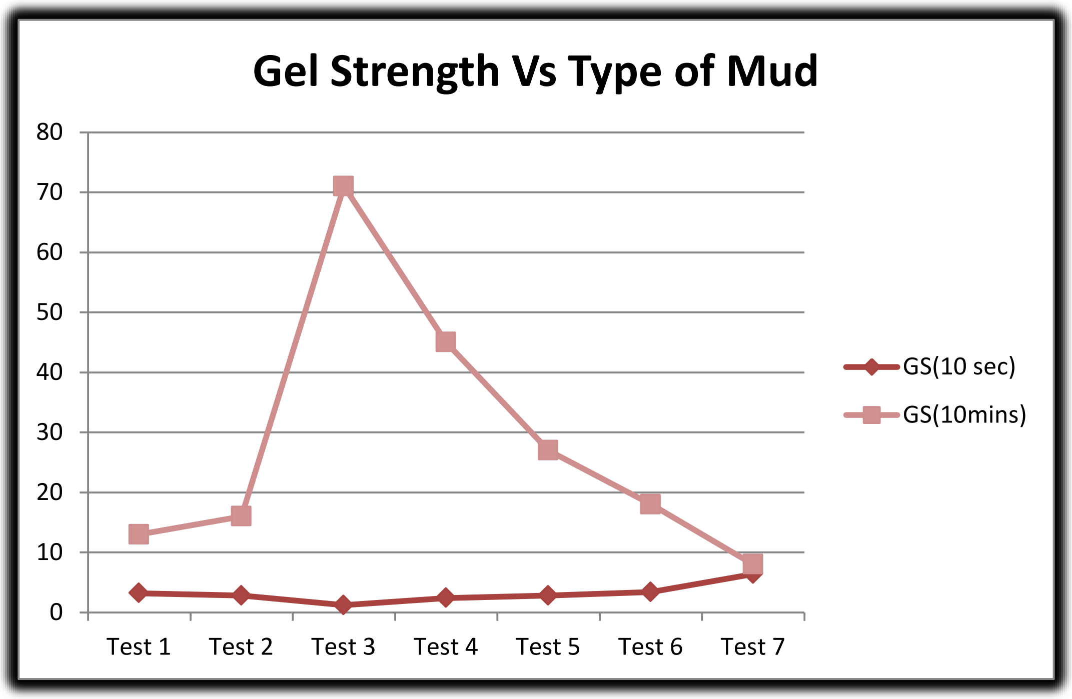

Figure 5.2: Graph of Yield Point of Base Fluid

Graph III: Electrical Stability

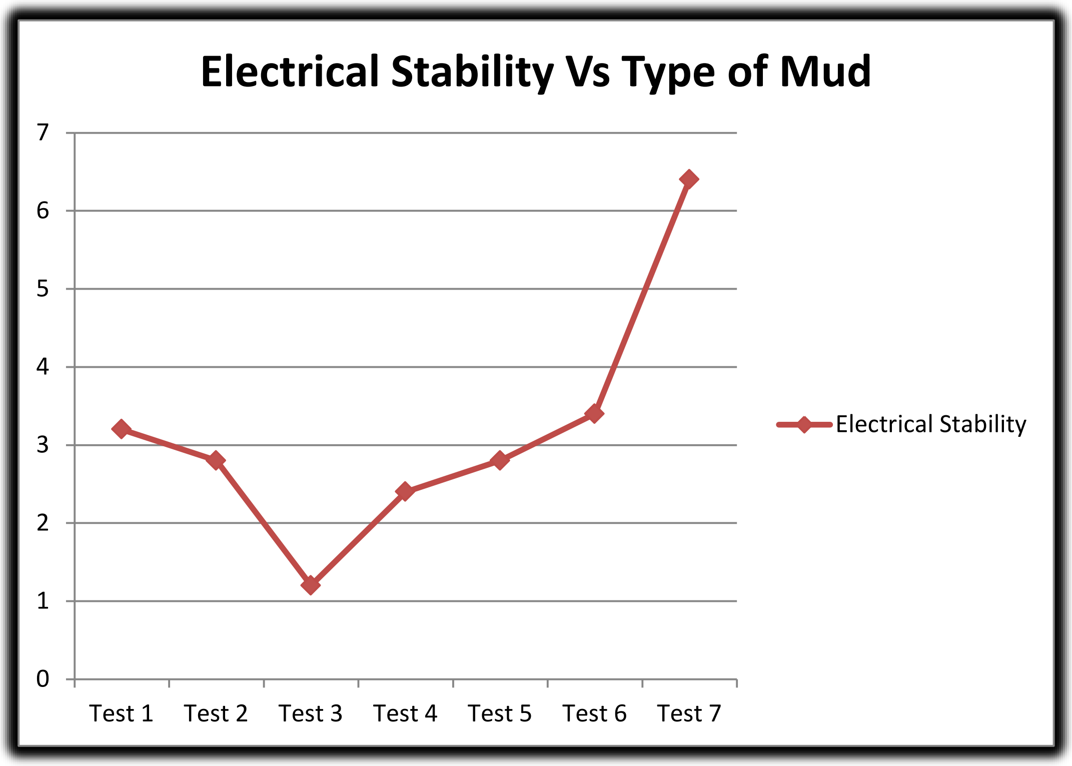

Figure 5.3: Graph of Electrical stability of Base Fluid

Graph IV: Filtration Loss

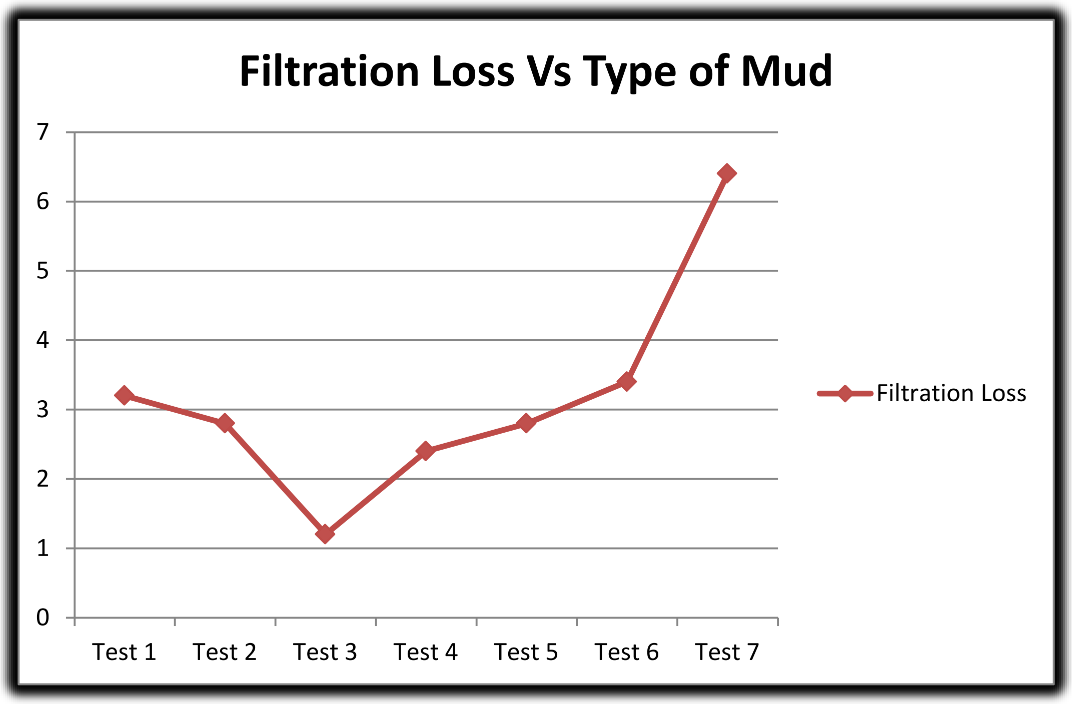

Figure 5.4: Graph of Yield Point of Base Fluid

From the rheology test resul, it shows that Castor Oil has high PV and YP but has preferable value of ES and Gel Strength. This shows that Castor Oil did not acquire the characteristic of a base fluid when compared to Methyl Ester Palm Oil. When, Castor oil is compared with Methyl Ester Palm Oil, Methyl Ester Palm Oil shows a better base fluid characteristic because it has lower PV but high YP and preferable value of ES and Gel Strength. Therefore, it also shows that between the vegetable oil, Palm Oil is a better candidate to be used as base fluid.

4.1.2 Elastomer Test Results

Liquid	**Methyl Esther Palm Oil**	**Saraline oil**			**Castor oil based mud**			**Castor oil based mud @ Toluene 20 g**		
Temp(F)	75	75			75			75		
Time(h)	0	24	48	168	24	48	168	24	48	168
Volume(in^3)	4.5	4.5	4.5	4.65	4.5	4.5	4.5	4.5	4.5	4.72
Weight(g)	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5

Table 7: Elastomer Test Results

The volume of rubber sheet doesn’t change in Castor oil but does change when Toluene is added. This is probably due to absorption of Toluene by the rubber over period of time, due to the existence of the aromatic group. Methyl Esther Palm oil proves to be the suitable oil phase for drilling mud as it only changes the physical structure a little and it is not significant..

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Based on the objectives stated author can conclude that, from rheology test result, Castor Oil, does not acquire much of an ideal base fluid to be use in drilling operation compared to Methyl Ester Palm Oil. But it can be treated to some extent by changing the composition of materials in the mud formulation because referring to Table 2.1, Castor Oil has the criteria of a base fluid. Therefore, it can be treated further to be used commercially as a base fluid in drilling operation. When, Castor Oil and Methyl Ester Palm Oil are compared, Methyl Ester Palm Oil attains the characteristics of a base fluid.

When Castor Oil and Methyl Ester Palm Oil are compared with Saraline Oil which is considered as a comparison between vegetable oil and mineral oil, mineral oil shows a better base fluid to be use in drilling operation. Mineral oil also has the criteria of a base fluid as shown in Table 2.1. The reason why mineral oil is far better compare to vegetable oil is Saraline is specially engineered to be used for commercial purpose in drilling fluid. Therefore, it has shown the most convincing result than the other two of the vegetable oil.

5.2 Recommendation

Conversion of Castor Oil into Castor Oil FAME is recommended by the author to have a better rheology test result since addition of Methyl-benzene proves to yield a result far from desired. That will also ensure that Castor Oil FAME can be a better candidate to replace diesel oil in drilling operation.

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APPENDIX

Appendix 1 – Recommended practice standard procedure for field testing oil-based drilling fluids(1998), American Petroleum Institute.

Recommended Practice for Field Testing of Oil-based Drilling Fluids

1 Scope

This Recommended Practice provides standard procedures for determining the following characteristics of oil-based drilling fluids:

a) drilling fluid density (mud weight);

b) viscosity and gel strength;

c) filtration;

d) oil, water and solids contents;

e) alkalinity, chloride content and calcium content;

f) electrical stability;

g) lime and calcium contents, calcium chloride and sodium chloride contents;

h) low-gravity solids and weighting material contents.

Annexes A, B, C, D, H, I, K and L provide additional test methods that may optionally be used for the determination of

i) shear strength,

j) oil and water contents from cuttings,

k) drilling fluid activity,

l) aniline point,

m) cuttings activity,

n) active sulfides,

o) PPA test method for cells with set screws,

p) PPA test method for cells with screw-on caps.

Annexes F, G and J provide procedures that may optionally be used for

q) sampling, inspection and rejection,

r) rig-site sampling,

s) calibration and verification of glassware, thermometers, viscometers, retort kit cups and drilling fluid balances.

Annex E provides examples of calculations for

t) lime, salinity and solids content.

Annex M contains an example of a drilling fluid report form.

2 Terms and definitions

For the purposes of this Standard, the following term and definition applies:

2.1
ACS reagent grade
grade of chemical meeting the purity standards specified by the American Chemical Society (ACS)

2.2
API
American Petroleum Institute, 1220 L Street NW, Washington, DC 20005

2.3
CAS
Chemical Abstracting Service

2.4
USC
United States Customary unit, shown in parentheses following SI unit

3 Abbreviations

ACS	American Chemical Society
BAD	Base alkalinity demand
EDTA	eithylenediaminetetraacetic acid
ES	electrical stability
HT/HP	high temperature, high pressure
OCMA	Oilfield Chemical Manufacturer's Association
PNP	propylene glycol normal-propyl ether
PTFE	polytetrafluoreoethylene, brand name Teflon®
TC	to contain
TD	to deliver
R_{300}	viscometer reading at 300 r/min
R_{600}	viscometer reading at 600 r/min
[illegible]	static filtration rate

m_1	mass of retort cup, lid and body with steel wool, g
m_2	mass of retort cup, lid, body and cuttings, g
m_3	mass of empty liquid receiver, g
m_4	mass of liquid receiver and fluid collected during solids analysis, g
m_5	mass of solids remaining in retort cup following solids analysis, g
R	static filtration rate
V	volume of liquid collected in receiver, ml
V_o	volume of oil, cm^3
V_s	volume of solids, cm^3
V_1	volume of filtrate after 7,5 min, cm^3
V_2	volume of filtrate after 30 min, cm^3
V_w	volume of water, cm^3
η_P	viscosity of plastic viscosity
η_Y	viscosity of yield point
η_A	appararent viscosity
φ_o	volume fraction of oil
φ_s	volume fraction of solids
φ_w	volume fraction of water
ρ	density
$\nabla\rho$	density gradient

4 Determination of drilling fluid density (mud weight)

4.1 Principle

A procedure is given for determining the mass of a given volume of liquid (= density). The density of drilling fluid is expressed as grams per cubic centimetre, kilograms per cubic metre, pounds per gallon or pounds per cubic foot.

4.2 Apparatus

a) Any **density-measuring instrument** having an accuracy of ± 0,01 g/cm^3, ± 10 kg/m^3, ± 0,1 lb/gal, or ± 0,5 lb/ft^3.

The mud balance is the instrument generally used for drilling fluid density determinations. The mud balance is designed such that the drilling fluid holding cup, at one end of the beam, is balanced by a fixed counterweight at the other end, with a sliding-weight rider free to move along a graduated scale. A level-bubble is mounted on the beam to allow for accurate balancing. Attachments for extending the range of the balance may be used when necessary.

The instrument should be calibrated frequently with fresh water. Fresh water should give a reading of 1,00 g/cm³ or 1 000 kg/m³ at 21 °C (70 °F). If it does not, adjust the balancing screw or the amount of lead shot in the well at the end of the graduated arm as required.

b) **Thermometer**, with a range of 0 °C to 105 °C (32 °F to 220 °F).

4.3 Procedure

4.3.1 The instrument base should be set on a flat, level surface.

4.3.2 Measure the temperature of the drilling fluid and record.

4.3.3 Fill the clean, dry cup with drilling fluid to be tested; put the cap on the filled drilling-fluid holding cup and rotate the cap until it is firmly seated. Ensure that some of the drilling fluid is expelled through the hole in the cap, in order to free any trapped air or gas.

4.3.4 Holding the cap firmly on the drilling-fluid holding cup (with cap hole covered), wash or wipe the outside of the cup clean and dry.

4.3.5 Place the beam on the base support and balance it by moving the rider along the graduated scale. Balance is achieved when the bubble is under the centreline.

4.3.6 Read the drilling fluid density at the edge of the rider toward the drilling-fluid cup. Make appropriate corrections when a range extender is used.

4.4 Calculation

4.4.1 Report the drilling fluid density, ρ_s, to the nearest 0,01 g/cm³ , 10 kg/m³, 0,1 lb/gal or 0,5 lb/ft³.

4.4.2 To convert the reading to other units, use the following:

$$\rho_s = 1\,000 \times \text{g/cm}^3 \quad (1)$$

$$\rho_s = 16 \times \text{lb/ft}^3 \quad (2)$$

$$\rho_s = 119{,}8 \times \text{lb/US gal} \quad (3)$$

where ρ_s is the density, expressed in kilograms per cubic metre.

$$\nabla\rho_s = 9{,}81 \times \text{g/cm}^3 \quad (4)$$

$$\nabla\rho_s = 0{,}0226 \times \text{psi/1 000 ft} \quad (5)$$

where $\nabla\rho_s$ is the drilling fluid density gradient, expressed in kilopascals per metre.

A list of density conversions from SI to USC units is given in Table 1.

Table 1 — Density conversions between SI and USC units

Grams per cubic centimetre[a] g/cm³	Kilograms per cubic metre kg/m³	Pounds per US gallon (lb/US gal)	Pounds per cubic foot (lb/ft³)
0,70	700	5,8	43,6
0,80	800	6,7	49,8
0,90	900	7,5	56,1
1,00	1 000	8,345[b]	62,3
1,10	1 100	9,2	68,5
1,20	1 200	10,0	74,8
1,30	1 300	10,9	81,0
1,40	1 400	11,7	87,2
1,50	1 500	12,5	93,5
1,60	1 600	13,4	99,7
1,70	1 700	14,2	105,9
1,80	1 800	15,0	112,1
1,90	1 900	15,9	118,4
2,00	2 000	16,7	124,6
2,10	2 100	17,5	130,8
2,20	2 200	18,4	137,1
2,30	2 300	19,2	143,3
2,40	2 400	20,0	149,5
2,50	2 500	20,9	155,8
2,60	2 600	21,7	162,0
2,70	2 700	22,5	168,2
2,80	2 800	23,4	174,4
2,90	2 900	24,2	180,7

[a] Same value as relative density.

[b] Accurate conversion factor.

5 Alternative method for determination of drilling fluid density

5.1 Principle

5.1.1 The pressurized mud balance provides a more accurate method for determining the density of a drilling fluid containing entrained air or gas than does the conventional mud balance. The pressurized mud balance is similar in operation to the conventional mud balance, the difference being that the slurry sample is placed in a fixed-volume sample cup under pressure.

5.1.2 The purpose of placing the sample under pressure is to minimize the effect of entrained air or gas upon slurry density measurements. By pressurizing the sample cup, any entrained air or gas is decreased to a negligible volume, thus providing a slurry density measurement more closely in agreement with that obtained under downhole conditions.

5.2 Apparatus

a) Any **density-measuring instrument** having an accuracy of ± 0,01 g/cm³, ± 10 kg/m³, ± 0,1 lb/gal, or ± 0,5 lb/ft³.

The pressurized mud balance is the instrument generally used for density determinations of pressurized drilling fluids. The pressurized mud balance is designed such that the drilling-fluid holding cup and screw-on lid, at one end of the beam, is balanced by a fixed counterweight at the other end, with a sliding-weight rider free to move along a graduated scale. A level-bubble is mounted on the beam to allow for accurate balancing.

Calibrate the instrument frequently with fresh water. Fresh water should give a reading of 1,0 g/cm³ or 1 000 kg/m³ at 21 °C (69,8 °F). If it does not, adjust the balancing screw or the amount of lead shot in the well at the end of the graduated arm as required.

b) **Thermometer**, with a range of 0 °C to 105 °C (32 °F to 220 °F).

5.3 Procedure

5.3.1 Measure the temperature of the drilling fluid and record.

5.3.2 Fill the sample cup to a level slightly (approximately 6 mm) below the upper edge of the cup.

5.3.3 Place the lid on the cup with the attached check-valve in the down (open) position. Push the lid downward into the mouth of the cup until surface contact is made between the outer skirt of the lid and the upper edge of the cup. Any excess slurry will be expelled through the check-valve. When the lid has been placed on the cup, pull the check-valve up into the closed position, rinse off the cup and threads with water, and screw the threaded cap on the cup.

5.3.4 The pressurizing plunger is similar in operation to a syringe. Fill the plunger by submersing its end in the slurry with the piston rod completely inside. Then draw the piston rod upward, thereby filling the cylinder with slurry. This volume should be expelled with the plunger action and refilled with fresh slurry sample to ensure that this plunger volume is not diluted with liquid remaining from the last clean-up of the plunger mechanism.

5.3.5 Push the nose of the plunger onto the mating O-ring surface of the cap valve. Pressurize the sample cup by maintaining a downward force on the cylinder housing in order to hold the check-valve down (open) and at the same time to force the piston rod inside. A force of approximately 225 N (50 lbf) or greater should be maintained on the piston rod.

5.3.6 The check-valve in the lid is pressure-actuated; when the inside of the cup is pressurized, the check-valve is pushed upward into the closed position. To close the valve gradually ease up on the cylinder housing while maintaining pressure on the piston rod. When the check-valve closes, release pressure on the piston rod before disconnecting the plunger.

5.3.7 The pressurized slurry sample is now ready for weighing. Rinse the exterior of the cup and wipe dry. Place instrument on the knife edge. Move the sliding weight right or left until the beam is balanced. The beam is balanced when the attached bubble is centred between the two black marks. Read the density from one of the four calibrated scales on the arrow side of the sliding weight. The density can be read directly in units of grams per cubic centimetre, pounds per gallon, and pounds per cubic foot, or as a drilling fluid gradient in pounds per square inch per 1 000 feet.

5.3.8 To release the pressure inside the cup, reconnect the empty plunger assembly and push downward on the cylinder housing.

5.3.9 Clean the cup and rinse thoroughly with base oil.

5.4 Calculation

Report the drilling fluid density to the nearest 0,01 g/cm³ , 10 kg/m³, 0,1 lb/gal, or 0,5 lb/ft³.

For conversions, use the formulas given in 4.4.2.

6 Viscosity and gel strength

6.1 Principle

Viscosity and gel strength are measurements that relate to the flow properties (rheology) of drilling fluids. The following instruments are used to measure viscosity and/or gel strength of drilling fluids:

a) Marsh funnel — a simple device for indicating viscosity on a routine basis;

b) direct-indicating viscometer — a mechanical device for measurement of viscosity at varying shear rates.

NOTE Information on the rheology of drilling fluids can be found in API RP 13D.

6.2 Determination of viscosity using the Marsh funnel

6.2.1 Apparatus

a) **Marsh funnel**, calibrated to deliver 946 cm^3 (1 quart) of fresh water at a temperature of 21 ± 3 °C (70 ± 5 °F) in 26 ± 0,5 s, with a graduated cup as a receiver.

The Marsh funnel shall have the following characteristics:

1) **funnel cone**, length 305 mm (12,0 in), diameter 152 mm (6,0 in) and a capacity to bottom of screen of 1 500 cm^3 (1,6 quarts);

2) **orifice**, length 50,8 mm (2,0 in) and inside diameter 4,7 mm (0,185 in);

3) **screen**, with 1,6 mm (0,063 in) openings (12 mesh); fixed at 19,0 mm (0,748 in) below top of funnel.

b) **Graduated cup,** with capacity at least 946 cm^3 (1 quart).

c) **Stopwatch**.

d) **Thermometer**, with a range of 0 °C to 105 °C (32 °F to 220 °F).

6.2.2 Procedure

6.2.2.1 Cover the funnel orifice with a finger and pour freshly sampled drilling fluid through the screen into the clean, upright funnel. Fill until fluid reaches the bottom of the screen.

6.2.2.2 Remove finger and start the stopwatch. Measure the time for drilling fluid to fill to the 946 cm^3 (1 quart) mark of the cup.

6.2.2.3 Measure the temperature of the fluid, in degrees Celsius (degrees Fahrenheit).

6.2.2.4 Report the time (6.2.2.2), to the nearest second, with the volume, as the Marsh funnel viscosity. Report the temperature (6.2.2.3) of the fluid to the nearest degree Celsius (degree Fahrenheit).

CAUTION Liquid trapped inside a hollow bob may vaporize when immersed in high-temperature fluid and cause the bob to explode.

6.3.2.2 Heat (or cool) the sample to the selected temperature. Use intermittent or constant shear at 600 r/min to stir the sample while heating (or cooling) to obtain a uniform sample temperature. After the cup temperature reaches the selected temperature, immerse the thermometer into the sample and continue stirring until the sample reaches the selected temperature. Record the temperature of the sample.

6.3.2.3 With the sleeve rotating at 600 r/min, wait for the viscometer dial reading to reach a steady value (the time required is dependent on the drilling fluid characteristics). Record the dial reading R_{600} in pascals for 600 r/min.

6.3.2.4 Reduce the rotor speed to 300 r/min and wait for the dial reading to reach steady value. Record the dial reading R_{300} in pascals for 300 r/min.

6.3.2.5 Stir the drilling fluid sample for 10 s at 600 r/min.

6.3.2.6 Allow drilling fluid sample to stand undisturbed for 10 s. Slowly and steadily turn the hand-wheel in the appropriate direction to produce a positive dial reading. Record the maximum reading as the initial gel strength. For instruments having a 3 r/min speed, the maximum reading attained after starting rotation at 3 r/min is the initial gel strength. Record the initial gel strength (10-second gel) in pounds per 100 square feet.

NOTE To convert the dial reading to pounds per 100 square feet: 1 Pa = 0,48 lb/100 ft^2.

6.3.2.7 Restir the drilling fluid sample at 600 r/min for 10 s and then allow the drilling fluid to stand undisturbed for 10 min. Repeat the measurements as in 6.3.2.6 and report the maximum reading as the 10-minute gel in pascals (pounds per 100 square feet).

NOTE To convert the dial reading to pounds per 100 square feet: 1 Pa = 0,48 lb/100 ft^2.

6.3.3 Calculation

$$\eta_P = R_{600} - R_{300} \quad (6)$$

$$\eta_Y = 0,48 \times (R_{300} - \eta_P) \quad (7)$$

$$\eta_A = R_{600}/2 \quad (8)$$

where

η_P is the plastic viscosity, in millipascal seconds;

NOTE Plastic viscosity is commonly known in the industry by the abbreviation PV.

η_Y is the yield point, in pascals;

η_A is the apparent viscosity, in millipascal seconds;

R_{600} is the dial reading at 600 r/min, in pascals (pounds per 100 square feet);

R_{300} is the dial reading at 300 r/min, in pascals (pounds per 100 square feet).

NOTE 1 To convert to CGS units of centipoise, 1 mPa·s = 1 cP.