UNIVERSITI
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PETRONAS

"FEASIBILITY STUDY OF JATROPHA BASED MUD FOR HIGH PRESSURE LOW TEMPERATURE WELLS"

By

ANNANUR KIZILOV

FINAL YEAR RESEARCH PROJECT REPORT

Submitted to the Mechanical Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Mechanical Engineering)

JUNE 2009

Universiti Teknologi Petronas
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CERTIFICATION OF APPROVAL

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BACHELOR OF ENGINEERING (Hons)
(MECHANICAL ENGINEERING)

Approved by.

(AP. DR, FAIZ AHMAD)
Main Supervisor

Universiti Teknologi PETRONAS
Tronoh, Perak
JUNE 2009

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.

ANNANUR KIZILOV

ABSTRACT

Growing demand for diesel oil and palm oil by consumers led increased their price in the world market. Increase in price means more expenses for consumers. Industries are mostly depended on diesel oil and palm oil, one of them is Oil and Gas industry, since diesel oil and palm oil widely used in the drilling operation, as the main oil additive for drilling mud This study is aimed to study the feasibility of using Jatropha Oil Based Mud as the alternative, cheap, requiring less chemical additives and environmentally safe drilling mud to replace or to be enough competitive with the current existing drilling mud using other oil additives.

These objectives were achieved by conducting multistage experiments in drilling laboratory. Multimixer, Mud Balance, and Viscometer experimental equipments were used to determine the mud rheology of Jatropha Oil Based Mud and to achieve the study's objectives.

From the experiments done, it could be seen that Jatropha Oil Based Mud (JOBM) could indeed be used as alternative drilling mud which requires less chemical additives, cheap and environmentally safe, comparable to the other drilling muds. It is seen that the JOBM requires less chemical additive in order to meet the standard requirements for the drilling mud. JOBM met requirement only by using three main additives: Jatropha oil, Thinner, and Barite Brown (KMC), and managed to exclude the water, Indian Bentonate and other high cost additives.

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ABBREVIATIONS AND NOMENCLATURES

JOBM	= Jatropha Oil Based Mud
POBM	= Palm Oil Based Mud
WBM	= Water Based Mud
OBM	= Oil Based Mud
SBM	= Synthetic Based Mud
MW	= Mud Weight
PV	= Plastic Viscosity
YP	= Yield Point
GS	= Gel Strength

CHAPTER 1
INTRODUCTION

1.1 Background

Since diesel oil and palm oil been introduced to the world as alternative source of oil to replace the crude oil, their prices significantly changed. Their high prices will lead consumer to more expenses.

Industry is mostly depended on diesel oil and palm oil, one of them is Oil and Gas industry. Diesel oil and Palm oil widely used in drilling mud. Their high price's in the market increased cost of drilling mud in drilling operation. Finding solution kept drilling engineers searching on new technologies for improving and reducing cost of drilling mud. Engineers found out that they can reduce the cost of drilling mud and reduce the impact on environment, by replacing existing liquid material diesel oil and palm oil to cheap and environmentally friendly oil. The oil capable of giving same or even great performance as existing ones used in drilling mud. After years of researches they discovered that vegetable oil could replace and achieve successful performance compared to existing oil used in drilling mud.

The advantage of my research work is to prove that Vegetable oil like Jatropha oil can replace diesel oil and palm oil in the drilling mud by conducting experiment "Jatropha Based Mud using Jatropha oil", and to prove its competence performance with existing commercialized Synthetic Based Mud.

1.2 Problem Statement

Diesel oil and Palm oil been used in drilling mud in order to avoid problems during the drilling operation and also to increase performance of drilling mud. Unfortunately these 2 categories of oils are very expensive to use in drilling operation. It makes even more expensive when extra chemical additives had been used in order to meet different requirements of drilling mud, at the end it will lead increase in the cost and more impact on an environment.

This project is to find out alternative oil for drilling mud which is cheap and friendly to environment, and also to decrease the number of additives had been used, in order to reduce the cost and impact on environment. In this project we are going to use Jatropha oil from Jatropha Curcas plant for our experiments. Experiments will be conducted in multiple stages and results will be compared with the API (American Petroleum Institute) standards and with the actual results of Diesel oil and Palm oil drilling mud.

1.3 Objective and Scope of Study

The objectives of this study are to investigate and analyze the behavior of the Jatropha Based Mud (JBM) by conducting the experiments and comparing the results with the actual drilling mud. In order to achieve this objective, a few tasks and research need to be carried out by collecting all technical details regarding the existing drilling in the market and by studying the fundamental behavioral of the drilling muds. A recommendation is to be made based on the findings of this study.

- To measure mud rheology of Jatropha Based Mud
- To compare JBM with palm oil drilling mud.

The scope of work of this project is to investigate the suitability of Jatropha oil to replace diesel oil and palm oil in drilling mud, and to conduct experiments using Jatropha oil to improve drilling mud performance. The experiments using Jatropha oil will be conducted in the lab. The results taken from the experiment will be analyzed and compared with API standards and with the current existing drilling muds in the market.

CHAPTER 2

LITERATURE REVIEW

2.1 Jatropha Curcas

1. The Name Jatropha is derived from the Greek word 'Jatros' means 'Doctor' and 'trophe' means 'Nutrition'. The botanical name of Jatropha Curcas is known as Jatropha Curcas L. and it belongs to the family Euphorbiaceae. Jatropha Curcas is a multipurpose shrub found throughout the tropics, known by 200 different names in various parts of the globe.

Figure -1' Jatropha Curcas Tree (*Technology Information, Forecasting and Assessment, New Delhi*)

Jatropha Curcas is a deciduous large shrub or small tree, about 3 - 5 m in height with smooth grey bark, which exudes whitish colored watery latex when cut. The cut branches sprout readily and grow rapidly which makes it suitable for fencing. The leaves are green to pale green, broad and usually simple, angular, deeply palmately 3-5 lobed.

Jatropha Curcas grows on a wide range of climates and soils. Jatropha plant be established on degraded, gravelly, sandy or loamy soil with adequate nutrient content. Being a species of arid and semi-arid tropics, it survives even on areas receiving very low rainfall. Jatropha Curcas is highly adaptable species and its strength as a crop comes from its ability to grow on poor and dry sites.

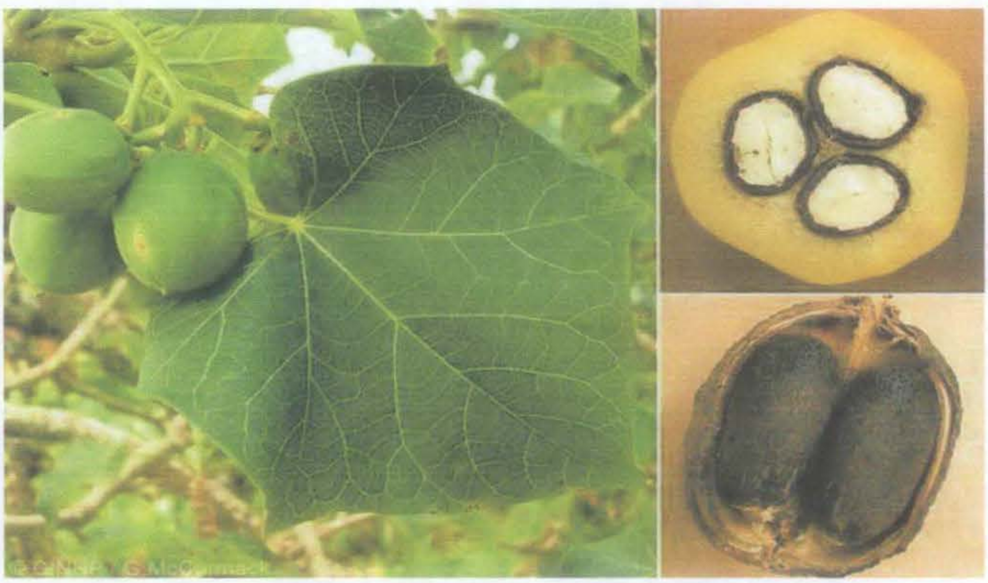


Figure-2' Jatropha Curcas Seed-A (Technology Information, Forecasting and Assessment, New Delhi)

Considering all the options available among non-edible Tree Bearing Oil (TBO) seeds, Jatropha Curcas has been identified as the most suitable seed. Jatropha is a genus of approximately 175 succulents, shrubs and trees from the family Euphorbiaceae. Plants from the genus are natives of Africa, North America and the Caribbean. Originating in the Caribbean, the Jatropha had spread as a valuable hedge plant to Africa, Asia and to India by Portuguese traders. Jatropha Curcas is a widely occurring variety of TBO. It grows practically all over India under a variety of agroclimatic conditions. Thus it ensures a reasonable production of seeds with very little inputs. (**S Biswas, N Kaushik & G Srikanth** Technology Information, Forecasting and Assessment Council (TIFAC) Department of Science & Technology, New Delhi).

Table-1, advantages and limitations of jatropha curcas

ADVANTAGES	LIMITATIONS
Jatropha can be grown in arid zones (20 cm rainfall) as well as in higher rainfall zones and even on land with thin soil cover.	Jatropha cannot be grown on waterlogged lands and slopes exceeding 30o.
It is quick yielding specie even in adverse land situations viz. degraded and barren lands under forest and non-forest use, dry and drought prone areas, marginal lands, even on alkaline soils and also as agro-forestry crops. Jatropha can be a good plantation material for eco-restoration in all types of wasteland.	The ideal climatic conditions for jatropha can be summarized as annual rainfall not exceeding 600 mm in moderate climatic conditions, 1200 mm in hot climatic zones and soil pH less than 9. The atmospheric temp should not fall below 0oC as the plants are sensitive to ground frost that may occur in winters.
Jatropha grows readily from plant cuttings or seeds up to the height of 3 - 5 m.	Jatropha seeds are hard and possess toxicity.
Jatropha is not considered good forage material.	
The plant is highly pest and disease resistant.	
Various parts of the plant are of medicinal value, its bark contains tannin, the flowers attract bees and thus the plant is honey production potential.	
Jatropha removes carbon from the atmosphere, stores it in the woody tissues and assists in the build up of soil carbon.	

2. Jatropha curcas L. (**Swahili: Mbono Kaburi**) is a perennial crop that grows in regions around the equator. It grows bushes of up to 6 meters in height and can live up to 50 years. After about three year the first seeds can be harvested. Jatropha can grow in areas that are unsuitable for other plants, because they are too dry or too arid, or because they have been left by humans because of soil depletion after excessive agriculture. The plant requires little water, fertilizer or pesticides. Many parts of Jatropha plants have been used historically by local cultures. The oil from the seeds has applications as a medicine, a lubricant or as a fuel. In present days it is mainly known as a feedstock for soap production. Jatropha soap (Sabuni ya Mmbono) is said to have healing properties for those who suffer from acne.

Figure-3'Jatropha Curcas Plantation (Indian Biofuels Awarness Centre SATISH LELE)

As the Jatropha plant and seeds are toxic, they are not eaten by goats or other animals. This means that a hedge of Jatropha plants keeps the cattle outside the fields where food crops are grown. Furthermore Jatropha plants can provide shadow in harsh conditions, allowing more delicate crops to be grown in between. Good results have been reported using this so-called intercropping. Growing, harvesting and processing of Jatropha offers a lot of local labour. For this reason Diligent is working with local farmers and presses the seeds to oil in Tanzania. Another advantage is the useful application of the remaining press cake in local communities.

Figure-4' Jatropha Curcas Seed-B (Indian Biofuels Awarness Centre SATISH LELE)

3. There are more than 100 tree species which bear seeds rich in oil having excellent properties as a fuel and which can be processed into a diesel substitute. Of these some promising tree species have been evaluated and it has been found that Jatropha curcas (Ratanjyot), Pongamia pinnata (Honge or Karanj) and Castor (Erand) are the most suitable (**Indian Biofuels Awarness Centre SATISH LELE**). However, the advantage is clearly in favour of Jatropha curcas due to the following reasons (Table-2).

Table-2, advantages of Jatropha curcas

• Oil yield per hectare is among the highest of tree borne oil seeds.
• It can be grown in areas of low rainfall (500 to 1,000 mm per year) and in problem soils. In high rainfall and irrigated areas too it can be grown with much higher yields. Therefore, it can be grown in most parts of the country. It can be grown in desert areas, with the help of drip irrigation (but it is expensive system).
• Jatropha / Castor is easy to establish, grows relatively quickly and is hardy.
• Jatropha / Castor plantations have advantage on lands developed on watershed basis and on low fertility marginal, degraded, fallow, waste and other lands such as along the canals, roads railway tracks, on borders of farmers' fields as a boundary fence or live hedge in the arid / semi-arid areas and even on slightly alkaline soils. As such it can be used to reclaim waste lands in the forests and outside.
• Jatropha / Castor seeds are easy to collect as they are ready to be plucked after the rainy season and as the plants are not very tall.
• Jatropha / Castor is not browsed by animals.
• Being rich in nitrogen, the seed cake is an excellent source of plant nutrients.
• Seed production ranges from about 0.4 tons per hectare in first year to over 5 tons per hectare after 3 years.
• The Jatropha plantation starts giving seed in a maximum period of two years after planting, while Castor bears seed in 5 months (It is a crop).
• Various parts of the plant are of medicinal value, its bark contains tannin, the flowers attract bees and thus the plant has honey production potential.
• Like all trees, Jatropha / Castor removes carbon from the atmosphere, stores it in the woody tissues and assists in the build up of soil carbon. It is thus environment friendly.
• Jatropha can be established from seeds, 3 months old seedlings and vegetatively from cuttings. Use of branch cutting for propagation is easy and results in rapid growth, but has no tap root. It makes plant weak. Castor is grown from seeds only.
• The plant is undemanding in soil type and does not require tillage.

One way of reducing the biodiesel production costs is to use the less expensive feedstock containing fatty acids such as **inedible oils,** animal fats, and waste food oil and by products of the refining vegetables oils. The availability and sustainability of sufficient supplies of less expensive feedstock will be a crucial determinant delivering a competitive biodiesel to the consumers. Fortunately, inedible vegetable oils, mostly produced by seed-bearing trees and shrubs can provide alternative. With no competing food uses, this characteristics turns attention to Jatropha curcas, which grows in tropical and subtropical climates across the developing world.

Jatropha oil is vegetable oil produced from the seeds of the Jatropha curcas, a plant that can grow in wastelands. Jatropha curcas grows almost anywhere, even on gravelly, sandy and saline soils. It can thrive on the poorest stony soil and grow in the crevices of rocks. It is easy to establish, grows relatively quickly and lives, producing seeds for 50 years. Jatropha the wonder plant produces seeds with an oil content of 37%- 64%. The oil can be combusted as fuel without being refined.

Table 3, chemical analysis of Jatropha curcas oil

ITEM	VALUE
Acid value %	**38.2**
Saponification value	**195.0**
Iodine value	**101.7**
Viscosity (31^{0}C) "Fatty acid"	**40.4**
Palmatic acid %	**4.2**
Stearic acid %	**6.9**
Oleic acid %	**43.1**
Linoleic acid %	**34.3**
Other acids %	**1.4**

The Acid value or neutralization number expresses the amount of free fatty acids in the oil and it's influenced (positively) by refining of the oil and (negatively) by aging. It must be kept as low as possible. Standard safe limit for the acid value is 2%.

The viscosity of the PPO is more or less constant for a given kind of oil, but may increase with aging of the PPO. The viscosity is dependent on the temperature of the oil. For PPO from Jatropha, the viscosity at room temperature is much higher than for rapeseed

Table 4, comparison of properties of Jatropha oil and standard specifications of diesel oil

Specification	Standard specification of jatropha oil	Standard specification of diesel
Specific gravity	**0.9186**	**0.82/0.84**
Flash point	**240/110^{0}C**	**50^{0}C**
Carbon residue	**0.64**	**0.15 or less**
Cetane value	**51.0**	**50.0 up**
Distillation point	**295^{0}C**	**350^{0}C**
Kinematics Viscosity	**50.73 cs**	**2.7 cs up**
Sulpher %	**0.13%**	**1.2% or less**
Calorific value	**9470 kcal/kg**	**10 170 kcal/kg**
Pour point	**8^{0}C**	**10^{0}C**
Colour	**4.0**	**4 or less**

From the results above, it was determined that Jatropha oil is more viscous when compared to diesel. Although Jatropha oil was only slightly higher than diesel. Jatropha oil was also determined to have twice the flash point temperature of diesel. Ta data also shows that Jatropha has higher energy released, but still slightly less energy than diesel as note by the **calorific value.**

Table 5, percentage oil composition and lipid classes of Jatropha curcas

Composition	Percentage, (%)
Oil	**66.4**
Unsaponifiable	**3.8**
Hydrocarbons/sytereo esters	**4.8**
Triacycerols	**88.2**
Free fatty acid	**3.4**
Diacylglycerols	**2.5**

Sterols	**2.2**
Monoacyglycerols	**1.7**
Polar lipids	**2.0**

Jatropha curcas oil (JCO) quality deteriorates gradually due to improper handling and inappropriate storage condition. It was known that improper handling of JCO could cause the water content increase. In addition, exposing the oil to open air and sunlight for along time would affect the concentration of Free Fatty Acid (FFA) increase significantly to high level of FFA above 1%. To prevent increasing of FFA over time, it is better to store the oil dry, cool and in closed cans.

2.2 DRILLING MUD

A drilling fluid is any fluid which is circulated through a well in order to remove cuttings from a wellbore. This section will discuss fluids which have water or oil as their continuous phase. Air, mist and foam, which can be used as drilling fluids, will not be discussed at this time. A drilling fluid must fulfill many functions in order for a well to be drilled successfully, safely, and economically. The most important functions are:

Table-6, functions of drilling mud

Remove drilled cuttings from under the bit	Provide enough hydrostatic pressure to balance formation pore pressures
Carry those cuttings out of the hole	Prevent the bore hole from collapsing or caving in
Suspend cuttings in the fluid when circulation is stopped	Protect producing formations from damage which could impair production
Release cuttings when processed by surface equipment	Clean, cool, and lubricate the drill bit
Allow cuttings to settle out at the surface	

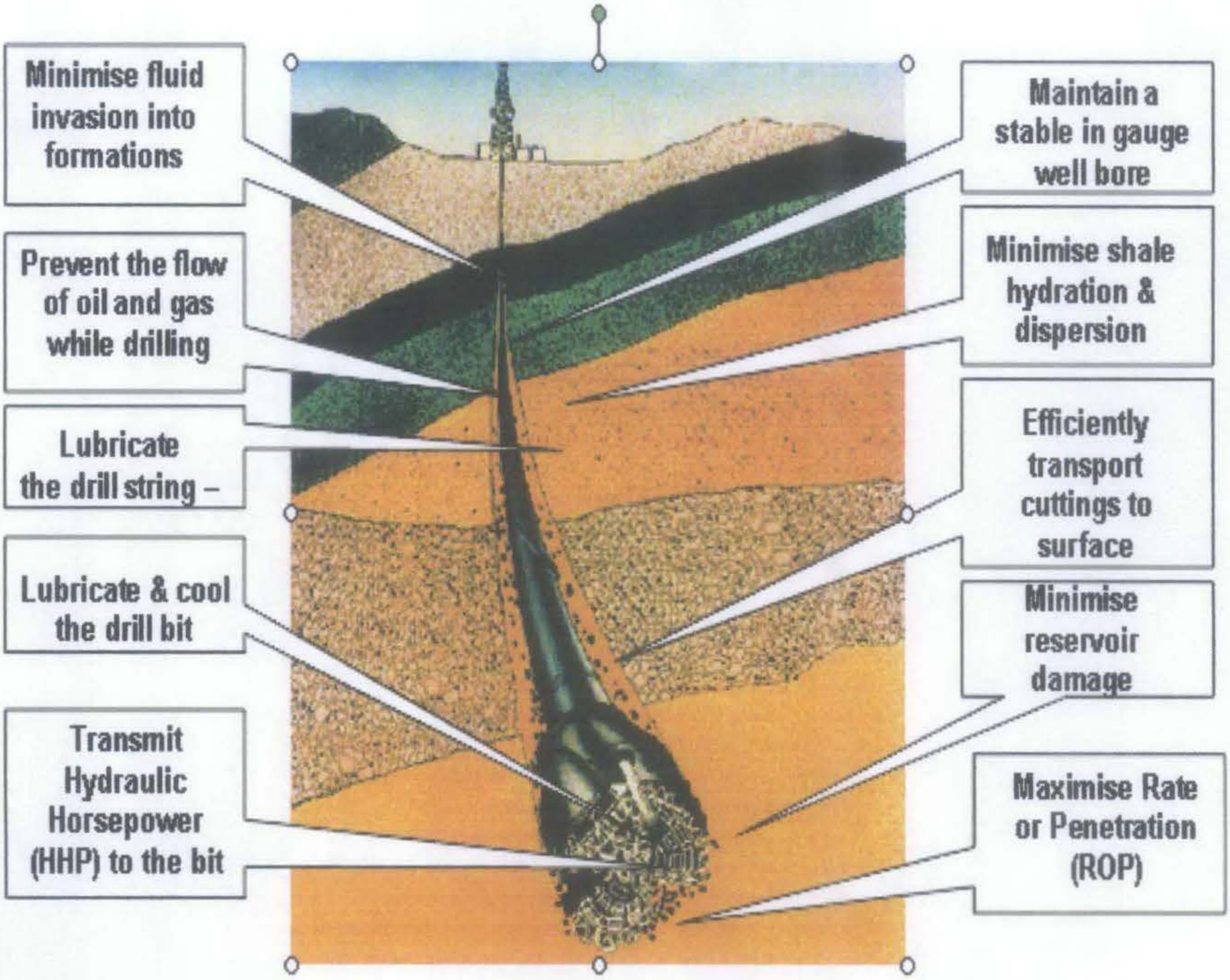


Figure-5' Drilling mud Function (API Standart -13B)

2.3 MAKE-UP OF A DRILLING MUD

In its most basic form a drilling fluid is composed of a liquid (either water or oil) and some sort of viscosifying agent. If nothing else is added, whenever the hydrostatic pressure is greater than the formation pore pressure (and the formation is porous and permeable) a portion of the fluid will be flushed into the formation. Since excessive filtrate can cause borehole problems, some sort of filtration control additive is generally added. In order to provide enough hydrostatic pressure to balance abnormal pore pressures, the density of the drilling fluid is increased by adding a weight material (generally barite).

2.3.1 DRILLING MUD CONSISTS OF:

2.3.1.1 The Base Liquid

- Water - Fresh Or Saline
- Oil - diesel or crude
- Mineral Oil or other synthetic fluids

Dispersed Solids

- Colloidal particles, which are suspended particles of various sizes

Dissolved Solids

- Usually salts and their effects on colloids most is important All drilling fluids have essentially the same properties, only the magnitude varies. These properties include density, viscosity, gel strength, filter cake, water loss, and electrical resistance.

2.3.1.2 Normal Drilling Mud

Though this type of drilling fluid is easy to describe, it is hard to define and even more difficult to find. In the field, a normal fluid generally means there is little effort expended to control the range of properties. As such, it is simple to make and control. General rules include:

Table-7, General rules

It is used where no unexpected conditions occur
The mud will stabilize, so its properties are in the range required to control hole conditions
The chief problem is viscosity control. Formations usually drilled with this type of mud are shales and sands. Since viscosity is the major problem, the amount and condition of the colloidal clay is important

To do this, two general types of treatment are used:

Table-8 a and b, General types of treatment

1. Water soluble polyphosphates
(a) They reduce viscosity
(b) Can be used alone or with tannins
(c) If filter cake and filtration control is required

- add colloidal clay to system
2. Caustic Soda and Tannins
(a) They also reduce viscosity
(b) Used under more severe conditions than phosphate treatment

The upper portions of most wells can use "normal" muds

1. Care must be taken not to add chemicals which may hinder the making of special muds later on
2. Native clays used to make the mud are usually adequate

2.3.1.3 Special Drilling Mud

These drilling fluids are made to combat particular abnormal hole conditions or to accomplish specific objectives. These are:

Table-9, drilling fluids specific objective

1. Special Objectives	2. Abnormal Hole Conditions
(a) Faster penetration rates	(a) Long salt sections
(b) Greater protection to producing zones	(b) High formation pressures

Lime Base Muds

Table-10, Lime based mud

1. Water base mud
2. Treated with large amounts of caustic soda, quebracho, and lime. Added in that order
3. Ratio of 2 lb caustic soda, 1.5 lb quebracho and 5 lb lime per 1 barrel of mud
4. Will go through a highly viscous stage, but will become stable at a low viscosity
5. Good points (a) Can tolerate large amounts of contaminating salts (b) Remains fluid when solids content gets high
6. Weakness - it has a tendency to solidify when subjected to high bottom-hole temperatures

Lime-Treated Muds

Table-11, Lime treated muds

1. Similar to lime based mud - differ only in degree
2. A compromise attempt at overcoming the high temperature gelation problem (a) Use less lime than lime-base mud (b) Not nearly so resistant to salt contamination

Emulsion Muds - Oil in Water

Table-12, Emulsion muds- oil in water

1. Oil can be added to any of the normal or special muds with good results
2. No special properties necessary
3. Natural or special emulsifying agents hold oil in tight suspension after mixing
4. Oils used are: (a) Crude oils (b) Diesel (c) Any oil with API gravity between 25 and 50
5. Oil content in mud may be 1% to 40%
6. Advantages are: (a) Very stable properties (b) Easily maintained (c) Low filtration and thin filter cake (d) Faster penetration rates (e) Reduces down-hole friction
7. Major objection is that the oil in the mud may mask any oil from the formations.

Inhibited Muds

Table-13, Inhibited muds

1. Muds with inhibited filtrates
2. Large amounts of dissolved salts added to the mud
3. High pH usually necessary for best results

4. Designed to reduce the amount of formation swelling caused by filtrate - inhibit clay hydration
5. Disadvantages (a) Need specialized electric logs (b) Requires much special attention (c) Low mud weights cannot be maintained without oil (d) Hard to increase viscosity (e) Salt destroys natural filter cake building properties of clays

Gypsum Base Muds

Table-14, a and b, Gypsum base muds

1. A specialized inhibited mud
(a) Contained large amounts of calcium sulfate
(b) Add 2 lb/bbl gypsum to mud system
(c) Filtration controlled by organic colloids

2. Advantages	**3. Disadvantages**
(a) Mud is stable	(a) Fine abrasives remain in mud
(b) Economical to maintain	(b) Retains gas in mud
(c) Filtrate does not hydrate clays	
(d) High gel strength	

Oil Based Muds

Table-15, a and b, Oil based mud

1. Oil instead of water used as the dispersant
2. Additives must be oil soluble
3. Generally pre-mixed and taken to the wellsite
4. To increase aniline value, blown asphalt and unslaked lime may be added

5. Advantages	**6. Disadvantages**
(a) Will not hydrate clays	(a) Expensive
(b) Good lubricating properties	(b) Dirty to work with
(c) Normally higher drill rates	(c) Requires special electric logs

Inverted Emulsions

Table-16, Inverted emulsion

1. Water in oil emulsion. Oil largest component, then water added. Order of addition is important
2. Have some of the advantages of oil muds, but cheaper. Somewhat less stable

Salt Water Muds

Table-17, Salt water muds

1. Can be used either completely or partly saturated
2. Weight can vary up to 10 lb/gal when saturated
3. No filter cake building properties, easily lost to porous formations

Silicate Muds

Table-18, Silicate muds

1. Composed of sodium silicate and saturated salt water
2. Has a pickling effect on shales which prevents heaving or sloughing
3. Will be 12 lb/gal or higher
4. Corrosive, expensive and gives poor electric log results

Table-18, Silicate muds

Low Solids Muds

Table-19, Low solid muds

1. Keeps amounts of clays in the mud at a minimum, which promotes faster and safer drilling
2. Three ways to remove solids from mud (a) Water dilution (b) Centrifuging (c) Circulate through large surface area pits
3. When clays are removed, a minimum of viscosity control chemicals are needed
4. When viscosity and gel strength become too low, clay solids are replaced by organic or suspended material - polymers

2.4 DRILLING MUD CLASSIFICATION SYSTEMS

Non-Dispersed System

This mud system consists of spud muds, "natural" muds, and other lightly treated systems. Generally used in the shallower portions of a well.

Dispersed Mud Systems

These mud systems are "dispersed" with deflocculants and filtrate reducers. Normally used on deeper wells or where problems with viscosity occur. The main dispersed mud is a "lignosulfonate" system, though other products are used. Lignite and other chemicals are added to maintain specific mud properties.

Calcium-Treated Mud Systems

This mud system uses calcium and magnesium to inhibit the hydration of formation clays/shales. Hydrated lime, gypsum and calcium chloride are the main components of this type of system.

Polymer Mud Systems

Polymers are long-chained, high molecular-weight compounds, which are used to increase the viscosity, flocculate clays, reduce filtrate and stabilize the borehole. Bio-polymers and cross-linked polymers, which have good shear-thinning properties, are also used.

Low Solids Mud System

This type of mud system controls the solids content and type. Total solids should not be higher than 6% to 10%. Clay content should not be greater than 3%. Drilled solids to bentonite ratio should be less than 2:1.

Saturated Salt Mud Systems

A saturated salt system will have a chloride content of 189,000 ppm. In saltwater systems, the chloride content can range from 6,000 to 189,000 ppm. Those at the lower end are normally called "seawater" systems.

These muds can be prepared with fresh or salt water, then sodium chloride or other salts (potassium, etc.) are added. Attapulgite clay, CMC or starch is added to maintain viscosity.

Oil-Based Mud Systems

There are two types of systems: 1) *invert emulsion, where water is the dispersed phase and oil the continuous phase* (water-in-oil mud), and 2) *emulsion muds, where oil is the dispersed phase and water is the continuous phase* (oil-in-water mud). Emulsifiers are added to control the rheological properties (water increases viscosity, oil decreases viscosity).

Air, Mist, Foam-Based Mud Systems

These "lower than hydrostatic pressure" systems are of four types: 1) *dry air or gas is injected into the borehole to remove cuttings and can be used until appreciable amounts of water are encountered,* 2) *mist drilling is then used, which involves injecting a foaming agent into the air stream*, 3) *foam drilling is used when large amounts of water is encountered, which uses chemical detergents and polymers to form the foam*, and 4) *aerated fluids is a mud system injected with air to reduce the hydrostatic pressure.*

Workover Mud Systems

Also called completion fluids, these are specialized systems designed to 1) *minimize formation damage,* 2) *be compatible with acidizing and fracturing fluids*, and 3) *reduce clay/shale hydration.* They are usually highly treated brines and blended salt fluids.

2.5 DRILLING MUD ADDITIVES

Many substances, both reactive and inert, are added to drilling fluids to perform specialized functions. The most common functions are:

Alkalinity and pH Control

Ddesigned to control the degree of acidity or alkalinity of the drilling fluid. Most common are lime, caustic soda and bicarbonate of soda.

Bactericides

Used to reduce the bacteria count. Paraformaldehyde, caustic soda, lime and starch preservatives are the most common.

Calcium Reducers

These are used to prevent, reduce and overcome the contamination effects of calcium sulfates (anhydrite and gypsum). The most common are caustic soda, soda ash, bicarbonate of soda and certain polyphosphates.

Corrosion Inhibitors

Used to control the effects of oxygen and hydrogen sulfide corrosion. Hydrated lime and amine salts are often added to check this type of corrosion. Oil-based muds have excellent corrosion inhibition properties.

Defoamers

These are used to reduce the foaming action in salt and saturated saltwater mud systems, by reducing the surface tension.

Emulsifiers

Added to a mud system to create a homogeneous mixture of two liquids (oil and water). The most common are modified lignosulfonates, fatty acids and amine derivatives.

Filtrate Reducers

These are used to reduce the amount of water lost to the formations. The most common are bentonite clays, CMC (sodium carboxymethylcellulose) and pre-gelatinized starch.

Flocculants

These are used to cause the colloidal particles in suspension to form into bunches, causing solids to settle out. The most common are salt, hydrated lime, gypsum and sodium tetraphosphates.

Foaming Agents

Most commonly used in air drilling operations. They act as surfactants, to foam in the presence of water.

Lost Circulation Materials

These inert solids are used to plug large openings in the formations, to prevent the loss of whole drilling fluid. Nut plug (nut shells), and mica flakes are commonly used.

Lubricants

These are used to reduce torque at the bit by reducing the coefficient of friction. Certain oils and soaps are commonly used.

Pipe-Freeing Agents

Used as spotting fluids in areas of stuck pipe to reduce friction, increase lubricity and inhibit formation hydration. Commonly used are oils, detergents, surfactants and soaps.

Shale-Control Inhibitors

These are used to control the hydration, caving and disintegration of clay/shale formations. Commonly used are gypsum, sodium silicate and calcium lignosulfonates.

Surfactants

These are used to reduce the interfacial tension between contacting surfaces (oil/water, water/solids, water/air, etc.).

Weighting Agents

Used to provide a weighted fluid higher than the fluids specific gravity. Materials are barite, hematite, calcium carbonate and galena.

2.6 WATER BASED MUD

WBMs are by far the most commonly used muds, both onshore and offshore; EPA (1993a) estimates that nearly all shallow wells (less than 10,000 feet deep) and about 85% of wells deeper than 10,000 feet are drilled with the use of WBMs. These muds generally consist of more than 90% water by volume, with added amounts of barite, clays, lignosulfonate, lignite, caustic soda, and other special additives for specific well conditions.

Table-20, advantages and disadvantages of Water Based Mud

ADVANTAGES	DISADVANTAGES
Economically cheap compared to Oil based mud and Synthetic based mud.	The inability of WBMs to effectively suppress the hydrational tendencies of some water-sensitive formations can result in hole enlargement or collapse.
Environmentally friendly compared to Oil based Mud.	WBMs are not suited for high temperature high pressure (HTHP) wells.
Beneficial to use in shallow wells.	Drill pipe becomes stuck in the hole (in high-angle, extended-reach wells and drilling through salt).

2.7 OIL BASED MUD

Recently deep drilling has been emerging as an important drilling activity to all oil and gas companies in order to increase daily crude oil production. Drilling deep wells normally associated with HPHT (High Pressure High Temperature) condition. Therefore Oil Based Mud (OBM) fluid is being chosen as drilling mud due to its excellent thermal-stability characteristics. Beside OBM was chosen because it has several advantages over the WBM (Water Based Mud) as follow:

Table -21, OBM advantages

1. inherent protection against acid gases and corrosion
2. capability of drilling water soluble formation with little or no water washout problem
3. improve lubricity that indirectly assists in drilling deviated or high angle holes and reduced 'stuck pipe' problem, and
4. ability drilled in water sensitive shale sections and thus preventing over-gauge hole problem

Diesel had been widely used as the base oil since the introduction of OBM as drilling mud for deep water drilling. In early 1980's, many researches on diesel oil as the base oil for drilling mud. From these researches output showed that diesel is not suitable to be used as base oil due to it high toxicity and aromatic contents exposure to the people and environment.

Table-22, advantages and disadvantages of Oil Based Mud

ADVANTAGES	DISADVANTAGES
-Do not react with clays in shales	-Much more expensive that WBM
-Do not cause wettability changes of the formation	-More careful handling due to pollution control (extra costs)
-Excellent wellbore and temperature stability	-Toxic, causing lasting environmental impacts
-Good lubrication	-Detection of kick is more difficult
-Reduced risk of differential sticking	-Reduced effectiveness of some logging tools (resistivity logs)
-Low formation damage potential	

2.8 SYNTHETIC BASED MUD

Synthetic based mud is classified according to the molecular structure of their synthetic compound (Zevallos et al, 1996). Synthetic based mud has been developed to meet difficult drilling targets with reduced environmental impact. During the 1980s, muds based on low toxicity mineral oils were heavily used, with unrestricted dumping of oily cuttings into the sea. Petroleum derived mineral oils did not biodegradable adequately in the cuttings pile to allow degradation of the oil and recovery of the sea bed in an acceptable period (Mckee, 1995). In Malaysia, primarily current environment regulations prohibit discharge of OBM or any oil mud cutting to the sea that will cause marine pollution (Aminuddin, 2005)

2.8.1 Advantages of Using Synthetic Based Mud

Introduction of SBM offers solution to the limitations of traditional oil-based and water-based muds. Limitations of WBMs are addressed by SBM because the formations is exposed to a synthetic liquid and not water, the high clay content shales do not hydrate and expand into wellbore. Gas hydrates in are suppressed in SBM and the stability and flexibility of rheological profiles allows proper hole cleaning of the riser. Besides limitation of OBM use are addressed because SBM can be discharged into the marine environment thereby eliminating logistical problems of OBM disposal In addition, gas is less soluble in SBM than in mineral and diesel oil based muds allowing for easier detection and control of gas kicks (Zevallos et al, 1996)

2.8.2 SYNTHETIC BASED MUD ADDITIVES

Different types of additives are useful for different of application, depends on the situation of the well being drilled. Table below shows the drilling fluid additives, description and functions. In real life applications, SBM consists of 30 to 90 percent of the total volume of the complex drilling fluid and about 20 to 40 percent of the mass of the drilling fluid (Aminuddin, 2006). Every SBF systems contain emulsifiers, wetting agents, thinners, weighting agents and gelling agents (Aminuddin, 2006). Table below shows the example of additives and its functions.

Table 23, Functions and examples of drilling fluid additives

FUNCTIONS	EXAMPLE OF ADDITIVES
Alkalinity/pH control	**Caustic soda, soda ash, common acids and bases**
Bactericides	**Starch, xanthan gum**
Corrosion inhibitors	**Amine- or phosphates-based-products,**
Emulsifiers	**Fatty acid, amine-based-products, detergent, organic acid**
Flocculants	**Hydrated lime, bicarbonate of soda, acrylamide-based polymer**
Lost circulation material	**Nut hulls, crystalline polymers**
Lubricants	**Oils, graphite, glycols, glycerin**
Temperature stability agent	**Acrylic polymers, sulfonated polymers, copolymers, lignite, tannin-based additives**
Viscosifiers	**Bentonite, attapulgite clays and polymers**
Weighting agents	**Barite, ion oxide, calcium carbonate.**

(Source: World Wide Web, http://findarticles.com/p/articles/mi_m3159/is_6_222/ai_75918338/pg_)

2.9 RHEOLOGICAL CHARACTERISTICS

The rheological behavior is the indication of ability of drilling fluid in (1) *hole cleaning and hole erosion,* (2) *suspension of drilling,* (3) *hydraulic calculation,* and (4) *requirements of drilling mud treatment*. The rheological properties of drilling mud are basically represented by plastic viscosity, yield point and gel strength.

The yield point is the measured of electrical attractive forces in the drilling mud system under flowing condition. No bulk movement of the mud occurs until the applied stress exceeds the yield point. Plastic viscosity indicates the drilled cuttings suspension and hole cleaning abilities under dynamic condition. It is mainly control by the solid particles inside the drilling mud. As the drilling process carried on, the plastic viscosity will be increased. This is due the increase of solid particles. On the other hand, the fluid thickening effect and suspension capabilities under static condition are controlled by gel strength.

The adjustable and flexibility of the drilling mud rheological properties plays important role in determined the success of overall drilling operation. In order to obtain proper function drilling mud, rheological properties should be continuously measured and modified if necessary.

2.9.1 DRILLING MUD REPORT

One of the most important reports at the wellsite is the daily drilling fluid report, or "mud report". In addition to containing basic well and rig information, chemical inventory and mud system costs, the mud report will contain a list of the fluid properties of the mud system. To maintain the required properties, certain tests are conducted on the drilling fluid. The most important are listed below.

Mud Density

The density of the drilling fluid is important to maintaining well control. As mentioned earlier, fresh water has a density of 8.34 lb/gal, with a corresponding gradient of 0.433 psi/ft. As long as the formations have the same gradient, fresh water will "balance" the formation pressures. Since this is generally not the case, some weight material must be added to the fluid, the most common being barite and hematite. The drilling fluids density is measured using a "mud balance". This balance contains a mud cup on one end of a beam with a fixed counter weight on the other end of the beam. The beam is inscribed with a graduated scale, contains a level bubble and a movable rider. When the cup is filled with fresh water, steel shot is added to the counter weight container until the beam is level, with the rider pointing at the 8.34 scribe line. During wellsite operations, the mud's density is checked by filling the cup with drilling fluid and moving the rider until the level bubble indicates the beam is balanced. The density is then read using the position of the rider.

Plastic Viscosity

The plastic viscosity (PV) is calculated by measuring the shear rate and stress of the fluid. These values are derived by using a Fann viscometer, which is a rotating-sleeve viscometer, and may be a simple hand operated two speed model or a more complex variable speed electric model. The two speed model operates at 300 and 600 rpm.

The Fann viscometer consists of an outer rotating sleeve and an inner bob. When the outer sleeve is rotated at a known speed, torque is transmitted through the mud to the bob. The bob is connected to a spring and dial, where the torque is measured. The shear rate is the rotational speed of the sleeve and the shear stress is the stress (torque) applied to the bob, measured as deflection units on the instrument dial. These measurement values are not true units and need to be converted. Shear rate is the rate of change as the fluid layers move past one another per unit distance, and is measured in reciprocal seconds (i.e. (ft/sec)/ft) and is usually written as seconds-1. To convert the dial reading to shear stress, the dial reading is multiplied by 1.067 to give a reading in lb/100ft2. The units of viscosity are poise or centipoise (1/100 poise) and are derived as follows:

Viscosity (poise) = (F/A) / (V/H) **(1)**

where: **F = Force (dynes)**

A = Area (cm2)

V = Velocity (cm/cc)

H = Distance (cm)

This produces viscosity as Dynes (sec/cm2) or poise. The Fann viscometer reading is therefore multiplied by 1.067 to obtain shear stress in lb/100ft2; or multiplied by 478.8, and divided by the shear rate in second-1 to get Dynes/cm2.

Viscosity then becomes:

511 x dial reading / shear rate (sec-1) **(2)**

since **511 sec-1 = 300 rpm**

or **(300 x dial reading) / Fann shear rpm** **(3)**

The viscometer is designed to give the viscosity of a Newtonian fluid when used at 300 rpm.

For Non-Newtonian fluids, the ratio of shear-stress to shear-rate is not constant and varies for each shear rate. With a Bingham plastic fluid, a finite force is required to initiate a constant rate of increase of shear-stress with shear-rate. To obtain a value for this constant rate of increase, readings are taken with a viscometer at 511 sec-1 and 1022 sec-1 (300 and 600 rpm). The 600 dial reading minus the 300 dial reading gives the slope of the shear-stress/shear-rate curve. This is the Plastic Viscosity. The "apparent viscosity" is given by the 600 reading divided by 2. This is a measure of that part of resistance to flow caused by mechanical friction between solids in the mud, solids and liquids and the shearing layers of the mud itself. We can see that control of the solids will give us control over our PV! This leads to "Why are we controlling the solids?" Since the viscosity of the mud is one of the principal factors contributing to the carrying capacity of the mud, the suspension of weighting materials, and pressure surges applied to the formation through frictional pressures in the annulus, it is obvious that increased solids will increase these annular pressures (and may increase the mud density), so a balance must be found in which thecorrect mud density and carrying capacity are maintained without exerting unnecessary pressures on the annulus. In the mud system, we have solids that are an integral part of the mud (bentonite, starch, CMC, etc.) and solids that are undesirable (sand, limestone, dolomite, etc.). As the mud density is increased, by the addition of barite or hematite (more solids), the PV will automatically increase. The PV is also a function of the viscosity of the fluid phase of the mud (as temperature rises, the viscosity of water decreases, and the PV will decrease).

Several methods of lowering the solids content of the mud are available, all of which will lower the plastic viscosity and apparent viscosity, as well.

Table-24, methods of lowering the solids content of the mud

1. **Dilution**; add water and lower the concentration of solids.
2. **Shaker Screens**; using the finest screens possible without "blinding" to remove solids. Avoid hosing water on the screens as this washes fine solids through the screens.
3. **Centrifuge**; these separate the solids by size and mass, reducing total solids concentration.
4. **Desander/Desilter**; these mechanically remove the sand/silt sized particles from the mud.

To increase the viscosity of a mud system, various "mud chemicals" can be added. These are mostly types of bentonite, but attapulgite clays, asbestos and gums (Guar or Xanthan) are also used.

The polymer viscosities such as XC polymer, consist of these gums. Most polymers provide a mud with a shear thinning effect. This is desirable as it allows viscosity to be maintained while circulating pressures are reduced.

Yield Point

This parameter is also obtained from the viscometer. The yield point (YP), as mentioned earlier, is a measure of the electro-chemical attractive forces within the mud under flowing conditions. These forces are the result of positive and negative charges located near or on the particle's surfaces. With this in mind, the yield point is then a function of the surface properties of the mud solids, the volume concentration of the solids, and the concentration and type of ions within the fluid phase. The yield point is the shear stress at zero shear rate, and is measured in the field by either;

$$\textbf{YP = 300 rpm reading – PV} \qquad (4)$$

$$\textbf{or YP = (2 x 300 rpm reading) - 600 rpm reading} \qquad (5)$$

This gives a Bingham yield point, which is generally higher than the actual or true yield. As stated earlier, at low shear rates, the Bingham model does not give particularly good readings.

High viscosity, resulting from a high yield point is caused by:

Table-25, High viscosity

1. Introduction of soluble contaminants such as salt, cement, anhydrite, or gypsum, which neutralize negative charges of the clay particles, resulting in flocculation.
2. The breaking of clay particles by the grinding action of the bit and pipe, which creates "broken bond valences" on the edges of the particles, causing the particles to pull together.
3. Introduction of inert solids causes the particles to be closer together into disorganized form or flocks.
4. Drilling of hydratable clays introduces active solids into the system, increasing the attractive forces by increasing the number of charges and by bringing the particles closer together.
5. Both insufficient or over-treatment of the mud with chemicals will increase the attractive forces of the mud.

Treatment for increased yield point may be controlled by chemical action, but reduction of the yield point will also decrease the apparent viscosity. Yield point may be lowered by the following:

Table-26, Yield point lowering

1. Broken bond valences may be neutralized by adsorption of certain negative ions at the edge of the clay particles. These residual valences are almost totally satisfied by chemicals such as tannins, lignins, lignosulfonates and complex phosphates. The attractive forces are satisfied by chemicals, and the clay's natural negative charge remains, so that the particles repel each other.
2. If calcium or magnesium contamination occurs, the ion is removed as an insoluble precipitate, thus decreasing the attractive forces and hence the yield point.
3. Water can be used if the solid content is very high, but it is generally ineffective and may alter other properties drastically (i.e., mud density).

As mentioned earlier, the chemicals that are added to deflocculate the mud and act as "thinners" are commonly lignosulfonates and tannins. These also have a secondary function of acting as filtration agents.

Gel Strength

This is a measurement that denotes the thixotropic properties of the mud and is a measurement of the attractive forces of the mud while at rest or under static conditions. As this and yield point are both measures of flocculation, they will tend to increase and decrease together, however a low yield point does not necessarily mean 0/0 gels!

Gel strength is measured with the viscometer by stirring the mud at high speeds for about 15 seconds and then turning the viscometer off or putting it into neutral (low gear if it's a lab model) and waiting the desired period, (i.e., 10 seconds or 10 minutes). If the viscometer is a simple field model, the "gel strength" knob is turned counter clockwise slowly and steadily. The maximum dial deflection before the gel breaks is then recorded in lb/100 ft2. With a lab model, the procedure is the same except a low speed is used. After a wait, the second gel can be taken in a similar manner.

Gels are described as progressive/strong or fragile/weak. For a drilling fluid, the fragile gel is more desirable. In this case, the gel is initially quite high but builds up with time only slightly. This type of gel is usually easily broken and would require a lower pump pressure to break circulation.

Drilling muds are always treated to be alkaline (i.e., a pH > 7). The pH will affect viscosity, bentonite is least affected if the pH is in the range of 7 to 9.5. Above this, the viscosity will increase and may give viscosities that are out of proportion for good drilling properties. For minimizing shale problems, a pH of 8.5 to 9.5 appears to give the best hole stability and control over mud properties. A high pH (10+) appears to cause shale problems.

The corrosion of metal is increased if it comes into contact with an acidic

fluid. From this point of view, the higher pH would be desirable to protect pipe and casing.

Carbon Dioxide corrosion can cause severe pitting and cracks in fatigueareas. If moisture is present, CO_2 dissolves and forms carbonic acid.

$$CO_2 + H_2O = H_2CO_3$$

This causes a reduction in the pH, which makes the water more corrosive to steel.

$$Fe + H_2CO_3 = FeCO_3 \text{ (iron carbonate scale)}$$

If a high pH is maintained, the water will tend to be less corrosive.

Standard treatments for CO_2 are:

Table-27, Standard treatment for CO_2

1. Kill the source of CO_2 (if it is a kick, then circulate out the gas through the degasser).
2. Re-establish proper alkalinity and pH by additions of lime and/or caustic soda.

While a high pH will combat corrosion, it may be necessary to add chemicals to remove the scale as well.

H_2S as a gas is not particularly corrosive, however if moisture is present it will become corrosive and in the presence of CO_2 or O_2, it becomes extremely corrosive. Since H_2S is soluble in drilling muds, as the pH increases, the total amount of sulfides existing as H_2S is reduced. The pH should be maintained above 10 if known H_2S bearing formations are to be drilled. A scavenger should also be added to remove sulfides. The most common scavengers are zinc carbonate, zinc chromate, zinc oxide, ironite sponge (Fe_3O_4) and copper carbonate. The pH will have to be treated as scavengers are added.

pH is commonly measured with pHydrion paper. This paper is impregnated with dyes that render a color which is pH dependent. The paper is placed on the surface of the mud which wets the paper. When the color has stabilized, it is compared with a color chart. An electronic pH meter may also be used.

Filtration Loss

These two properties shall be dealt with together, as it is the filtration of mud that causes the build up of filter cake. Loss of fluid (usually water and soluble chemicals) from the mud to the formation occurs when the permeability is such that it allows fluid to pass through the pore spaces. As fluid is lost, a build up of mud solids occurs on the face of the wellbore. This is the **filter cake.**

Two types of filtration occur; **dynamic,** *while circulating* and **static,** *while the mud is at rest.*

Dynamic filtration *reaches a constant rate when the rate of erosion of the filter cake due to circulating matches the rate of deposition of the filter cake.*

Static filtration *will cause the cake to grow thicker with time, which results in a decrease in loss of fluids with time.*

Mud measurements are confined to the static filtration. Filtration characteristics of a mud are determined by means of a filter press. The test consists of monitoring the rate at which fluid is forced from a filter press under specific conditions of time, temperature and pressure, then measuring the thickness of the residue deposited upon the filter paper.

Excessive filtration and thick filter cake build up are likely to cause the following problems:

Table-28, Excessive filtration and thick filter cake build up

1. Tight hole, causing excessive drag.
2. Increased pressure surges, due to reduced hole diameter.
3. Differential sticking, due to an increased pipe contact in filter cake.
4. Excessive formation damage and evaluation problems with wireline logs.

Most of these problems are caused by the filter cake and not the amount of filtration because the aim is to deposit a thin, impermeable filter cake. A low water loss may not do this, as the cake is also dependent upon solids size and distribution.

The standard fluid loss test is conducted over 30 minutes. The amount of filtrate increases with direct proportion to the square root of the time. This can be expressed by the following;

$$Q2 = (Q1 \times T2)/T1 \qquad (6)$$

Where: Q2 is the unknown filtrate volume at time T2

Q1 is the known filtrate volume at time T1

Pressure also affects filtration by compressing the filter cake, reducing its permeability and therefore reducing the filtrate. Small plate-like particles act as the best filter cake builders and bentonite meets these requirements.

Increased temperature has the effect of reducing the viscosity of the liquid phase and hence increasing filtration. With all other factors being constant, the amount of filtrate will vary with the square root of time.

Proper dispersion of the colloidal clays in the mud gives a good overlap of particles, thus giving good filtration control. A flocculated mud, which has aggregates of particles, allows fluid to pass through easily. The addition of chemicals to act as dispersants will increase the efficiency of the filter cake.

The standard test is conducted at surface temperature at 100 psi and is recorded as the number of ml's of fluid lost in 30 minutes. An API high pressure/high temperature (Hp/Ht) test is conducted at 300F and 500 psi. The tests may be conducted using a portable filter press that uses CO2 cartridges or using a compressed air supply.

The high pressure and high temperature test is conducted to simulate downhole conditions, since the degree of filtration may vary, depending upon the compressibility of the filter cake. A mud sample may be tested at standard temperatures and pressures, increased temperature and 100 psi, or at high temperatures and pressures. Increased pressure will indicate if the filter cake is compressible.

The primary fluid loss agent in most water based muds are the clays. These solids should have a size variation with a large percentage being under 1 micron. This will produce a filter cake with low porosity and permeability. The use of centrifuges or cyclone solids removal equipment may cause filtration problems by removing the small size solids. Starch is also used as a fluid loss agent, the starch being treated is so that it will easily gelatinize and swell. Water soluble polymers are commonly used as viscosifiers, acting on the fluid phase which also reduces fluid loss.

Sodium Carboxyl-Methyl Cellulose (CMC) is an organic colloid with a long chain structure that can be polymerized into different lengths or grades. It is thought to act by either the long chains plugging narrow openings in the filter cake, curling into balls to act as plugs, or by coating the clay particles with a film. It will however, lose its effectiveness as salt concentrations rise above 50,000 ppm. A polyanoinic cellulose is used as the fluid loss agent in high salt concentration, low solids drilling fluids.

All the information been used in this project, particular for the drilling mud part are from:

"Baker Hughes INTEQ, Drilling Engineering Workbook, A Distributed Learning Course"
80270H Rev. B December 1995, Baker Hughes INTEQ, Training & Development 2520 W.W. Thorne, Houston, TX 77073, United States of America, 713-625-4415

2.10 RECOMMENDED MUD FLOW PROPERTIES

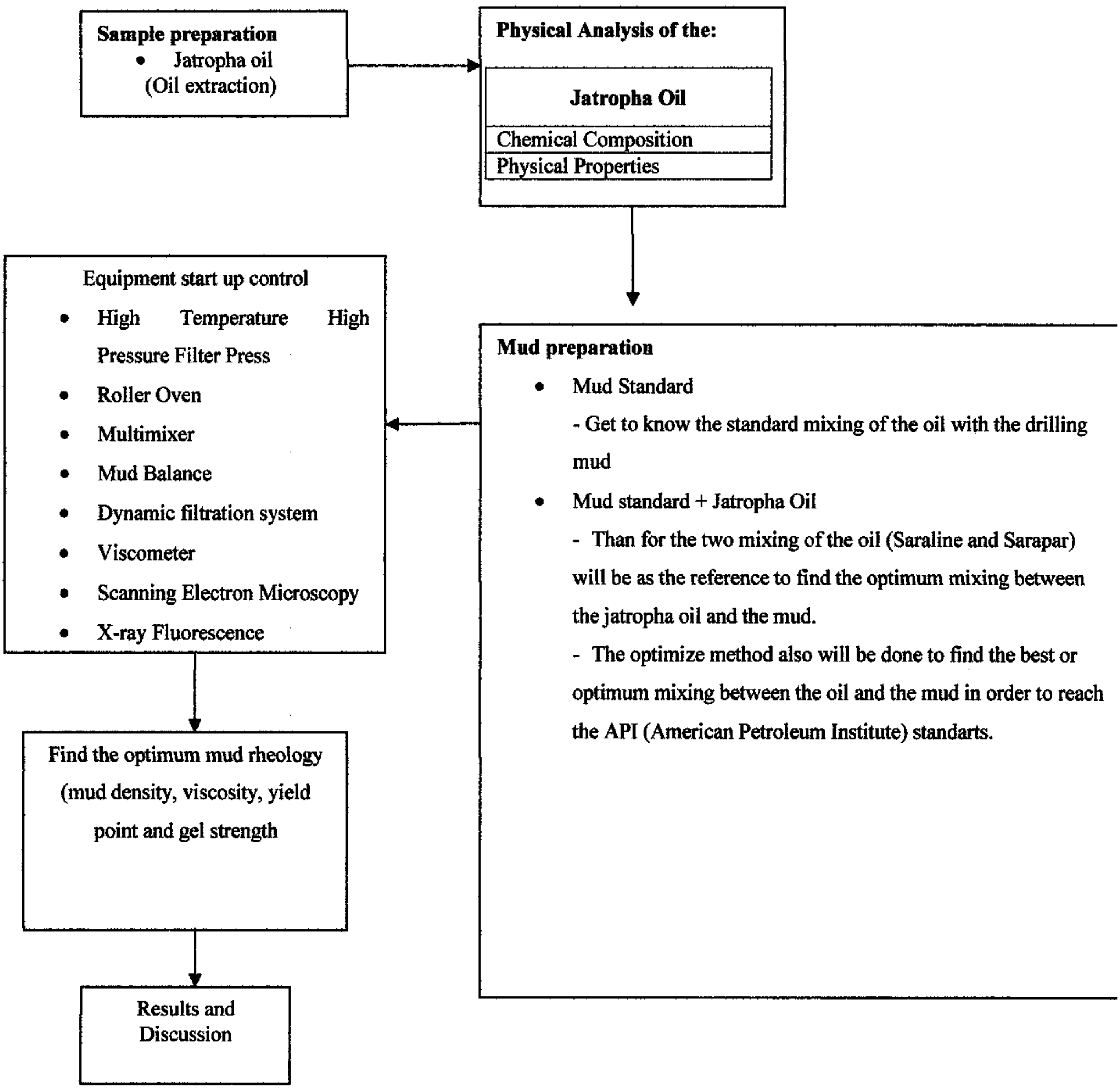
The empirical correlations are used to compute the recommended upper and lower limits of the plastic viscosity and the yield point which is shown in the following figure. All the correlations below are based on the mud density and suitable for all types of fluids.

Table-29: Empirical correlations to determine upper and lower limits of Plastic Viscosity and Yield Point. (Drilling Engineering Manual, Department of Petroleum Engineering, Curtin University of Technology)

	Acceptable Plastic Viscosity Range	
	Plastic Viscosity (cP)	
Mud Weight (ppg) Range	High range	Low Range
$\rho_m < 14$	$3.40\ \rho_m - 18.6$	$2\ \rho_m - 14$
$14 \leq \rho_m < 17$	$5\ \rho_m - 40$	$4.33\ \rho_m - 46.95$
$17 \leq \rho_m < 18.4$	$8.57\ \rho_m - 100.25$	$8.57\ \rho_m - 118.25$
$\rho_m \geq 18.4$	$16.68\ \rho_m - 248.73$	$16.67\ \rho_m - 266.73$
	Acceptable Yield Point Range	
	Yield Point, (lb/ft^2)	
Mud Weight (ppg) Range	High Range	Low Range
$\rho_m < 11$	$-4\ \rho_m + 66$	$0.4\ \rho_m - 0.6$
$11 \leq \rho_m < 14$	$-1.67\ \rho_m + 40.04$	$0.4\ \rho_m - 0.6$
$\rho_m \geq 14$	$-0.6\ \rho_m + 25.4$	$0.4\ \rho_m - 0.6$

CHAPTER 3
METHODOLOGY & GANTT CHART

3.1 PROCEDURE IDENTIFICATION



3.2 JATROPHA OIL EXTRACTION PROCEDURE

Dehulling, separating hull from the nut

↓

Grinding the seeds using grinding machine

↓

Drying the grinded seed in the oven

↓

Oil extraction using n-Hexane

Process:

- 300ml(C_6H_{24})+50gr(grinded seeds)=20ml of Jatropha Oil
- Single process takes 4hours and more

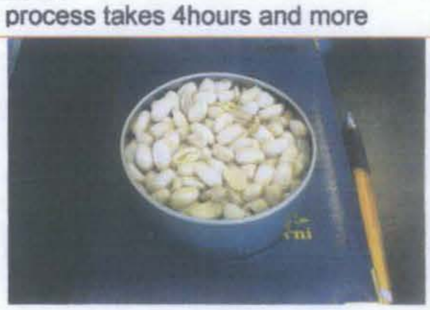


Figure-A: Dehulling

Figure-B Grinding Machine

Figure-B.1 Grinded seed

Figure-C Drying (Oven)

Figure-D Extraction process

3.3 PREPARATION MUD SAMPLE

A mixer; Hamilton Beach Multimixer was used extensively. Mud mixing is a continuous process and proper timing for each samples mixing is being done with full care (Aminuddin, 2006). The oil-water ratio was set at 70:30, as recommended by the API code. Below are the steps in preparing the sample.

I. Required volume of Jatropha oil was poured into mixing container (as shown in figure 5)
II. Required mass of primary emulsifier (Confimul P) was added and stirred for 5 minutes
III. Required mass of secondary emulsifier (Confimul S) was mixed and stirred for 2 minutes
IV. Required mass of lime was added and stirred for 2 minutes
V. Brine (calcium chloride + water) was added and stirred for 15 minutes
VI. Required amount of additives was added.
VII. Required amount of bentonite was mixed and stirred for 10 minutes

Figure-6' Multimixer (Hamilton Beach, API Standard -13B)

The experiment will be conducted according to the standard which has stipulated in American Petroleum Institute - API 13B-2; Recommended Practice Standard Procedure for Testing Oil-Based Drilling Fluid.

3.4 MAJOR EQUIPMENTS AND PROCEDURES

3.4.1 Mud Weight (Density)

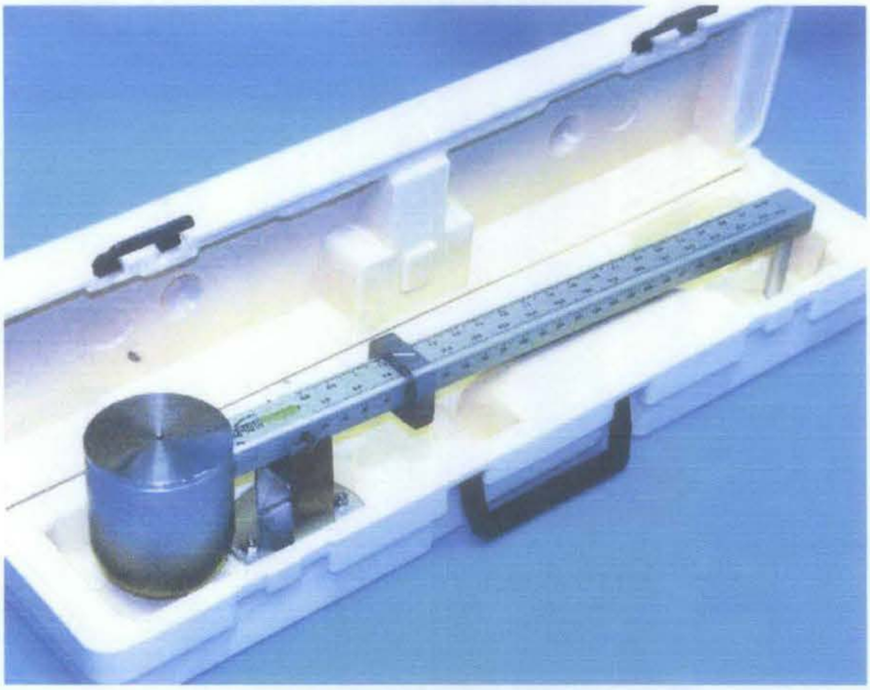


Figure-7' Mud Balance and Case (API Standard -13B)

Procedure:

1. The instrument base should be set on a flat, level surface.
2. Measure the temperature of the mud and record on the Drilling Mud Report form.
3. Fill the clean, dry cup with mud to be tested; put the cap on the filled mud cup and rotate the cap until it is firmly seated. Insure that some of the mud is expelled through the hole in the cup in order to free any trapped air or gas.
4. Holding cap firmly on mud cup was or wipe the outside of the cup clean and dry.
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 centre line.
6. Read the mud weight at edge of the rider toward the mud cup. Make appropriate corrections when a range extender used.

The instrument should be calibrated frequently with fresh water. Fresh water should give a reading of 8.3lb/gal or 62.3 lb/ft^3 (1000 kg/m^3) at 70^0F (21^0C). 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.

Calculation:

Report the mud weight to nearest 0.1 lb/gal or 0.5 lb/ft^3 (0.01 g/cm^3, 10 kg/m^3). To convert the reading to other units, use the following:

$$Specific\ gravity = g/cm^3 = lb/ft^3/62.43 = lb/gal/8.345 \qquad (7)$$

$$kg/m^3 = (lb/ft^3)(16) = (lb/gal)(120) \qquad (8)$$

$$Mud\ gradient,\ psi/ft = (lb/ft^3)/144,\ (lb/gal)/19.24,\ 10\ kg/m^3/2309 \qquad (9)$$

(A list of density conversion may be found in Appendix – A)

3.4.2 VISCOSITY AND GEL STRENGTH

Direct-Indicating Viscometer

Figure-8' Viscometer and Controlled Cup (API Standard -13B)

Procedure

1. Maximum operating temperature is 200^{0}F (93^{0}C). If fluids to be tested, a solid metal bob or a hollow metal bob, with a completely dry interior, should be used. Liquid trapped inside a hollow bob may vaporize when immersed in high temperature fluid and cause the bob to explode.
2. Place a sample of the drilling mud in a thermostatically controlled viscometer cup. Leave enough empty volume in the cup for the displacement of the viscometer bob and sleeve. The bob and sleeve will displace approximately 100 cm^3 of the drilling mud. Measurements in the field should be made with minimum delay from the time of sampling. Test should be made at either 120±2^{0}F (50^{0}C) or 150±2^{0}F (65±1^{0}C). The place of sampling should be stated on the report.
3. Heat or cool the sample to the selected temperature. Intermittent or constant shear at the 600 rpm speed should be used to stir sample while heating or cooling to obtain a uniform sample temperature, immerse the thermometer into the sample and continue stirring until the sample reaches the selected temperature. Record the temperature of the sample.
4. With the sleeve rotating at 600 rpm, wait for dial reading to reach a steady value (time required dependent on mud characteristics). Record the dial reading for 600 rpm.
5. Shift to 300 rpm and wait for dial reading to reach steady value. Record the dial reading for 300 rpm.
6. Stir drilling mud sample for 10 seconds at high speed.
7. Allow mud to stand undisturbed for 10 seconds. Slowly and steadily turn the hand-wheel in the direction to produce a positive dial reading. The maximum reading is the initial gel strength. For instruments having a 3-rpm speed, the maximum reading attained after rotation at 3-rpm is the initial gel strength. Record the initial gel strength (10 sec gel) in lb/100ft^2 (Pa).
8. Restir the mud at high speed for 10 seconds and then allow the mud to stand undisturbed for 10 minutes. Repeat the measurements as in 7 and report the maximum reading 10 minute gel in lb/100ft^2 (Pa).

Calculation

$$\text{Plastic viscosity, cP} = [600\text{ rpm reading}] - [300\text{ rpm reading}] \quad (10)$$

$$\text{Yield Point, lb/ft}^3 = [300\text{ rpm reading}] - \text{Plastic Viscosity} \quad (11)$$

$$\text{Apparent Viscosity} = 600\text{ rpm reading}/2 \quad (12)$$

3.5 GANTT CHART

Gantt chart for the First Semester of 2-Semester Final Year Project

No	Activities/ Week	1	2	3	4	5	6	7	8	9	10		11	12	13	14
1	Literature Survey starts															
2	Preliminary Research Work - Studying Research Papers done by industrial companies and by other research institutes											MID				
3	Submission of Preliminary Report											SEM				
4	Seminar 1											BREAK				
5	Project Work Continue - Finding and contacting Jatropha oil supply company															
6	Submission of Progress Report															
7	Project Work Continue -Studying experiments procedure based on API 13-B Standart - Preparing equipments and chemicals for the experiments															
8	Submission of Interim Report															
9	Oral Presentation															

Gantt chart for the First Semester of 2-Semester Final Year Project

No	Activities/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Preparing Equipment for Lab Work - Getting approval from petroleum department to run experiments in the drilling lab - arranging an appointment with lab technicians															
2	Submission of Progress Report 1															
3	SBM using Jatropha oil experiments1 - conducting experiments using jatropha oil in the drilling lab (Stage 1)															
4	Submission of Progress Report 2								MID							
5	Seminar 2								SEM							
6	SBM using Jatropha oil experiments2 - conducting experiments using jatropha oil in the drilling lab (Stage 2) - Analyzing the results								BREAK							
7	Poster Exhibition															
8	Submission of Dissertation (soft bound)															
9	Oral Presentation															
10	Submisstion of Project Dissertation HB															

CHAPTER 4

RESULT & DISCUSSION

1. Our first experiment was extracting jatropha oil in laboratory condition using Hexane process. We had required equipments for our experiments. Totally we had conducted 10 experiments. Each experiment required minimum 5 hours in order to extract the oil. We managed to extract 20 ml of Jatropha oil from each experiment, totally 200.

300ml ($C6H24$) +50gr (grinded seeds) =20ml of Jatropha Oil

But unfortunately later on we had to stop our extraction process. Because it was time consuming, required more Hexane which is highly cost, and work limitation of equipment. Later on we faced another problem, separating oil from hexane. The reason was high distillation point of Jatropha Oil (up to 240°C). Our equipment was limited only up to 130 °C. Final result was, 200ml of extracted Jatropha Oil with hexane in.

2. Total 20 (17 + 3 "Filtration Loss") experiments had been conducted in the laboratory using Jatropha oil, water, thinner and barite. Each of them was different from one another, because we used and mixed different amount of Jatropha oil with various types of chemicals. All the ingredients had been mix within 1 hour to make sure that all been mixed

The 1st experiment has been conducted in order to find the FFA (Free Fatty Acid) value, as the result:

- The value of the FFA is high in the jatropha oil **(6.753%)**. *The industrial requirements for Jatropha oil use is less than 2% of FFA.*
- The affect of the high FFA will produce the soap when mix with the other chemical.

2nd and 3rd experiments conducted as an introduction, in both of them I used different kinds and amounts of the drilling chemicals based on field data. Chemicals like: Sarapar oil, Versamul, Versacoat, Lime, Drill Water, Calcium Chloride, Visplus, Versatrol, and Barite. The results are not satisfactory enough.

Table-30, Experimental results

Property	Density (ppb)	Viscosity (600 rpm)	Viscosity (300rpm)	PV	YP	YP/PV	GS (10s)	GS (10m)
EXP5	9.2	231	132	99	33	0.33	226	245
EXP6	10.7	270	156	114	42	0.37	286	299
EXP7	10.6	234	134	100	34	0.34	225	255
EXP8	9.2	170	95	85	10	0.12	170	190
EXP9	9.2	204	128	76	52	0.68	206	236
EXP10	9.2	265	148	117	31	0.26	263	290
EXP11	10.5	94	55	39	16	0.41	102	104
EXP12	8.5	105	71	34	37	1.09	92	97
EXP13	9.2	32	18	14	4	0.29	30	27
EXP14	8.9	28	15	13	2	0.15	27	25
EXP15	10	30	17	13	4	0.30	30	25
EXP16	9.8	30	18	12	6	0.50	29	24
EXP17	7.4	25	13	12	1	0.08	25	26
EXP18	9.6	27	15	12	3	0.25	27	26
EXP19	10.6	35	19	16	3	0.19	35	34
EXP20	9.9	29	16	13	3	0.23	28	27

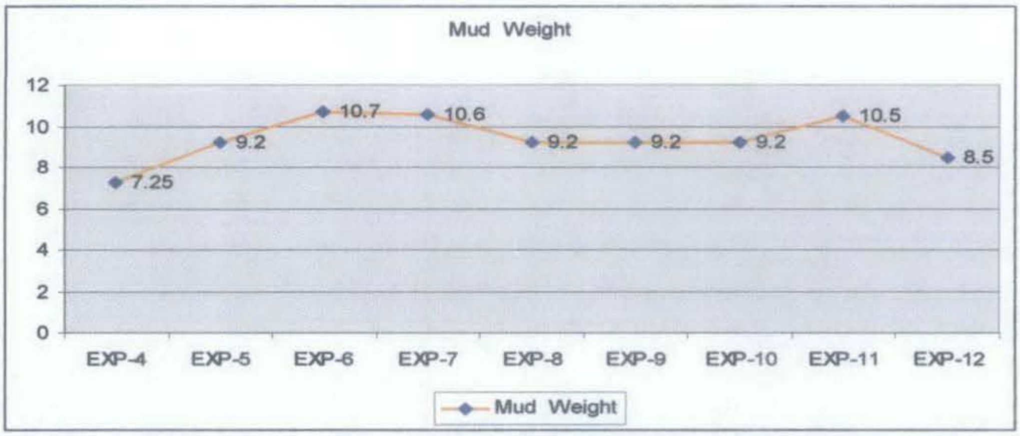


Figure-12' Mud Weight (exp 4-12, Mud Composition: Jatropha Oil, Water, Barite and Thinner)

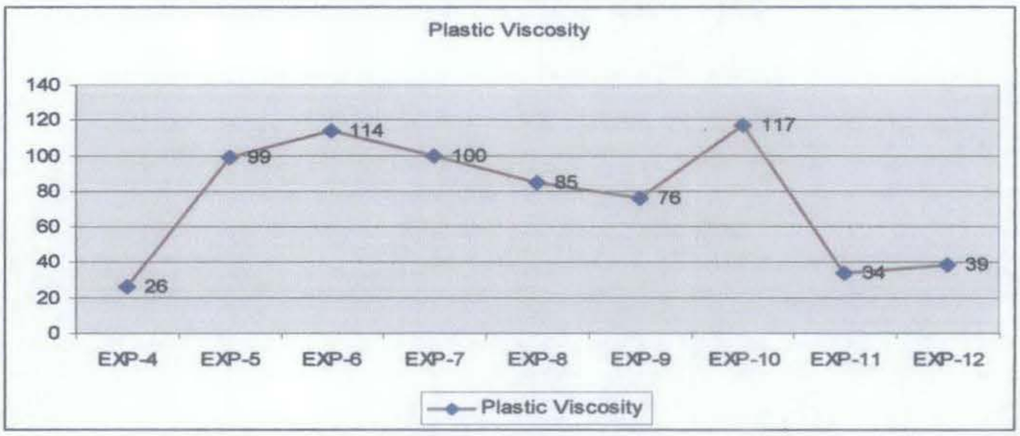


Figure-13' Mud Weight (exp 4-12, Mud Composition: Jatropha Oil, Water, Barite and Thinner)

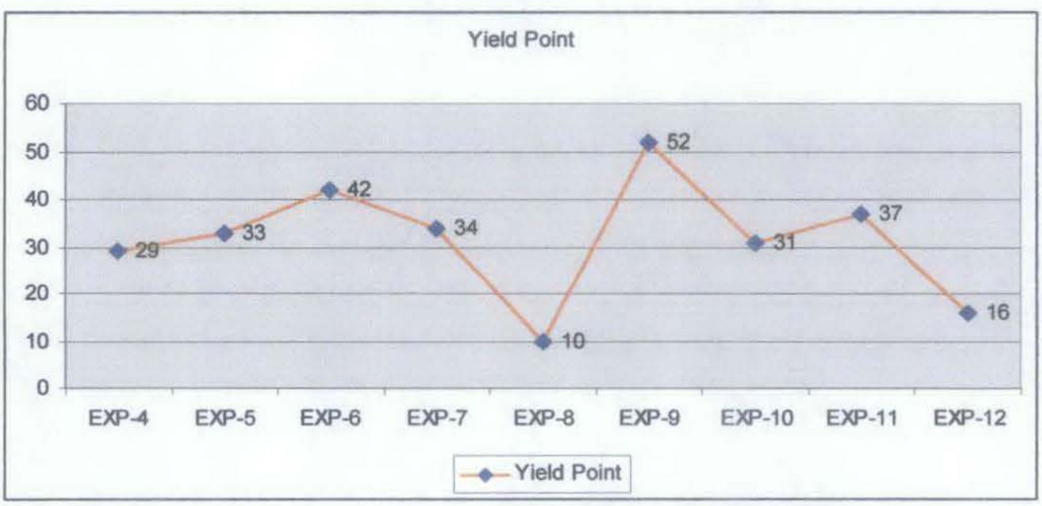


Figure-14' Mud Weight (exp 4-12, Mud Composition: Jatropha Oil, Water, Barite and Thinner)

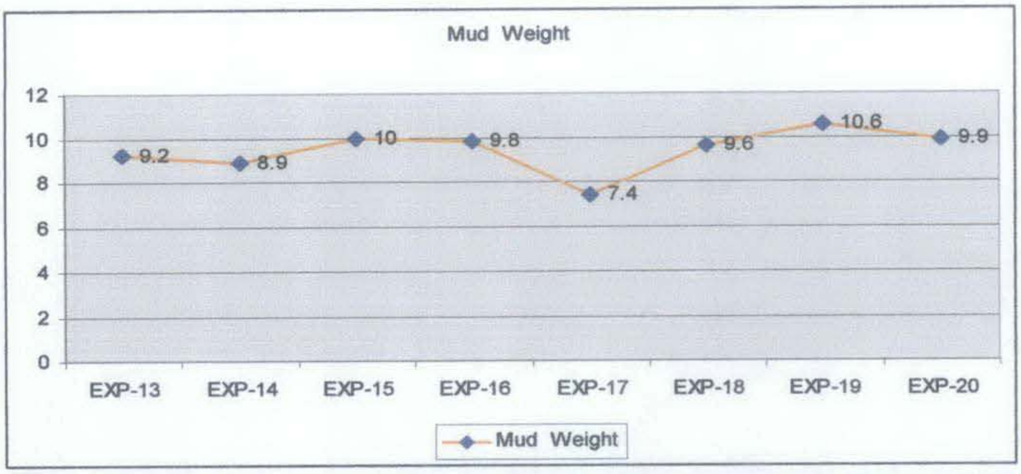


Figure-15' Mud Weight (exp 13-30, Mud Composition: Jatropha oil, Thinner, Barite)

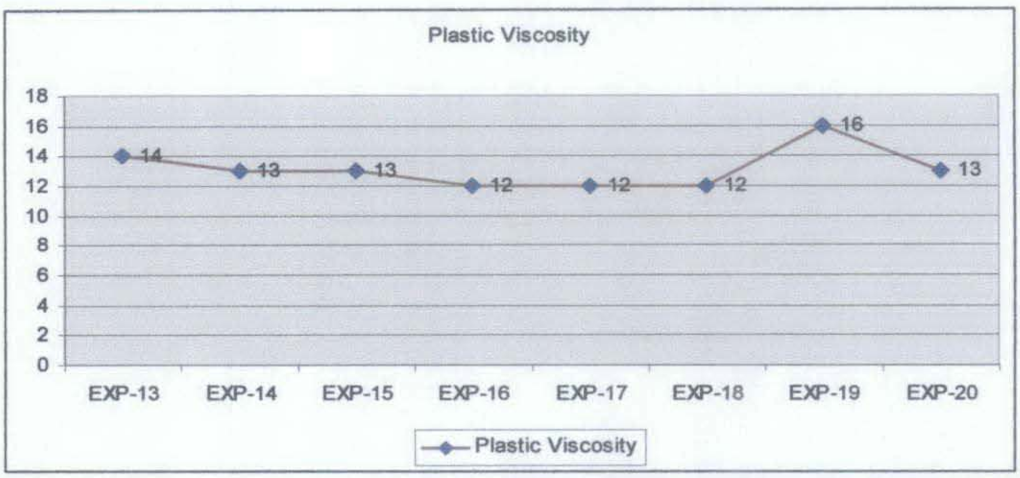


Figure-16' Plastic Viscosity (exp 13-30, Mud Composition: Jatropha oil, Thinner, Barite)

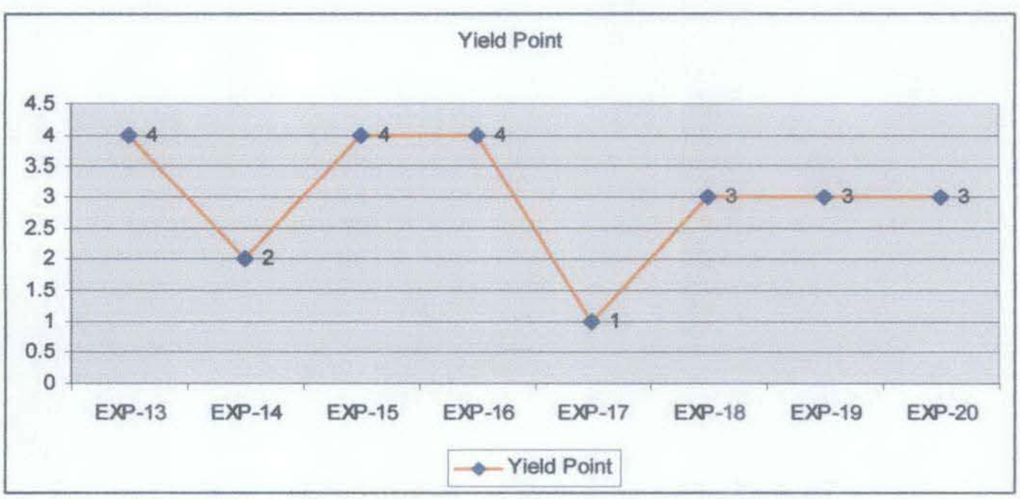


Figure-17' Yield Point (exp 13-20, excluding water)

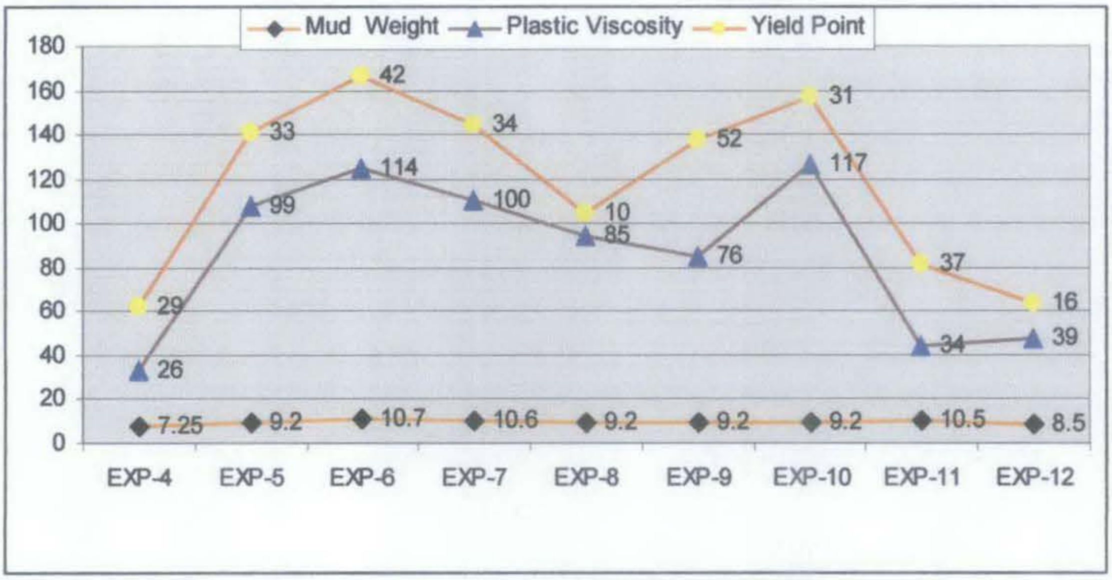


Figure-18' Mud Weight, Plastic Viscosity, and Yield Point (exps 4-12, using water)

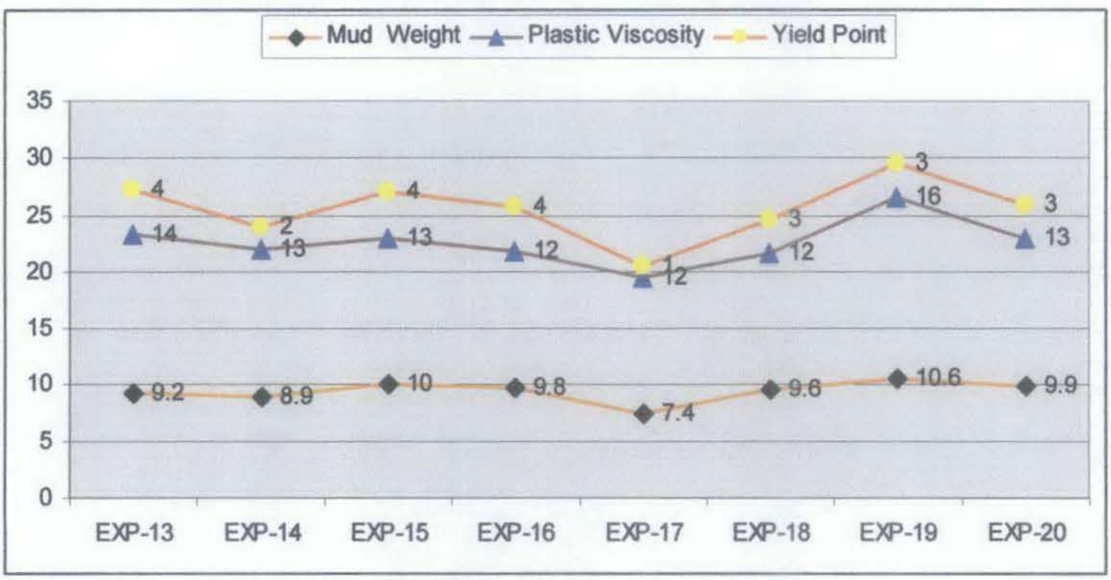


Figure-19' Mud Weight, Plastic Viscosity, and Yield Point (exps 13-20, excluding water)

Rheological analysis of the drilling fluid system displayed similar results for plastic viscosity value for all the fluid systems as shown in Figure -20. The representative bar for water-based system in Figure-200 appears only individually and differently from those systems since it's contains only phase in the formation. Figure-20 shows that JOBM are compatible to the commercially systems in the sense of drilled cuttings suspension and hole cleaning capability.

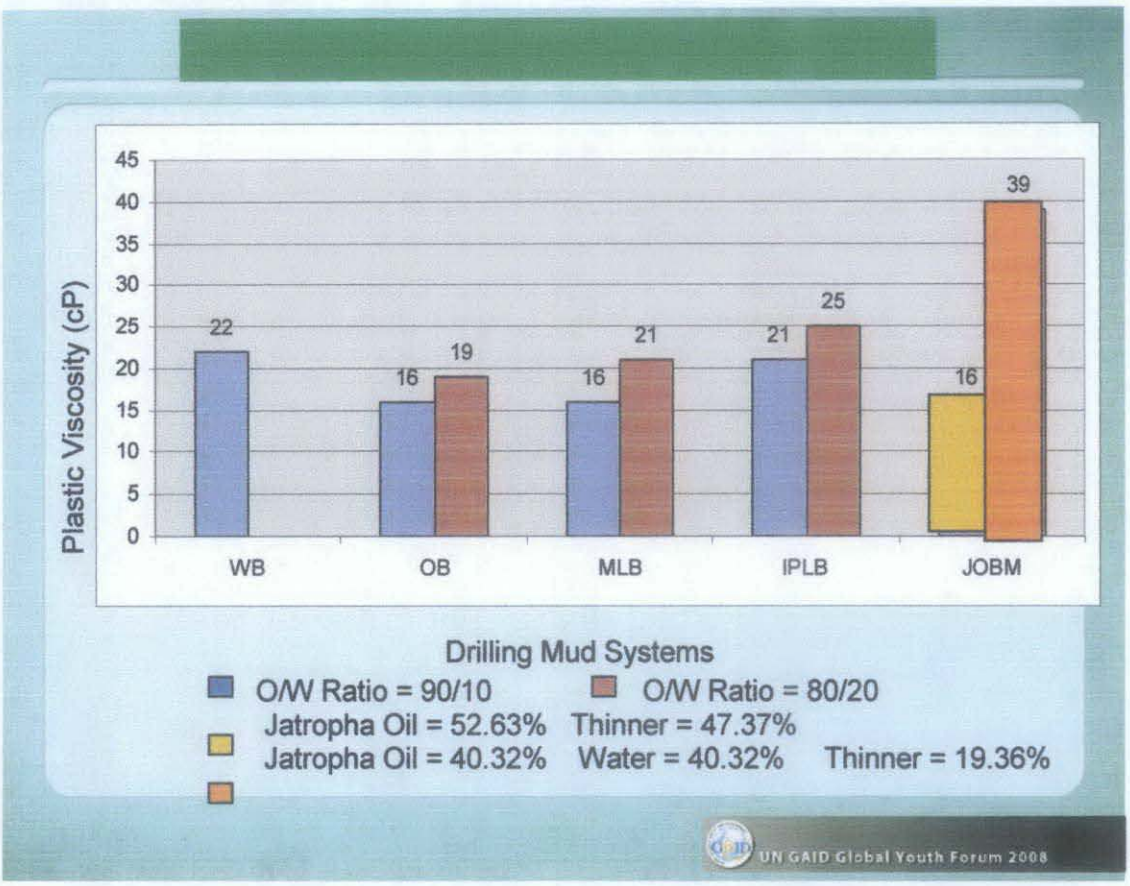


Figure-20' rheological analysis, Plastic Viscosity

Figure-21, shows plots of yield point for the formulated drilling fluid systems. JOBM systems demonstrate lower yield point values than the WB and OB systems. This incorporates the limitation of the JOBM systems in drilled cuttings removal especially at low rate. Results also suggest that increases if the brine water content in the systems can increase the yield point. However such approach is not recommended practice since the additional water content would increase the plastic viscosity to some extend which eventually will cause severe pressure loss throughout the drilling fluid circulating process. Application of suitable gelling agent or increase the dosage of the gelling agent is more practical and effective method to improve the yield point of the JOBM systems.

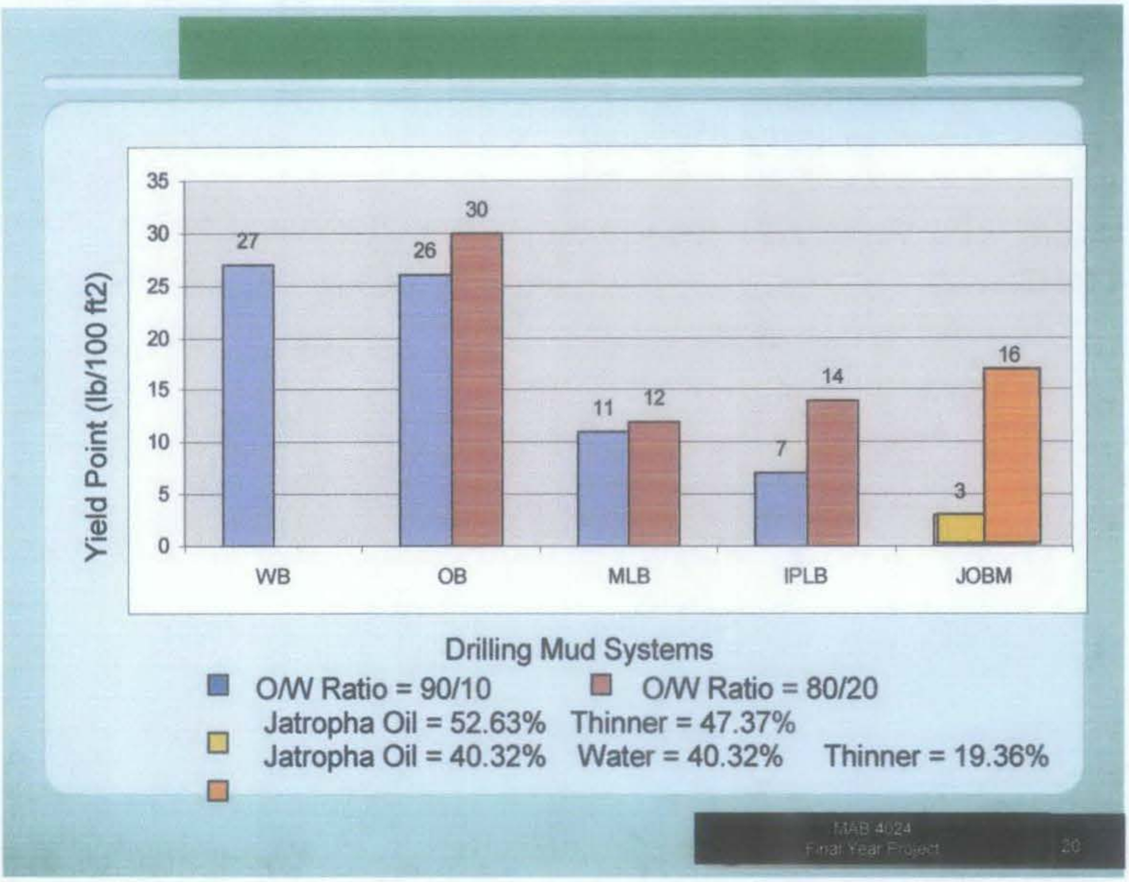


Figure-21' rheological analysis, Yield Point

Gel strength represents the gelling effect of the drilling mud systems during motionless. Gel building up property is significant to suspend the drilled cuttings and drill pipe stripping and casing. Figure-C, illustrates the gel strength for o/w ration 90/10 and each of the drilling mud systems. JOBM systems show an acceptable gelling effect (big tolerance) compared to other systems Better performance of gelling can be obtained by increasing the water content which aid in suspension capability of the mud systems.

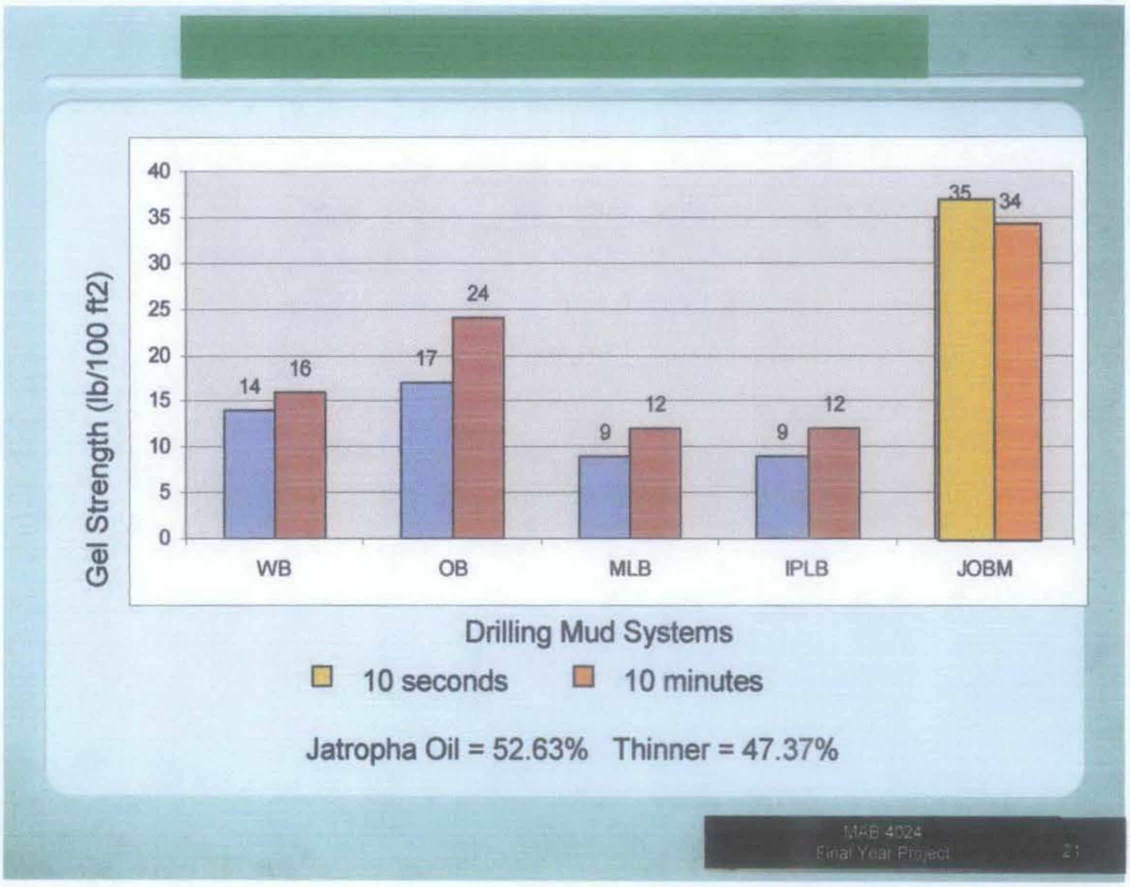


Figure-22' rheological analysis, Gel Strength

CHAPTER 5

CONCLUSION

This study exhibits that Jatropha Oil can be used to develop drilling mud systems. The presence of the plastic viscosity, yield point and gel strength of JOBM systems suggest the non-Newtonian behavior of the mud systems (EXLOG, 1985). The rheological properties of JOBM systems are depending on water content in the systems. Although exceptional lower YP was observed for the JOBM system, we strongly believe that this can be improved by the use of other suitable additives.

In the First stage of the experiments (exps 5- 12), three types of material been used for drilling mud. Those are: Jatropha oil, Water and Barite. The results showed that, Mud weight is within the range of requirement, but Plastic and Yield Point showed unstable result and plus the concentration of the soap in the mud were high.

In the second stage we made an addition add to our mud, by adding the Thinner. The purpose of the thinner was to reduce the viscosity. Experiments showed a minimal improvement in the Plastic Viscosity and Yield Point, we also observed that thinner managed to reduce the concentration of soap in the mud.

The results proved that water increases the viscosity of the mud and reduces the mud weight. So we excluded the water from the mud. The results taken from the experiments were totally different from the both stages. The mud weight, plastic viscosity and yield point improved highly.

RECOMMENDATION

Based on results, I would like to recommend for future, to continue research and investigation on Jatropha Oil Based Mud. Using modern laboratories and advanced technologies of Oil and Gas Research Institute's. Additional study should be conducted to investigate the rheological properties of the mud systems at the bottom hole conditions, also study on filtration loss

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