THE EFFECT OF CONTAMINANTS ON THE RHEOLOGICAL PROPERTIES OF A WATER-BASE LIGNOSULFONATE DRILLING MUD.

BY

UGWULEBO REMIGIUS OBINNA

97/6183EH

A RESEARCH WORK SUBMITTED TO THE DEPARTMENT OF
CHEMICAL ENGINEERING SCHOOL OF ENGINEERING AND
ENGINEERING TECHNOLOGY.

FEDERAL UNIVERSITY OF TECHNOLOGY MINNA,
NIGER STATE.

IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE
AWARD OF THE B.ENG IN CHEMICAL ENGINEERING.

OCTOBER, 2003

DECLARATION

UGWULEBO REMIGIUS OBINNA of Chemical Engineering Department, Federal University of echnology Minna, with Reg. No 97/6183EH. Hereby declare that this project-Effect of ontaminants on the Rheological properties of water base lignosulfonate mud is entirely my efforts, nd to the best of my knowledge has not been wholly or partially submitted elsewhere before now.

Ugwulebo Remigius

CERTIFICATION

This is to certify that UGWULEBO REMIGIUS OBINNA in Chemical Engineering tment, Federal University of Technology, Minna, Niger State carried out this project work. egistration No. 97/6183EH under the Supervision of

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. (MRS) EJ. ETERIGHO
ROJECT SUPERVISOR)

DATE

AD OF DEPARTMENT
F.I Aberuagba
EMICAL ENGINEERING DEPARTMENT)

DATE

. SUPERVISOR

DATE

DEDICATION

This project is dedicated to the most high God for his protection and guidance throughout he duration of achieving my First Degree Certificate.

Also, it is dedicated to my lovely parents MR. AND MRS. R. A. UGWULEBO and the ntire UGWULEBO'S family members.

ACKNOWLEDGEMENT

From the innermost parts of my heart, I am glad to thank my "big" brother Mr Camillus gwulebo (camico), his lovely wife Mrs. Jacinta Ugwulebo, for their financial and moral support roughout my entire programme in F.U.T Minna.

My sincere thanks also goes to my dearest parents Mr. and Mrs. R.A Ugwulebo for their couragement and advice to me.

Furthermore, I am immensely grateful to Mr. Pedro Ugwulebo, Mr. Emma Nwaonu, Mr. he Ameachi, Mrs. T. Oyegunle, Mrs. Njoku, Miss Rhoda Ogwala, Mrs. Edena Nworgu all of om play important role to the successful completion of my programme.

I also acknowledge my supervisor, Engr. (Mrs.) L. Eterigho, my co-ordinator, Engr. M. utoye, Dr. Aberuagba (H.O.D), Dr. Edoga, Engr. Fatai, Engr. Saka, Engr. Kovo, Mr. Moh'd gr. Adeniyi, Engr. Azeez and all the entire staff of Chemical Engineering Department F.U.T nna for the noble roles they played during my programme in the department.

My appreciation also goes to my classmates and friends – Andy Uloko, Pius, Francis, e,Emma Ihedioha, Emma Akut, Degele, Doris, Phillippa, Emeka, (Prince), Okoro A.C ommate) and others too numerous to mention for their encouragement during my academic ggle, may the good Lord bless you all and grant you your heart desire. Amen.

NOMENCLATURE

V - Apparent Viscosity (CP)
P - Centipoise
\- Foot
Pa - Kilopascal
\- Pounds
pb - Pounds per barrel
pg - Pounds per gallon
pm - Pounds per million
v - Plastic Viscosity (CP)
t - quart (946cm^3)
AAP - Sodium acid pyrophate
P - Yield Point (lbf/100ft^2)
S - Yield Stress (lbf/100ft^2)
h - Hydrostatic Pressure
r - formation Pressure
UD - True Value dept
\- Mud weight (ppg)
\- Diameter, (inches)
\- Fortage per bit, (Ft)
\- Viscometer reading, lbf/100ft^2
\- Viscosity (Cp)
\- Well dept in feet
\- Famming friction factor, (Dimensionless)
\- Viscosity of liquid filtrate in centipoise
mf - Resistivity of mud filtrate

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ABSTRACT

In order to drill deeper, in more hazardous oil wells and to exploit productive hydrocarbons more fully, the drilling mud must have properties (physical and chemical) that will enable it to withstand with greater variety of well conditions. The quality of mud used in drilling is one of the major factors in the success or failure of the drilling operation and one of the contributing factors to unstable mud properties is contamination.

During the course of this project, A laboratory test was carried out to determine how contaminants such as salt (Nacl), cement, carbonate and temperature effect affect the rheological properties such as viscosity, gel strength, yield point, weight and pH of a water based higroslfonate drilling mud.

A prepared mud was mixed with varying quantities of the contaminants while for temperature, the ranges were increased by a constant value (20°c). different equipment such as viscometer, mud balance and phydrion dispenser etc. were used, it was observed that except for temperature, other properties had steady and progressive increase as the mud contaminants were increased while there was turbulent condition with temperature increase. Also it was observed that water based lignosulfonate mud cannot function well at high pounds per million (ppm) eg. Above 100,000ppm at high mud contaminant and at high temperature range in the hole.

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CHAPTER ONE

1.0 INTRODUCTION

The first reported use of drilling mud was noted in France in 1845, when water was pumped down a hallow bearing rod while drilling water wells to bring cuttings from the bit to the surface (Dermot, 1973).

Through the 1920's iron oxide and Barium sulphide (Barite) were use to increase the density of mud thus preventing entry of the formation fluid into the bore hole. The use of bentonite clays in the 1930's to suspend barite formed the basis of today's large commercial drilling industry.

Generally speaking, a "Drilling Mud" describes a broad range of fluid both liquids and gases, use in drilling operations to achieve specific purposes which ranges from lubricating to carrying capacities. (Adam, 1985).

A mud is a mixture of fine clay particles and water, prepared such that the clay particle are suspended in water (Mikhailov, 1973). The success of any drilling operation in the oil industry depends largely on the quality of the drilling mud and in order to drill deeper and consequently more hazardous wells and to exploit productive formation more fully, the drilling mud must have physical and chemical properties. These properties are related to the fundamental characteristics of density which indicates the weight per unit volume of the drilling mud that may be use to determine the hydrostatic pressure exacted by the mud, the viscosity which has to do with the flow and gelatin properties such as Apparent viscosity, plastic viscosity, gel strength and yield point of the drilling mud, also the pH properties that deals with the acidity or alkalinity of the drilling mud, and filtration which involves the ability of the solid compound of the mud to form a thin, and other important properties like solid content, specific gravity and colloidality.

The physical and chemical properties of the drilling mud are affected by contaminants such as sodium chloride (HCl), cement, carbondioxide, carbonate, bicarbonate, saltwater, sand, H_2S, anhydrite, temperature and hydrocarbon, some of which are encountered in the mud system during drilling operation. These contaminants exist in the drilled formation and are often experience during period of circulation of mud from the pit down the hole and back to the surface through the annulus. These contaminants alters the drilling properties in an undesirable manner even as it is one of the contributing factors to unstable mud

Properties, which may be due to difficulty in controlling the fluid loss, alkalinity or rheology and they are commonly experienced in water base and oil, base mud. This is usually why a mud once used, should be subjected to test, for various properties to determine its ability to function again. A drilling mud is therefore under continuous monitoring to correct or remove these contaminants. (Walter, 1963).

1.1 AIMS/OBJECTIVES

(1) To study the various drilling mud

(2) To analyze the effect of the various types of drilling mud contaminants on water base – lignosulfonate mud

(3) To analyse subsequent impact to the rheological properties of drilling mud on the oil drilling process

1.2 APPROACH/METHODOLOGY

The project was carried out through the following approach,

1. Examination of the impact of contamination on the rheological properties of a water base hignosulfonate mud.
2. Create~~s~~ condition of contamination similar to those in the field were carried out for the rheological properties of water - base lignosulfonate drilling mud. (Laboratory test)
3. Results from above were analysed in relation to drilling operations and general hole stability.

CHAPTER TWO

2.0 LITERATURE REVIEW

Most oil and gas wells are drilled by pushing a drill bit against the rock and rotating it until the rock wears away. A drilling rig and system is designed to control how the drill bit pushes against the rock, how the cuttings are removed from the well by drilling mud, and how the cutting are then removed from drilling mud so that the mud can be reused, during drilling, mud is injected down the drill string through small holes in the drill bit designed with holes to allow the mud clean the cuttings away from the bit. The fluid with suspended cuttings, then flow back to the surface in the annulus between the drill string and formation. At the surface, the cuttings are separated from the mud while some retained muds are then placed on the mud pit for later treatment and disposal. The separated mud is then re-injected down the drill string to lift more cuttings.

The mud mostly used in the drilling process is water followed by oil, air, natural gas, and foam. When water or oil is used as the base mud, it is called "Mud". Water base drilling mud is used in about 85% of the wells drilled worldwide while oil-based muds are used for virtually all of the remaining wells (George, 1980).

During drilling process, some mud can be lost to the permeable underground formations, to ensure that mud is always available to keep the well full, extra mud is always mixed at the surface and kept in reserves or mud pits for immediate use.

The pits are also used to store supplies of water, waste fluids, formation cuttings, rigwash and rainwater runoff. (Adams, 1985).

2.1 DRILLING MUD

The term drilling mud include air, gas, water or a combination of two or all the above, it is referred to as a suspension of clay in water or oil in which all the components of clay and additives suspensions present are used to effect the removal of rock cuttings from the earth subsurface (bottom hole) to the surface during drilling operations. (Dermot, 19 73).

When selecting a drilling mud, the type of mud to be used on a particular well depends on factors such as formation characteristics, composition, temperature, drilling hazards and the quality and source of water to be used in making the mud.

2.2 CLASSIFICATION OF DRILLING MUD

Drilling mud are classified according to the constituent of the continuous phase, this is due to the fact that as drilling operations progresses and well gets deeper, the constituent of a mud might change from the basic mixture of clay and water to a more complex mixture of other chemicals, depending on the nature of the formation being drilled. This account for different types of drilling mud used in the oil industry.

Drilling mud are classified into:

- Water base mud
- Oil base mud

- Air – gas mud

Each has many sub categories based on purpose, additives or clay states.

2.2.1 Water Base Drilling Mud

Water is the most commonly used based mud for drilling operations. This is because, it does not have the physical and chemicals properties needed to fulfill all the requirement of a drilling mud; therefore a number of additives are used to alter its properties. During drilling operation, formation materials get incorporated into the drilling mud, further altering its composition. Some elemental composition of common constituent of water-base drilling mud include Al, Barium, Calcium, Cadmium, Chromium, Cobalt, Cu, Fe, Pb, Zn, Mercury, Nickel, Na, Mg, K and Silicon. Water is a continuous phase, but it may contain oil (emulsion mud) or air (aerated mud) as the discontinuous phase that must remain as segregated droplets and not combine in a distinct phase termed "discontinuous".

There are three basic types of water base mud, they include:

- Fresh water
- Inhibited water
- Water base emulsion.

2.2.2 Fresh Water

This is one of the oldest mud used in the oil industry, it is generally used with no special additives except perhaps a corrosion inhibitor such as high molecular morpholines and oil-soluble organic inhibitors, it is usually the base fluid when adding many chemicals such as clay, polymer, weight materials, and additives to control various properties. Fresh water may hydrate the clay and often contain dissolved salts that are incorporated into the mud as contaminants during operations. (Dermot, 1973).

Under these we have,

(i) Spud Mud: It consists of viscous slurry of bentonite, which provides enough carrying capacity to clean large diameter surface holes. It is not costly and is easy to maintain. It is commercial clay usually added to a water based mud system to enhance viscosity, gel strength, and suspension; it is plate like in nature. The plate is thin and the total particle size is less than 0.1 of a micronian size. It has a high lubricating property and improved the filter cake and this help to reduce the torque, drag and differential pressure sticking. It also offers aid to control filtration and hydration, there for swelling is accomplished primarily by the adsorption of water to the surface of the clay. It has a high cation exchange capacity, a high surface per unit weight and is easily dispersed therefore it absorbs substantially more of the methyl one blue solution than the ordinary low yield clays.

(ii) Low Solid Mud: This is different from the spud mud in the polymers (Starch) and are used for filtration control and either as inorganic phosphates or organic thinners (lignite or lignosulfonate) to control viscosity. It usually becomes excessive during operation that water cannot control its composition.

(iii) Lignosulfonate Mud: This is essentially a spud mud with lignosulfonate added to control viscosity and filtration rate. It is a high temperature stabilizer, dispersant, biocide and a corrosion inhibitor. It is used for the control of mud density because of it high specific gravity and can constitute up to 35% by volume of the mud. It reduces the attraction of solid to each other in the mud; they are organic in nature and starts to decompose at 300°f though it does not mean that they can't be used above the temperature. They are used to control filtration rate in weighted mud and helps to prevent high temperature solidification. It is not usually affected by gypsum, salt or cement contamination. It has good tolerance to excessive clay content and is used in conjunction with another filtration control substance, it is one of the best thinners that produces the best result. They do little to prevent hole erosion in the upper hole but are good water sensitive shale, but can be improved upon with the addition of other filtration control chemicals.

(iv) Lignite Mud: A lignite mud uses lignite as its primary thinner and as a primary filtration control agent. It is very expensive and can be converted to a spud mud by adding lignite into its mixture.

(v) Lignite - Lignosulfonate Mud

This is not pH sensitive and is good in water sensitive shales, but can be improved upon with the addition of other filtration control chemicals such as lignosulfonate. It has good tolerance to excessive clay content. The lignite -lignosulfonate mud has successfully drilled wells with bottom hole temperature over 400^0F. Gypsum, salt and cement contaminants have little effect on the thinning ability of lignite lignosulfonate mud.

(vi) Low- Lime Mud

The low lime mud helps to avoid the problem of high temperature solidification encountered with lime mud, it is formulated with less alkaline materials than the conventional lime mud, which results in increasing temperature stability. They are used at bottom hole temperature as high as 350^0F. Since the total alkali (pH control materials) in low lime mud is reduced, the mud alkalinity must be monitored closely to avoid a depletion of alkali and subsequent development of high viscosity and gel. (Adam, 1985).

.2.3 Inhibited Water Mud

They are water base muds that repress the hydration (swelling due to water wetting) an inhibited water base mud is often used to minimize hole-sloughing problems. "Inhibition" refers to retarding the rate at which formation clays hydrate. Hydration reduces the structural stability of the borehole, allowing it to fall or slough, into the well bore. There are two main types of inhibited water mud, namely Gypsum mud system and K-plus mud.

(i) Gypsum Mud System

Gypsum mud are similar to lime mud in that both system uses calcium as their inhibiting ion. They function at lower alkalinities than lime mud and also contains more soluble calcium than lime mud and are therefore more inhibitive. They are more resistant to contamination than lime mud and also in temperature over 350^0F.

(ii) K-Plus Mud

The K-plus mud is one of the best-inhibited systems because it used both potassium and chloride as inihitors but it is very expensive when compared with the oil mud.

2.2.4 Water Base Emulsion Mud

This is the condition where one liquid is dispersed as small droplets into another liquid with which the dispersed liquid is incapable of causing the second liquid to become variation of itself, in emulsion, the liquid being dispersed into the second liquid is known as the discontinuous phase of the system. The liquid that is used in the greatest amount is the continuous phase. There are two types of emulsion system used in drilling fluids; they are the oil in water and water in oil.

Some functions of water emulsion mud are

- Reduction in pipe torque
- Increase in penetration rate
- Increased bit life
- Alleviation of differential sticking
- Better filtration control
- Better protection of possible production zones.

2.2.5 Treatment Of Water-Base Mud

The function of a drilling mud is directly related to its density, viscosity, gel strength and yield point, and treatment can rarely be considered as affecting one of these properties rather than all of them.

Treatment of the mud requires certain operations such as:

- Mud up
- Weight up
- Thinning
- Water-back
- Emulsification

(i) Mud – Up

Here, bentonite is added to fresh water mud generally having less than 6,000ppm of chloride ion and 10,000ppm of calcium ion to increase viscosity and gel strength and to lower water loss.

Premium clay are used in the presence of slightly more contaminated mud while salt clays or asbestors fibers are used in salty mud. This increases viscosity but do not improve filtration rate.

(ii) Weight – Up

This is the addition of weight materials such as barite to increase density, this controls formation fluid pressure and in some cases affords better support to hole walls and decreases shale troubles.

(iii) Thinning

This is the proper addition of chemical thinners such as lignosulfonate, or defloculate to improve the clay fraction of uncontaminated mud by thinning it and lowering the water loss, some lignosulfonate mud, provides good thinning even in contaminated mud.

(iv) Water-Back

This corrects the water to-solid ratio by adding water. When a chemically treated mud is too thick, it may become solid due to accumulation while drilling.

(v) Emulsification

Oil can be emulsified in clay water mud. This often provides improved lubricating properties, lower water loss, and decreased balling of bit, therefore giving lower pumping pressures and faster shale drilling (Moore, 1974).

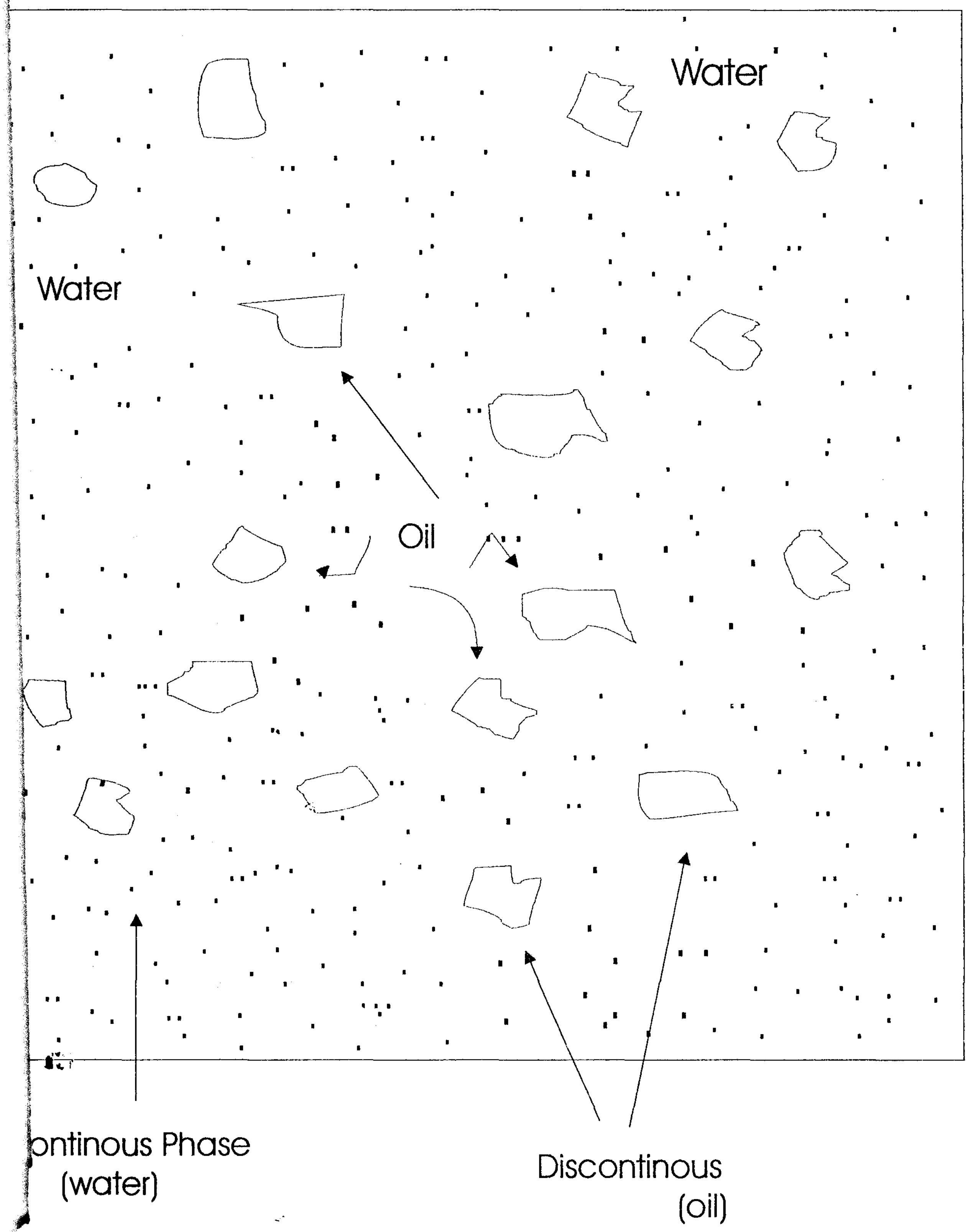


Fig. 2.1 Water-based mud

2.3 Oil Base Mud

Oil-based mud uses crude or refined oil as the continuous phase. These muds have water emulsified in the oil. An oil mud has less than 5% water. An invert emulsion has a water concentration greater than 5%. They are usually used for specific purposes, such as maintaining hole stability in hydratable formations or drilling hydrogen sulphide bearing zones. Mud contaminants from H_2S or $C0_2$ gas can be controlled with excess lime in an oil-based system.

Oil base mud like water do not contain all the proper physical and chemical properties needed to fulfil all the requirement of a drilling mud, so various additives are added but their properties are superior to that of water base even as they are preferred in high temperature well greater than 300^0F which above that level additives used with water-based fluid can breakdown, but they have the disadvantage of high cost and greater potential for adverse environmental impact, including reduction in drill rate and maintenance cost.

The properties of oil-based mud are influenced by the following:

- Oil/water ratio
- Emulsifier type
- Solid content. (Adams, 1985)

TABLE 2.1 **CLASSIFICATION OF OIL-BASED MUD SYSTEM (Thurber, 1990)**

SYSTEM	APPLICATION
TIGHT-EMULSION	- For high temperature areas - For general well use
RELAXED FILTRATE R(F) ALL OIL	- To provide increased drilling rates - For high temperature.
HIGH WATER	- To minimize oil retention on cuttings - For environmental sensitive areas.

2.4 GAS BASE DRILLING MUD

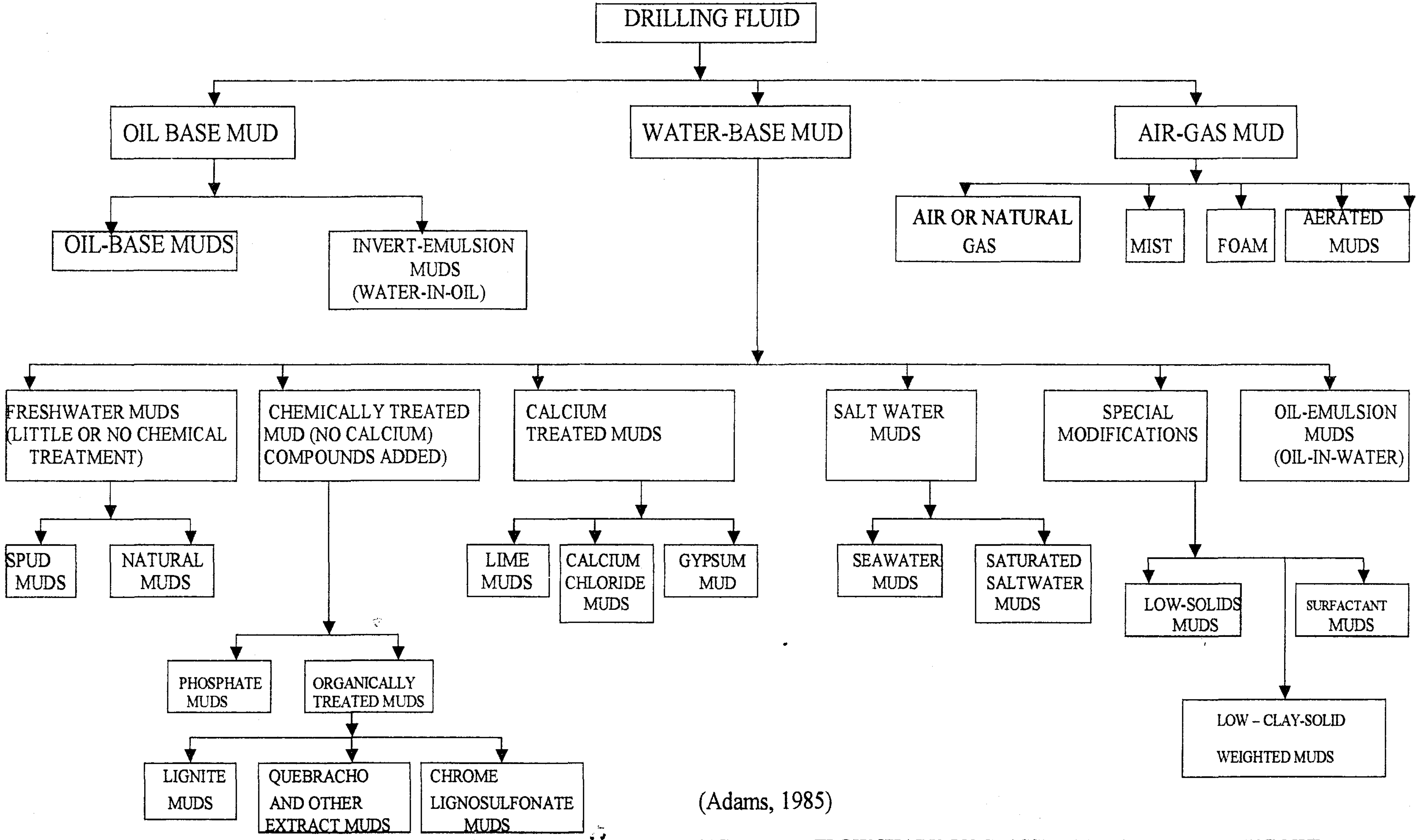
Water insoluble gases mostly encountered are the air and natural gas which forms on appreciable portion of drilling fluid. Gas drilling is the ideal medium for fastest penetration rates. Applicably, air drilling is restricted by unstable well bores, water producing formations, proceed in the presence of gas influx, the possibility of downhole explosion at a critical air-methane mixture is an ever existing threat, it is sub divided into foam and aerated mud.

2.4.1 Foam Drilling Mud

Form muds are made by injecting water and foaming surfactant into an air stream, creating viscous foam. Stable foams are made by injecting a gel base mud containing a foam surfactant into an air-stream. The carrying capacities depend more on the cuttings removal instead of air velocity. It requires less volume than air drilling and relies on bubble strength to remove cuttings.

2.4.2 Aerated Mud

This involves the injection of large quantities of compressed air, about 95% at atmospheric conditions into the circulating mud to lower hydrostatic pressure to secure increase drilling rate and lower well cost where circulation are encountered. (George, 1980).



(Adams, 1985)

FIG. 2.2 **FLOWCHART ON CLASSIFICATION OF DRILLING MUD**

2.5 Properties of Drilling Mud

The properties of drilling mud are related to the fundamental characteristics of density, rheology, filtration and chemical inhibition. Any other property is of secondary importance. The drilling mud properties can be used both as a quantitative and qualitative guide for controlling drilling fluid performance.

2.5.1 Mud Weight or Density

This is the weight per unit of various volumes. In practice, mud weight of oil may be necessary to control formation fluid influx and prevent a "well kick" that is, an unplanned entry of fluids into a well which causes the well to flow spontaneously and control hole collapse in troublesome formation. These controls result from pressure exterted by the weight of the mud column at a particular depth that is the hydrostatic head.

The instrument used in the field to determining mud weight are calibrated in several scales such as pound per gallon, (ppg), pounds per cubic feet, ponds per square inch per 100ft of depth and specific gravity and the instrument is bariod mud balance, frequent testing of density helps in preserving a safety factor by disclosing any change taking place in the unit weight of the mud. It is known that increase in mud weight will decrease drilling rate. The quantitative relationship between mud weight and drilling rate has not been established for general use. However, the use of prediction methods has proved to be a reasonable relationship. (Jones, 1988).

2.5.2 Viscosity

Viscosity is the measure of the internal resistance of fluid to flow, as the resistance increases, the viscosity of the fluid also increases, viscosity is a term used to describe the thickness of a mud in motion, in scientific term, it is a proportionality constant between the shear stress and shear rate for a Newtonian fluid in laminar flow, so as a constant shear rate would have no effect on it, this is true for Newtonian fluid such as water but not for drilling mud. In drilling mud, viscosity has been adopted as the common expressions for describing thickness but unfortunately certain thickness levels have been presented for drilling mud base on common usage rather than current requirement.

Viscosity of mud need to be controlled and a standard means of measurement should be provided, the factors influencing the viscosity specification of any given mud are hole size, hole condition, pumping rate, drilling rate, cutting size, caving, presence or absence of shale, separations of mud weight designs of the pit system and gel.

2.5.3 Fluid Rheology

During drilling operations, it is vital to control the various physical properties of drilling fluid. These properties must be controlled at different values to provide the drilling fluid with optimum characteristics to enhance drilling performance. The two main properties that require control in fluids are viscosity and gel strength.

In the control of viscosity, two reasons are considered, namely direct reasons which include to control the circulating pressure losses in the annulus, to provide adequate lifting capacity for the removal of formation solids and to help control surge and swarb pressure while the second which is the indirect reasons is that drilling rate are high with low solids and with these fluid, and mud may be thickened to minimize erosion in some unconsolidated shale formation because turbulent flow pattern with these fluids may create hole erosion and excessive hole enlargement, therefore rheology has to do with all the characteristics that define the flow and gelation properties of a drilling fluid. In lamina flow the mud thickness is defined by two terms, either plastic viscosity and yield point or from power-law concept by n and k while in turbulent flow thickness is primarily a function of solid content, and the laminar flow viscosity terms have no meaning for thickness in turbulent flow. The laminar flow viscosity effect would affect drilling rate only by the additional circulating pressure loss imposed in the annulus as the mud thickens. This additional pressure would increase the effective hydrostatic pressure head in the annulus and affects drilling rate.

The flow pattern of the drilling mud will be turbulent as it passes through the bit and the laminar flow viscosity properties of the mud cannot be used to determine the mud thickness. However, because plastic viscosity is used as a means to determine the relative solids content of a mud it can also be used as an indicator of the mud thickness in turbulent flow. It has been generally determined that a thin mud at high shear rate will result in high penetration rates than a thick mud if no other change in mud properties occur. There for when yield point to plastic viscosity increase the shear thinning characteristics of the mud also increases. (O' Brien, 1977).

Two main types of instruments used in measuring viscosity are:

A marsh funnel and the rotating viscometer.

Marsh funnel was the first method used to determine mud thickness, the measurement is made by comparing the time required for one quart of mud to run out of the funnel to the time required for one quart of water, the funnel is a calibrated instrument that is filled with 1,500cc of fluid and fluid discharge is through a sized nozzle. One quart of water is supposed to be discharged in 26. 5 sec. the relative time for the discharge of one quart of mud is an indication of mud thickness. Though there is no quantitative basis for using any number when both fluids are in motion.

The second is the rotating viscometer, which is usually the field model temperature type that runs at only two speeds of 300rpm and 600rpm. The 300rpm represent on approximate shear rate of 511sec while the 600rpm speed represent an approximate shear rate of 1022sec, there are also six speed models of the rotating viscometer which in general are designed for speed of 3, 6, 100, 200, 300 and 600rpm (Moore, 1985).

2.5.4 Gel Strength

Gel strength is a rheological property of drilling mud used to describe the thickness of mud that have been left quiescent (in active) for a period of time and it is also the force that initiate movement of fluid into motion, that is, it is the measure of the attractive forces between the clay platelets in the drilling mud under static conditions. It is measured with use of fann viscometer. Gel strength is needed to suspend drilled cuttings and weight materials during trips, it also has a direct bearing on the swab and surge pressure created while out of or going into the hole with the pipe and initiate pump pressure required to break circulation, an increase in gel, observed in a drilling well may indicate that the mud is thickening to much during trips and therefore should be treated or perhaps high temperature shear test should be ran to substantiate gel evidence.

2.5.5 Filtration Property

The filtration properties of drilling mud are a measure of the ability of the solid components of the mud to form a thin, low permeability filter cake on the well bore during operations, the lower the permeability, the thinner the filter cake and the lower the volume of the filtrate from mud of comparable solid concentration. This property is dependent upon the amount and physical state of the colloidal material in the mud. A mud low in colloidal and high in solid, deposites a thick filter cake in the walls of the wells inside the holes and this prevent the passage of tools allowing an excessive cause of covering, when the walling properties are not met, it may result to further troubles such as difficulty in running casing, creating a swabbing effect which may cause the formation to cave or swab reservoir content into the hole and also problem in securing a water shut off because of channeling of cement. The standard instrument for the filtration properties measurement is the barriod standard filter press. The filtration rate of mud generally controls the thickness and characteristics of the filter cake that is deposited on permeable formations and to limit total filtrate that enters underground formations. The concept that drilling rate increased with increase in filtration rate was introduce by the operating personnel. Drillers noted that drilling rate were decreased when the filtration rate were decreased. In all probability this reduction in drilling rate was due to more because of the materials added to reduce filtration rate than because of the filtration rate reduction.(Gray and Chapman, 1942).

2.5.6 Sand Content

Sand is any solid greater than 75 microns in size and its determination is necessary because excessive sand results in the deposition of thick filter cake on the wall of the hole which may settle in the hole around the tools when circulation is in progress, thus interfering with successful operation of drilling tools or the setting of casing, also non-reactive low gravity solids creates an erosive environment which is detrimental to circulating equipment and high sand contents also causes excessive abrasion of pumps and pipe connection. Sand content is determined by elütriation, settling or sieve analysis, the later being preferred due to its reliability and the simplicity of the void space between grains, is usually expressed as percentage by volume. A heavy and coarse solids material increases the density of the slurry but with minimum effect on the mud property and solid volume. (Lummus, 1960).

2.5.7 pH of the mud

pH is one of the most important measurable characteristics of mud and is defined as the degree of acidity or alkalinity of drilling mud indicated by the hydrogen ion concentration which is commonly expressed in terms of pH or defined as the negative logarithm of the hydrogen ion content, pH = - Log H^+ A perfectly neutral solution has a pH of 7.0. Alkaline solution has P^H reading ranging above 7 for slight alkalinity to 14 for strongest alkalinity while acidity solution has pH below 7.

The pH measurement is used in determining the need for chemical control of mud as well as indicating the presence of contaminants such as cement, gypsum. The drilling pH for any drilling mud is dependent upon the type of mud being use, there are two methods of measuring the pH of a drilling mud, they are calorimeter method such as the phydrion dispenser and an electrometer such as Beckman or analytical pH meter (Clerk, 1994).

2.6 DRILLING MUD ADDITIVES

The properties of drilling mud can be adjusted to meet any reasonable set of condition, thereby overcoming most drilling problems such as abnormal pressure, lost circulation, sloughing of shales and pipe sticking. Mud additives are selected according to their application or specific performance requirement. The control of drilling fluids is associated with two problems

- The determination of what is needed in the way of properties (weight, viscosity, gel strength, filtration), for drilling mud to satisfactorily handle a drilling operation.
- The chemical selection of the type of mud, materials, and chemicals that will produce the desired properties.

.6.1 Classification Of Mud Additives And Control

The chemical additives commonly in use are pH control, viscosity control and filtration control.

(1) pH Control

Caustic Soda (NaoH) is used to alter the pH of a mud as high pH is desirable to suppress corrosion rate, Hydrogen embrittlement if H_2S enters the mud. High pH also lowers the solubility of Ca^{2+} and Mg^{2+} to minimize their dissolution and increase the solubility of lignosulfonate and lignite additives. A high pH is also beneficial for the many new organic viscosity control additives, to keep the pH in the desired range, NaoH is normally added, some of the new polymer mud, however have better shale stabilization properties at lower pH. The pH of most mud must be maintained between 9.5 and 10.5 range that is necessary for clays to disperse and chemicals to react as well as for corrosion protection and provision of reserve $0H^-$, which provides a measure of safety against contaminants that may reduce the acid – neutralizing ability of the filtrate. (Dermot, 1973).

(2) Viscosity Control

The control of viscosity or mud thickness depends on the operator's objectives. Viscosity may be maintained at high levels to ensure adequate hole cleaning, additives may be added to increase mud thickness for adequate hole cleaning and keeping the mud weight and total solid content at low level.

When more viscosity is required, it may be obtained by adding bentonite, flocculating the clay solids or by adding polymers designed for such purpose. Bentonite is the primary viscosity builder in the mud system, if fresh water is used it will increase viscosity with only small increase in mud weight. Flocculation is a quick and cheaper method of increasing viscosity and can be done by adding cement or lime and is throught to render ineffective the positive charge located on the edge of the clay platelet and this destroying their ability to link together.

Viscosity control is generally considered in terms of reducing mud thickness and the methods used in controlling it include mechanical aid, water dilution and chemical thinners that reduce the attraction of solids with each other. (Baroids, 1987).

(3) **Filtrate Control**

Several types of material are used to reduce filtration rate and improve mud cake characteristics, they include starch, sodium carboxymethylcellulose (CMC), lost circulation control (LCC). Drilling rate increases in filtration due to addition of materials added to reduce filtration rate and may not be affected by change in filtration rate. (Foster and Chapman, 1942).

(4) **Density Control Additives**

Barium sulphite is the primary additive to increase the density of the drilling mud. Densities ranging from 9-19PPg can be obtained using mixtures of $BaS0_4$, clay and H_20. The specific gravity of pure barite is 4.5, other weighting agents include Haematite (Fe_20_3) with specific gravity ranging from 4.5 to 5.11. (Dermot, 1973).

TABLE 2.2 CLASSIFICATIONS **OF MUD ADDITIVES AND THEIR CHEMICALS**

(Dermot, 1973)

VEIGHTING IATERIALS	- Stabilization of temperature - Increase of fluid pressure to prevent blow out - To obtain the required density in terms of High specific gravity	$BaS0_4$ $CaC0_3$ Fe_20_3 $Feo - T10_2$ Dissolved Salt.
ISCOSIFIERS	- Hole cleaning purpose - Providing of adequate lifting capacity - Control circulating pressure losses in the annulus - To minimize erosion in some formation.	Bentonite premium clay polymers (dextrid)
HINNERS OR EFLOCCULATING GENTS	- For viscosity and gel strength control as Emulsifiers	Lignosulfonate (Q-Broxin) Lignite Phosphate mix
ILTER LOSS	- Improve filter cake thickness - Limitation of filtrate that enters underground Formation.	Bentonite Lignosulfonate

LOST CIRCULATION MATERIALS	- Prevention of the whole mud loss to the formation - Restoration of mud circulation - Improve permeability	Sulfur Flakes Feberous granular
EMULSIFIERS	- Control of specific mud properties - Increasing of the stability of mud emulsion - Reduces water wetting tendency of insoluble solids	- Oil in water - Water in oil

2.7 FUNCTIONS OF DRILLING MUD

The functions of drilling mud are quite complex and the success of a drilling program depends on proper understanding and application of these functions.

The following functions are listed in order of increasing mud complexity.

.7.1 Cooling and Lubricating the Bit And Drill Pipe

Considerable frictional resistance is encountered by the bit in drilling the formation and by the drill pipe in coating against the side of the hole. If no fluid were present the bit would soon be burned and severely abraded. The presence of a liquid mud reduces the friction factor of the pipe and bit, for the hole and dissipates any heat so generated. The presence of a slick, low resistance film on the walls of the hole also reduces the frictional load when the pipe is pulled. All of the fluids circulated to date as drilling mud have had a sufficiently high specific heat and enough lubricating qualities to adequately cool the bit and drill pipe. (Adam, 1985).

.7.2 Cleaning Of the Hole Bottom

The removal of cuttings from below the bit is one of the most important functions of a drilling mud. Cuttings removal is controlled by factors such as the chip hold down effect of the mud, cross flow of the mud, fluid viscosity, density of the cuttings, size of the cuttings and density of the fluid.

.7.3 Maintaining Hole Integrity

Well bores often exhibit stability problems resulting from geological phenomena such as fracture zones, unconsolidated, hydrated clays and pressured sections. The drilling mud must control these problems so that as drilled section remain open and deeper, drilling can proceed.

7.4 Carrying Cuttings to the Surface

Transporting the cuttings that are removed from below the bit is essential for a mud system. The fluid velocity in the annulus must exceed the downward falling, or slip velocity rate. Mud weight, fluid viscosity, suspension and gelatin properties of the mud affects its carrying capacity.

When circulation is stopped, the cuttings that have not been removed must be suspended or they will fall downward. If a mud does not exhibit the proper characteristics to suspend the cuttings, re-entry into the hole and reaching bottom through the settled cuttings may become very time consuming and expensive.

2.7.5 Control Formation Pressure

Drilling intervals that have abnormal high formation pressure require that the mud system be able to provide sufficient pressure equal to or exceed the formation pressure. The hydrostatic pressure of the mud exceed the formation pressure, insufficient pressure control can cause hole heaving, kicks and blowouts.

2.7.6 Well Logging

The physical and chemical properties of a drilling mud may affect the well logging program. As an example, a high salt content mud may prevent the use of a spontaneous potential (SP) tool since the salt concentration of the mud and formation may be approximately equal. The selection of an adequate type of logs must be co-coordinated with the drilling fluids program to allow proper formation evaluation.

2.7.7 Improve Drilling Rate

The drilling rate is affected by various properties of the mud system. High viscosity mud reduces the cross flow velocity beneath the bit, which inhibits cuttings removal, lower water losses and high solids content, retard equalization of pressure around the drilled chip, thereby requiring regrinding prior to removal. Mud selection to optimize drill rates can reduce the drilling time, however caution must be exercised so that other problems do not occur- formation damage, hole stability, or stuck pipe.

2.7.8 Removal of Cuttings From Mud Surface

Drilled rock cutting must be removed from the mud system at the surface to prevent a high solids concentration build up.

Mud pits usually do not allow sufficient time for solids to settle out. Mechanical solid removal equipment such as shale shakers, desilters, mud cleaners and centrifuges has proven its worth in effective drilling.

Placement of the solid control equipment in conjunction with surface circulation system is also very important. Removal of larger solids should occur near the flow line, while removal of finer solids should occur prior to entering the suction pit.

2.7.9 Minimizing Contamination Problems

The mud system must often control various types of contaminants, including toxic gases, high solid contents, hydrocarbon gases and ionic contamination. Mud types commonly used in the drilling phase have varying abilities to control these contaminants. For example, a dispersed Lignosulfonate mud has a high solids tolerance, whereas some polymer system functions poorly with even small concentrations of solids. Drilling environments must be evaluated when developing the well plan to allow selecting the proper mud system to control possible contaminants.

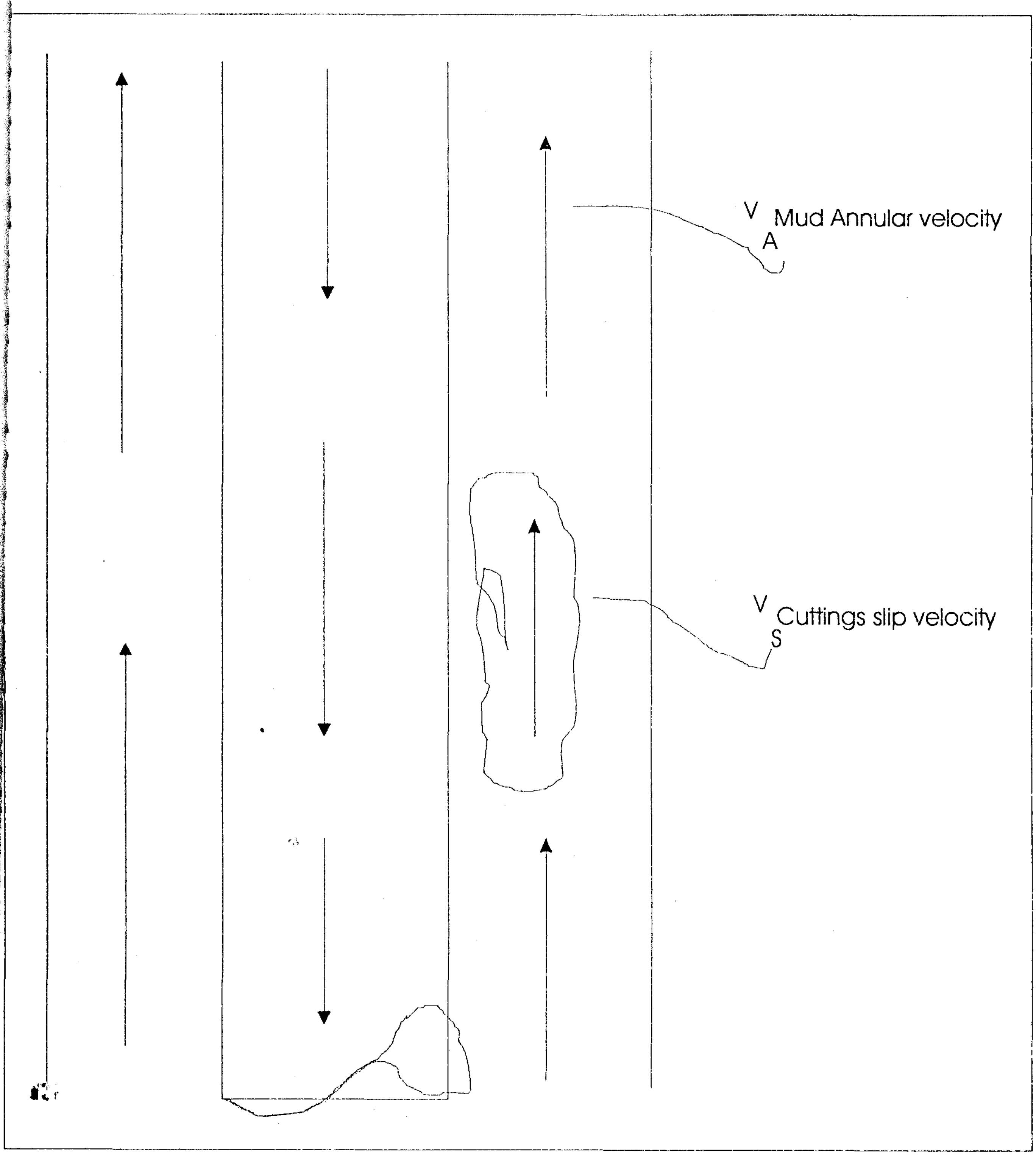


Fig. 2.3 The Upward annular Velocity of mud and slip velocity of the cuttings

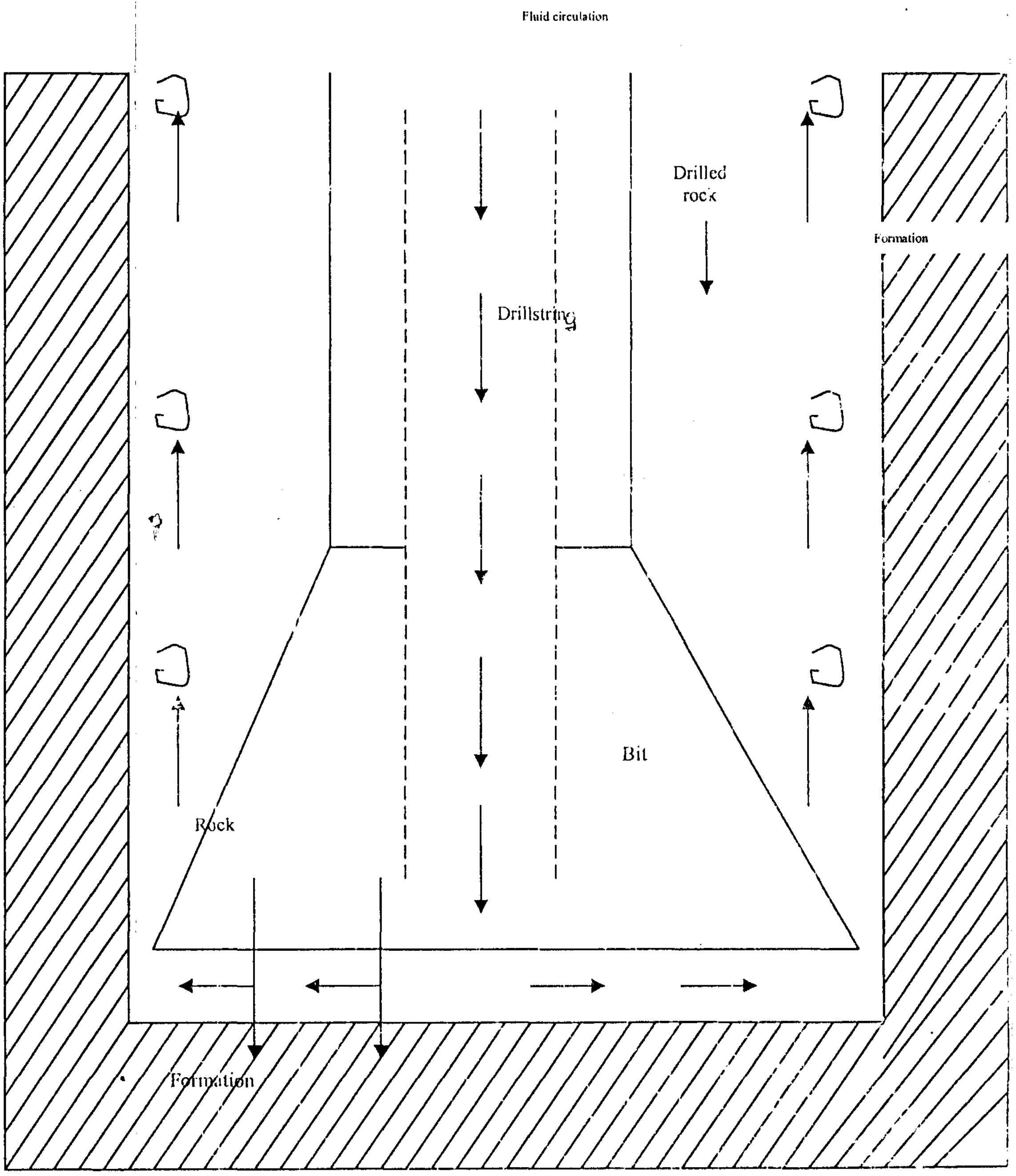


Fig 2.4 chip removal from below the bit

2.8 WATER-BASE MUD CONTAMINANTS

A mud contaminant is any material incorporate into a drilling mud, that has an adverse effect on the rheological characteristics of a drilling mud.

Some contaminants that are found in water base mud include, cement, solids, salt, carbonate etc and their occurrence depends on the area of operation as what constitute a contaminant in one mud system may not, necessarily be a contaminant to another. They can alter the physical and chemical properties of drilling mud only in one circulation. In many cases, however, they may be tolerated for extended periods with no apparent adverse effect. The severity of the problem experienced depends on the type and degree of contamination, and the type of mud in use.

The Instability of mud properties caused by contaminants may be due to the form of difficulty in controlling the fluid loss, alkalinity or rheology. Contaminants can be both specific and general due to the complexity of some chemical interactions and the difficulties experienced in the correct evaluation of results.

From many field level analytical procedures, situations can arise where more than one contaminant are simultaneously be responsible for the problem, that is contaminants can have a "MASKING" effect on each other, creating a situation where accurate determination of the contaminant most responsible for the problem is made difficult or even impossible, by the presence and effect of another. (Walter, 1963).

2.8.1 Types Of Water Base Mud Contaminants

Potential contaminants exist in great number depending on a number of related factors. Some common contaminants include:

- Sodium Chloride (Salt)
- Cement
- Gypsum or Anhydrite ($CaS0_4 - 2H_20$ or $CaS0_4$)
- Sand/Solid
- Acid gases ($C0_2$ and H_2S)
- Carbonates
- Bacteria
- Temperature
- Hydrocarbon (oil)

2.8.2 Contamination Due To Solids

These are contaminant that occurs in all mud types. They may be drilled solids or over – treatment with commercial clay. Their effect on drilling mud include high viscosity, high gel strength and high fluid loss. A relatively low percentage of solids may develop viscosities and gel strength of such high value as to convert the mixture into a plastic mass. The continued grinding of clay and shale cuttings into colloidal particles in water clay mud is particularly responsible for high mud viscosities and it becomes extremely troublesome at times to keep this viscosity reduced to a reasonable value.

2.8.3 Salt Contamination (NaCl)

Sodium chloride is encountered in make-up water, sea water, from drilling massive salt sections, salt stringers and high pressure salt water flows.

In bentonite base fluids, the presence of NaCl above 10,000 ppm will result in severe flocculation. This is recognized by an increase in viscosity, gel strength, high fluid loss and chlorides.

The most extensive contamination of mud with salt comes from the drilling of salt beds and domes. In these cases, depth up to several thousands feet of salt may be penetrated and the mud fluid soon becomes saturated. Contamination may also occur from the entrance of salt water bearing fluid from drilled permeable horizons such fluids normally contain dissolved salt concentration up to 15 percent. The mechanism of contamination in the case of salt is based on cation exchange reactions with the clays, mass action by the predominant cation and sometimes pH.

2.8.4 Contamination Due To Cement

Cement contaminations exist in almost all wells. The contamination is man-made through the use of cement for casing, squeezing pipe, plugging back operation etc, that is, the drilling mud suffers cement contamination from close contact it maintains with cement either in the slurry or hardened stage. The hardened cement is drilled out with the mud and in the course of performing this operation; cement particles can be introduced into the mud. The mud gets thicker and highly alkaline.

The visible sign of cement contamination is high viscosity and pH.

On further mud check, there is high filtrate alkalinity and high fluid loss, usually when circulating out cement; phenolphthalein is dropped on mud from the flow line to detect the presence of cement in the mud. Before the cement job, the drill mud is pretreated with precipitant to reduce the advance effect of cement contamination; in this case, some sacks of sodium bicarbonate are dropped into the active mud system. The severity of cement contamination depends on the previous chemical treatment, solid type concentration, the amount of cement drilled and the extent of its hardness in the hole.

Cement consists of silicates of lime (Calcium hydroxide) - $Ca\ (0H)_2$. When solubilized in water or water phase of drilling mud, an abundance of hydroxyl ion $(0H^-)$ are produced. The $(0H^-)$ produced by the cement contamination increase the pH which renders the calcium (cement) insoluble, therefore, a severely contaminated mud may have typically low flow properties (Due to calcium ion exchange reaction) high pH, high alkalinities, low filtrate calcium and generally high fluid loss depending on the chemical concentration of the mud. (Clark, 1994).

2.8.5 Contamination Due To Hydrogen Sulphide (H_2S)

Hydrogen sulphide (H_2S) is a very dangerous, high toxic and corrosive acidic gas that occurs naturally in many formations. It is formed primarily by the decomposition of organic matter that contains sulphur. The presence of small amounts of H_2S in a drilling mud can cause order to reduce or affect the harmful aspect of H_2S, the pH must be increased to atleast 11 or a safer level of 12 by adding caustic soda or lime.

(i) Sources Of Hydrogen Sulphide (H_2S)

- Thermal deposits
- Formation gas
- Biological degradation
- Breakdown of sulphur containing materials.

(ii) Identification Of Hydrogen Sulphide (H_2S)

- Reduction of pH of the mud
- Discoloration of the mud to dark colour due to the formation of FeS from barite.
- Rotten egg smell
- Viscosity and fluid loss increase due to pH reduction.

2.8.6 Contamination Due To Carbonate

Carbonate accumulate in alkaline drilling mud due to the presence of carbon dioxide ($C0_2$), which reacts with hydroxyl ions ($0H^{2-}$), to form carbonate ion ($C0_3^{2-}$).

Soluble carbonate may be incorporated into a drilling mud in a number of ways:

1. Carbon dioxide from drilled formation
2. Bacteria attack on organic materials
3. Thermal degradation of organic materials
4. Entrained air from surface mixing equipment
5. Over treatment with sodium carbonate or sodium bicarbonate
6. Carbonates from commercial barite or bentonite

Carbonate contamination is recognised with increased in high flow line viscosity, progressive gel strength, yield point, and increase in pH.

Bicarbonate on the other hand, shows detrimental effect at relatively low level, increasing both the gel strength and yield point, and also reduces the pH.

2.8.7 Contamination Due To Gypsum Or Anhydrite

Gypsum Anhydrite contamination results from the drilling of beds. Contaminations range in thickness from that of stringers of several inches to beds of soft thick. Gypsum and Anhydrite are names for the chemical compound calcium sulphate ($CaS0_4$).

Anhydrite refers to anhydrous form of the material while gypsum is calcium sulphate with water of crystallization ($CaS0_4$ - $2H_20$).

In the drilling of wells the material is usually found in the anhydrous condition and is referred to as gypsum. The contaminating effect of anhydrite is due to both calcium and sulphate ions in the compound, although the former is responsible for the greater amount of trouble. Anhydrite contamination is similar to ions that flocculate sodium bentonite as calcium bentonite. The flocculation of Bentonite results in an increase in the mud water loss.

The water loss value of the drilling fluid may be 8cc at the time of entering a massive anhydrite section and 24 hours anywhere from 25 to 27cc.

2.8.8 High Temperature Contamination

Although temperature could be said to be in a different class, since it is not made of physical particles, like other contaminants but it is still not out of place, considering the fact that its effect works hand in hand with thousand of other contaminants.

Generally the temperature of a mud increases with well depth, although the temperature depth gradient varies widely from one place to the other.

Increased mud temperature increases the chemical reactive properties of the mud and the reaction of cement, and gypsum salt for the mud and there by become more pronounced at high temperatures.

The rate of fluid filtration through a filter cake is among other relations inversely proportional to the viscosity of the filtrate. The viscosity of most liquids decreases with temperature increase.

Thus the wall cake will tend to be thicker in holes of high bottom –hole temperature, due to these decrease in the viscosity of the fluid phase.

2.8.9 Oil Contamination

Though oil is the continuous phase of oil base drilling mud, it is also a contaminant in both oil-base drilling mud and water-base mud. It becomes a contaminant in oil-base drilling mud when its required concentration is exceeded.

Effect of oil in drilling mud, is decreased in mud weight, when the weight of the drilling mud is reduced it becomes difficult for it to suppress the formation pressure which is one of the mud functions. It also causes the velocity to rise undesirably in water base muds. (George, 1980).

2.9 TREATMENT FOR WATER - BASE CONTAMINATS

2.9.1 Solid Control

Control of solids in the mud may be accomplished by the following methods.

- Settling method
- Dilution method
- Mechanical separation method
- Chemical treatment method

Each of these methods exhibits certain advantages and disadvantages. In practice, the most efficient form of solids control is often the combination of all methods.

1. **Settling Method:** The reduction, or removal of drilled solids by this means is achieved by retaining the drilling fluid in an undisturbed state, long enough to allow the solids, which are heavier than water, to settle out.

The speed of settling can be increased by use of a flocculant to increase the particles size, or by inducing centrifugal force to increase the gravitational effect.

2. **Dilution Method:-** Dilution occurs at all times during the drilling of a well, it takes place in the form of water, added in chemical treatment, for washing and cleaning the mechanical solids.

All drilling mud require a certain amount of fresh water phase to offset the losses that were accumulated during the course of drilling and thus maintain volume.

Even though large scale dilution can increase cost, it is still the only satisfactory means of removing undesirable ultrafine re-cycled solids from the fluid.

3. **Mechanical Separation Method:-**

Mechanical separation devices are available in two basic types, vibrating screening devices and system based on an increased settling rate through the use of centrifugal force.

The various types of devices include shale shakers, desilters, Descender, mud clearer and centrifuge. (Bariod, 1987).

TABLE 2.3 **TREATMENTS OF MUD CONTAMINANTS**

(N.L. Bariod Handbook, 1986)

CONTAMINANTS	**TREATMENT**
Cement	Add soda ash or sodium bicarbonate Optimize solid control equipment Treat with thinner Covert to a system that tolerate high cement levels when treatment are not sufficient to counter indicator.
Salt (NaCl)	Displace oil based mud system or synthetic system, when treatment is not sufficient to counter indications or convert to saturated saltwater system.
H_2S	Treat with hydrogen sulphide scavenger Adjust the pH with caustic soda
$C0_2$	Increase the mud weight.
Carbonates	Treat the mud with lime or gypsum
Gypsum/ Anhydrite	Treat with soda ash to maintain acceptable calcium levels Convert to a system that tolerates high calcium level when treatment is not sufficient to counter indications.

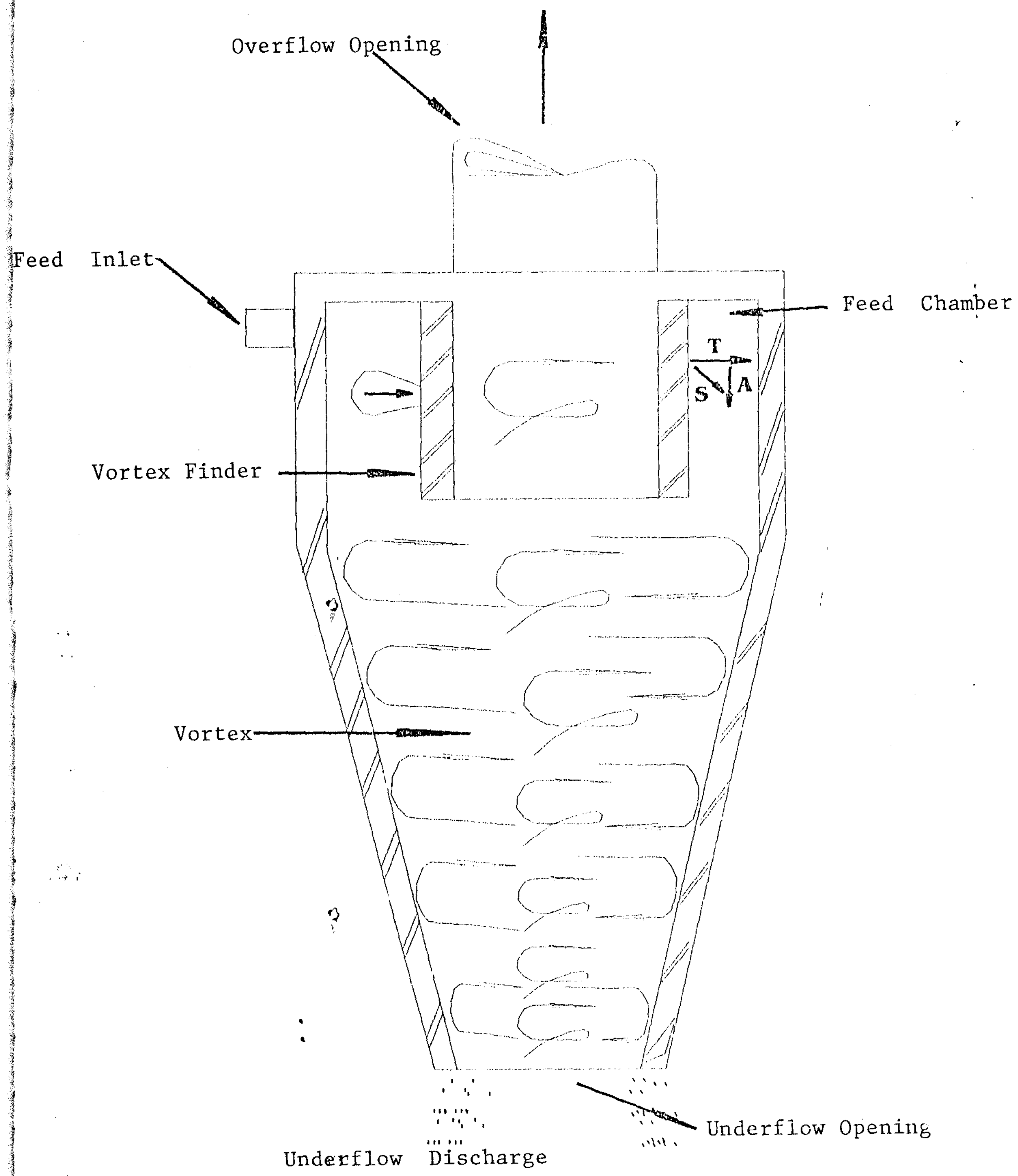


Fig. 2.5 Illustration of Basic Principles of a Hydrocyclone

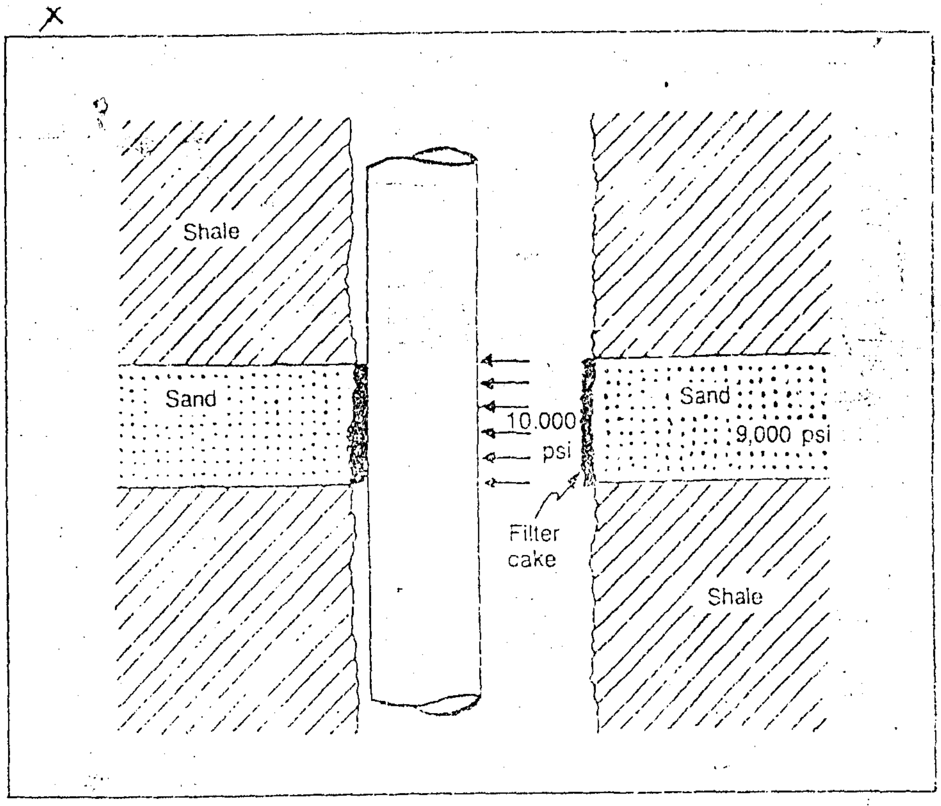


Fig 2.6 Differential Pressure Sticking

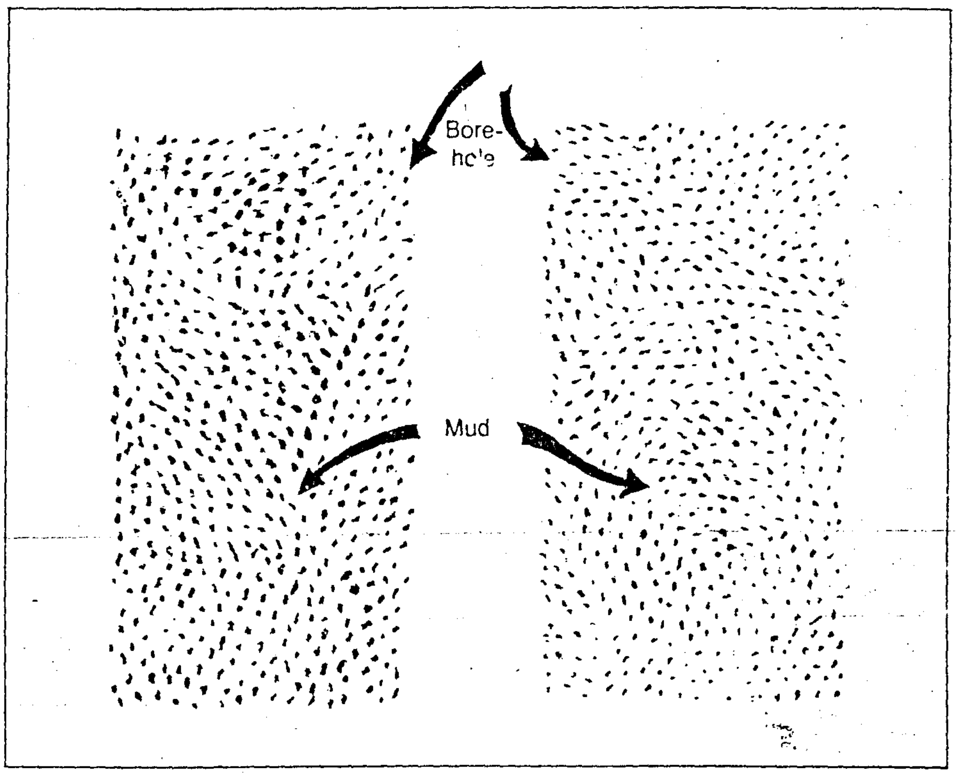


Fig. 2.7. Porous Permeable Zone

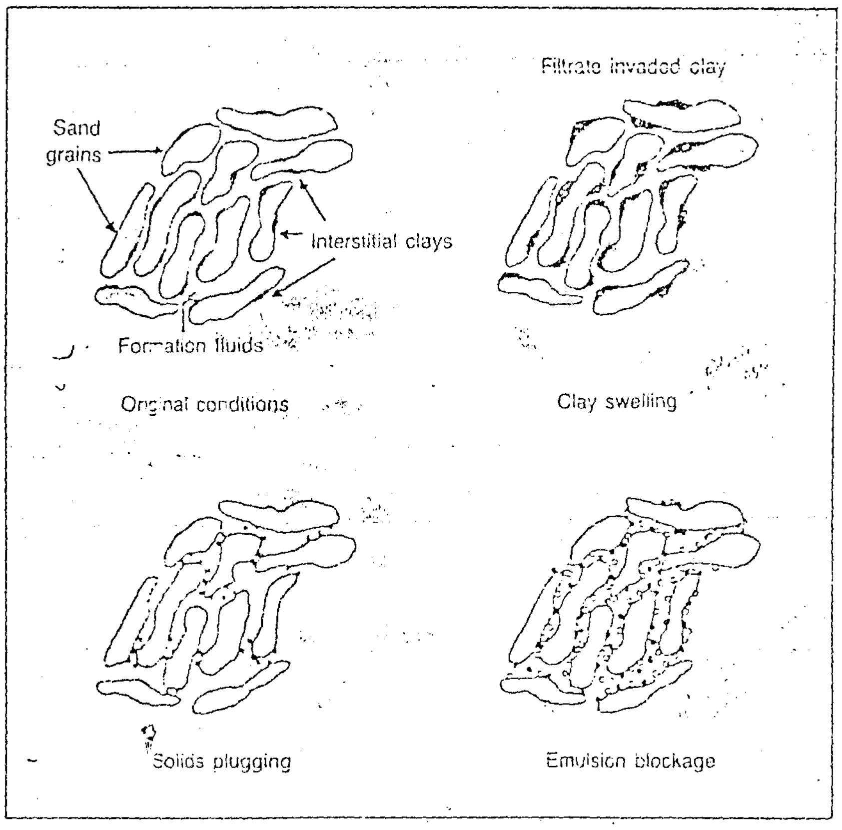
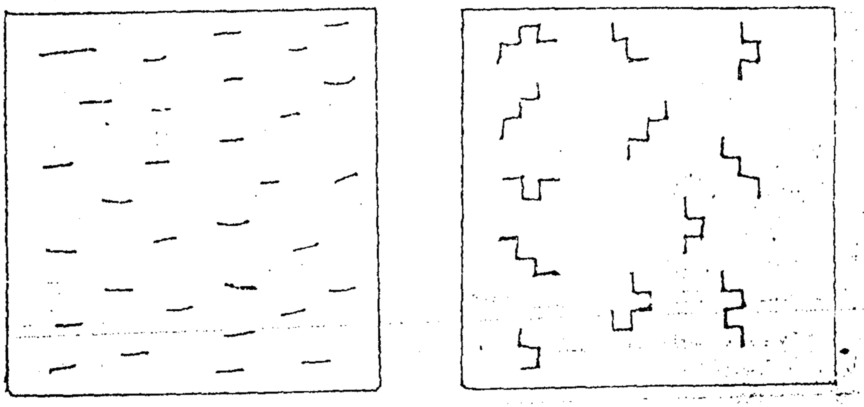
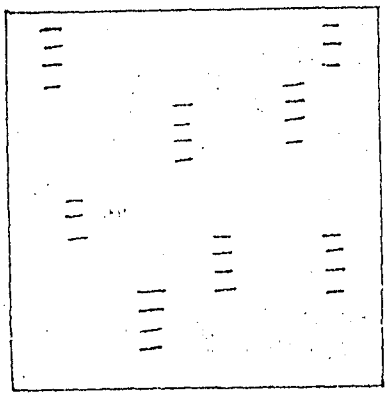


Fig. 2.8 Types of Formation Damage



Dispersed clays

Flocculated end-to-end arrangement



Aggregate structure

Fig. 2.9 Arrangements of Clay Particles

CHAPTER THREE

3.0 MATERIALS/EXPERIMENTAL PROCEDURE

Various laboratory experiment were carried out to see how water - based Lignosulfonate mud reacts to certain contaminants.

The equipment and materials used includes:

- Mud balance (Beam type)
- Mud can
- Measuring cylinder
- Multimixer (Electric type)
- Weighing balance
- Stop watch
- Spatula
- Marsh funnel
- 200 mesh screen
- Viscometer – (rotational type)
- Graduated cup
- Thermometer (0-104^{0}C)
- Retort stand
- Measuring glass tube
- Phydrion Dispensers
- Distilled water
- pH meter
- Oven
- Cold water bath

3.1 SAMPLE PREPARATION

The two samples prepared are Spud Mud (bentonite) and lignosulfonate mud.

3.1.1 Preparation Of Spud Mud

350ml of distilled water (Lab. equivalent of one barrel) was measured and poured into a mud can, and 17.5kg of spud mud was measured out and injected into the mud can, the mixture was stirred for 5 minutes using an electric multi-mixer, after which the rheological properties of mud - pH, viscosity, gel strength, weight, sand content were recorded. These were repeated after aging for 24hours.

3.1.2 Preparation Of Lignosulfonate Mud

350ml of distilled water (Lab equivalent of one barrel) was measured and poured into a mud cup, the water was stirred for 5 minutes before addition of beam balance, additives were measured in order of 14.0g of aquagel, 3.5g of Q Broxin, 2.0g of K-Lig, 2.0g of Dextrid, 92.0g of barite, 1g of Pac-R. And each was added to the water and stirred for another 5 minutes using electric multi- mixer The Mud mixture was then left to age for 24 hrs.

3.2 DETERMINATION OF RHEOLOGICAL PROPERTIES

The three important parameters associated with the rheology of drilling mud are:-

1. Viscosity
    - (a) Apparent Viscosity
    - (b) Plastic Viscosity
2. Yield point (yield stress)
3. Gel strength

Other properties include mud weight, pH and sand contents.

3.2.1 Determination Of Viscosity

The top of a marsh funnel was covered with a finger and the mud sample was poured through the screen until the level reaches the bottom of the screen. Then the funnel was held over the graduated mud cup in an upright position, the finger was removed from the funnel orifice, and stopwatch was started immediately, and the time required in seconds for one quarts of the sample to flow out of the funnel was carefully recorded using the stopwatch.

3.2.2 Determination Of Plastic Viscosity, Yield Point And Gel Strength.

The mud sample was collected and poured into a viscometer cup and the viscometer rotor sleeve was immersed to the scribe line, and was rotated at 600rpm by turning the hand wheel until a steady dial reading was obtained and recorded ($\theta600$).

Again, the sleeve was rotated at 300rpm until a steady dial reading was obtained and recorded ($\theta300$). Next the samples were stirred for 10 seconds at high speed after which it was left undisturbed for 10 seconds and the maximum dial readings were obtained for 600rpm and 300rpm respectively. The sample was again stirred for 10 seconds at high speed after which it was allowed to stay undisturbed for 10 minutes and maximum dial readings were obtain at 10 minutes gel strength lbf/100ft^2.

3.2.3 Determination Of Sand Content

The fluid sample was collected and poured into the sand content tube mark and the base fluid was added to reach the water mark, a finger was placed over the tube opening and poured over a 200 mesh screen and the fluid that passes through it were discovered.

This procedure was repeated until the sand content tube became clean, the sand on the screen were washed out with the base fluid, then the wide end of the funnel was placed over the top of the mesh screen and inverted the screen and funnel slowly while turning the top of the funnel into the mouth of the sand content tube. The base fluid was later sprayed on the screen and the tube placed in a full upright position to settle the sand, then the volume in percentage of the sand in the sand content tube was obtained and recorded.

3.2.4 Determination Of Mud Weight (Density)

The mud balance base was set up to a leveled position and the graduated cup cleaned and filled with unweighted mud, then a lid was placed on it and sealed firmly while the hole in the cup was covered with a finger and the mud outside the cup were washed out. The knife of the balance was set on the fulcrum, and the sliding weight was moved along the graduated arm until cup and arm balanced. The weight of the mud at the left hand edge of the sliding weight was read and recorded to the nearest lb/gal.

3.2.5 Determination Of pH (Hydrogen Ion Concentration)

The mud obtained was mixed and 1 inch of the pH indicator paper was dipped into it for 10 seconds and was brought out and compared with the standard colour on the phydrion paper chart and the corresponding pH were recorded.

3.3 DETERMINATION OF THE EFFECT OF SALT (NaCl) CONTAMINATION ON MUD PROPERTY.

The prepared lignosulfonate mud was measured out in five portions in a mud cup, each containing 250ml. The salt was also measured out in varying weight of 31g, 32g, 33g, 34g and 35g and each was added to each of the five portion of the mud cup and the mixture was stirred for 5 minutes, using the oven, the mixture was heated to 150^0C temperature, it was later cooled and stirred for 5 minutes. Then, the sample was tested for various rheological properties such as Apparent and plastic viscosity, weight and P^H. The procedure was repeated after each stage of 1g increment and the values recorded in parts per million (ppm) after converting from grams.

3.4 DETERMINATION OF THE EFFECT OF CEMENT CONTAMINATION ON MUD PROPERTIES.

The cement (contaminant) was measured out in varying weight of 26g, 27g, 28g, 29g and 30g, also the lignosulfonate sample was measured out into five mud cup each containing 250ml. The two samples were introduced into the multi-mixer and stirred for 5 minutes, the mixture was heated to 150^0C temperature using the oven, then it was cooled and stirred for 5 minutes and tested for various rheological properties such as Apparent and plastic viscosity, yield point, gel strength, pH and weight.

The procedure was repeated at the end of each stage with increment of 1g and the various values obtained and recorded.

3.5 DETERMINATION OF EFFECT OF CALCIUM CARBONATE CONTAMINATION ON THE MUD PROPERTY

250ml of lignosulfonate mud was measured out into a mud cup and varying weight of $CaC0_3$ contamination in five portions of 22ml, 24ml, 26ml, 28ml and 30ml, each added into the mud cup and placed in the multi mixer were stirring took place for 5 minutes. After which the mixture was tested for various rheological properties, the procedure was repeated at the end of each stage with increment of 2ml and the reading recorded.

3.6 DETERMINATION OF THE EFFECT OF TEMPERATURE ON THE MUD PROPERTY

The lignosulfonate mud was measured out in five portions of 250ml each into a mud cup. Then it was heated progressively in the oven at different temperature of 150^0C, 170^0C, 190^0C, 210^0C and 230^0C, the samples were then allowed to cool, with the aid of cold-water bath. The mud was then stirred for 5 minutes and the rheological properties test were carried out and the values were recorded.

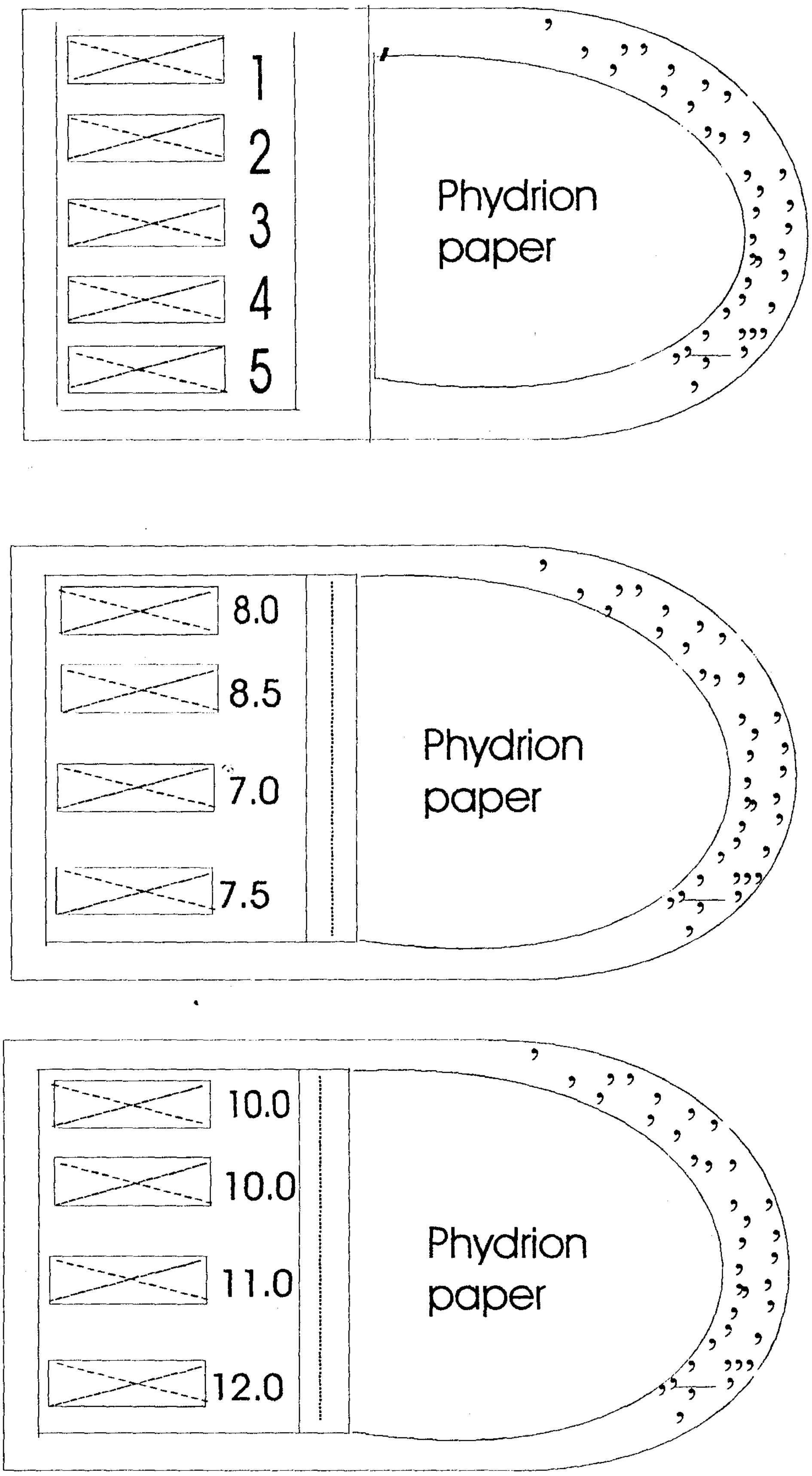


Fig. 3.1 Phydrion Dispensers

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

TABLE 4.1 RHEOLOGICAL TEST RESULT OF SPUD MUD (BENTONITE MUD) BEFORE AGING

Mass of Bentonite and 350ml of water	Rheological reading before aging for 24 hrs	Mud weight lb/gal	pH	PV (c.p)	AV (c.p)	YP lb/100ft^2	Gel strength lbf/100ft	Sand content (%)	Funnel viscosity sec/qt
	600 rpm 300 rpm						10 sec		
	23.0 15.0	8.8	8.0	8.0	11.5	7.0	10.0	0.1	72

TABLE 4.2 RHEOLOGICAL TEST RESULT OF SPUD (BENTONITE) MUD AFTER AGING

Mass of Bentonite and 350ml of water	Rheological reading after aging for 24hrs	Mud weight lb/gal	pH	PV (c.p)	AV (c.p)	YP lbf/100ft^2	Gel strength lbf/100ft^2	Sand content (%)	Marsh funnel viscosity sec/qt
	600 rpm 300 rpm						10sec		
	19.0 12.0	8.7	8.5	7.0	9.5	5	3.0	0.025	60

TABLE 4.3 RHEOLOGICAL TEST RESULT OF LIGNOSULFONATE MUD BEFORE AGING.

gnosulfonate ud and 350ml water	Rheological reading Before aging for 24 hrs	Mud weight lb/gal	pH	PV (c.p)	AV (c.p)	YP Ibf/100ft^2	Gel Strength lbf/100ft^2	Sand content %	Marsh funnel viscosity sec/qt
	600 rpm 300 rpm						10 Sec		
	59 35	8.8	6	24	29.5	11	10	0.10	82

TABLE 4.4 RHEOLOGICAL TEST RESULT OF LIGNOSULFORNATE MUD AFTER AGING

ignosulfonate ud and 350ml f water	Rheological reading after aging for 24 hrs		Mud weight lb/gal	p^H	PV (c.p)	AV (c.p)	YP Ibf/100ft^2	Gel strength lbf/100ft^2	Sand content %	Marsh funnel viscosity sec/qt
	600 rpm	300 rpm						10 Sec		
	48	30	8.7	6.6	18	24	12	3.0	0.025	70

TABLE 4.5 SALT CONTAMINATION RESULT LIGNOSULFONATE - 250ml

oncentration f salt	Rheological reading after 24 hrs aging		Mud weight lb/gal	pH	PV (c.p)	AV (c.p)	YP Ibf/100ft^2	Gel strength lbf/100ft^2	
	600 rpm	300 rpm						10 Sec	10min.
24,000 ppm	71	45	10.5	11.5	26	35.5	19	10	12
28,000 ppm	72	45	11	12	27	36	18	10.5	14
32,000 ppm	78	49	11	12	29	39	20	10.5	15
36,000 ppm	81	51.5	11	12	29.5	40.5	22	11	16
40,000 ppm	83	53.0	11	12	30	41.5	23	11.5	18

Table 4.6 CEMENT CONTAMINATED RESULT

LIGNOSULFONATE - 250ml

Cement Concentration	Rheological reading after 24 hrs aging		Mud weight lb/gal	pH	PV (c.p)	AV (c.p)	YP Ibf/100ft^2	Gel Strength YP Ibf/100ft^2	
	600 rpm	300 rpm						10 Sec	10mins
104,000 ppm	62	35	10.8	7.0	27	31.0	8	10	12
108,000 ppm	64	36	10.85	7.0	28	32.0	8	12	12
112,000 ppm	70	40	10.90	7.0	30	35.0	10	13	14
116,000 ppm	76	44	11.0	8.0	32	38.0	12	13	14
120,000 ppm	84	48	11.15	8.0	36	42.0	12	15	14

TABLE 4.7 CARBONATE CONTAMINATION RESULT

LIGNOSULFONATE - 250ml

$CaC0_3$ Concentration	Rheological reading after 24 hrs Aging		Mud weight lb/gal	pH	PV (c.p)	A.V (c.p)	YPlbf/100ft	Gel Strength lbf/100ft^2	
	600 rpm	300 rpm						10 sec	10 min
8.8%	72.5	44.0	9.0	11.5	28.5	36.3	15.5	11.0	14.5
9.6%	74.0	45.0	9.5	11.5	29.0	37.0	16.0	11.0	11.5
10.4%	76.3	46.5	9.5	12.0	29.8	38.15	16.7	11.5	15.0
11.2%	82.5	50.5	9.6	12.0	32.0	41.3	18.5	12.0	16.0
12%	84.5	51.5	9.6	12.5	33.0	42.3	18.5	13.0	17.0

TABLE 4.8 TEMPERATURE EFFECT RESULT

Temperature ^{0}C	Rheological reading after 24 hrs aging		Mud weight lb/gal	pH	PV (c.p)	AV (c.p)	YP Ibf/100ft^2	Gel Strength Ibf/100ft^2	
	60 rpm	300 rpm						10 Sec	10mins
150	39.5	23.0	9.4	6.5	16.5	19.8	6.5	12	13
170	46.0	24.0	9.7	6.0	22.0	23.0	2	10	10
190	50.0	22.0	9.7	7.0	28.0	25.0	-6	9	4
210	40.0	18.0	9.5	7.0	22.0	20.0	-4	9	4
230	50.0	24.0	9.0	7.5	26.0	25.0	-2	7	3

4.1 SALT CONTAMINATION

The experimental analysis in table 4.5 shows rheological behaviour observed in mud contaminated with salt. From the values observed in the table, it shows a steady increase in plastic viscosity and apparent viscosity of the mud as the salt contamination was increased this was also observed in the gel strength rheological property, as the time increases from 10 seconds to 10 minutes.

There was a small increase in weight of the mud with increase in concentration of salt from 124,000 ppm to 128,000 ppm before being unaffected as the contamination increases, also the pH remained unchanged basically within the range of salt contamination from 128,000 ppm to 140,000 ppm. A slight decline in the yield point was noticed from 124,000 ppm to 128,000 ppm but there was a gradual and steady increase from 128,000 ppm as the contamination increases.

4.1.1 Possible Effect On Drilling Operation

Although the lignosulfonate mud is designed to withstand some concentration of salt contaminants at concentration up to 124,000ppm it can no longer withstand the contamination. Therefore at this concentration, the readings from the logging operations would be affected, since the viscosities and gel strength are increased, mud pumping rate might become difficult thereby causing formation fraction. Also at high viscosity, the mud carrying capacity will be reduced and its ability to clean the hole properly also decreases leading to regrinding of the cuttings and the separation of the cuttings become difficult.

The increase in gel strength gives rise to hole problems such as sloughing, bore fracture and causes pipe sticking while the increase in yield point reduces drilling efficiency by cutting penetration rate, increases circulation pressure and poses danger of lost circulation, and also reduces mud carrying capacity.

4.2 CEMENT CONTAMINATION

The experimental analysis in table 4.6 shows the rheological behaviour observed in mud contaminated with cement. From the values observed, there was a rapid increase in both the plastic and Apparent viscosities from 104,000ppm concentration to 120,000ppm of cement concentration, also there was a general increase in the weight while it was observed that the pH remain unchanged from 104,000 ppm to 112,000 ppm and also from 116,000 ppm to 120,000 ppm as the contamination lasted. There was a stable condition in the yield point between 104,000 ppm and 108,000 ppm after which it increase at 112,000 ppm before being unaffected between contamination range of 116,000 ppm and 120,000 ppm. Also the gel strength increases as the time was increased from 10 seconds to 10 minutes during the contamination process.

4.2.1 Possible Effect On Drilling Operation

Increase in the plastic and apparent viscosity of lignosulfonate mud due to cement contamination alters smooth operation of the drilling process by increasing pressure drop in the mud circulating system thereby causing formation fraction.

The yield point of the mud is influenced by the concentration of the solid content in cement thus increase in cement contamination increases the solid concentration and if the yield point is not at a proper value, it causes reduction in drilling efficiency by altering pipe penetration rates, increasing the circulating pressure thereby possing the danger of lost circulation even as the carrying capacity of the mud could also be altered.

The low pH values may lead to increase in corrosion of drilling equipment and increases in mud properties.

The increase in weight of the mud, causes increment in the hydrostatic pressure exerted by the mud and if not controlled causes formation fracture, also it causes difficulties in maintaining a high pH and increase in drilling rate.

The increase in the gel strength causes the pipe to stuck in the hole and also well bore fracture is feasible.

4.3 CARBONATE CONTAMINATION

The experimental analysis in table 4.7 shows the rheological behaviour observed in mud contaminated with carbonate. From the table, it was observed that there was a steady increase in the plastic and apparent viscosity as the carbonate concentration increases from 8.8% to 12%. Also there was a gradual increase in the yield point till 10.4% carbonate concentration before it became stable between 11.2% and 12%. The mud weight increases gradually as carbonate concentration increases. Also there was a rapid and visible increase in the gel strength as the time of contamination increases from 10 seconds to 10 minutes while carbonate concentration increases.

4.3.1 Possible Effect On Drilling Process

Increase in the viscosities due to carbonate contamination causes fractured formation in the well, reduction in mud cutting carrying capacity and reduction in mud pumping rate.

Due to high pH value, some thinners effectiveness in the mud are hindered such as lignosulfonate mud that operate at pH below 10.

The small increase of the mud weight might affect the drilling rate and leads to fracture of the formation. The yield point and gel strength increment may lead to sloughing and stucking of the pipe in the hole.

4.4 TEMPERATURE EFFECT

The experimental analysis in table 4.8, shows the temperature effect of the rheological behaviour observed in lignosulfonate mud. From the value obtained, it was observed that as the temperature increases, there was falling and rising in the plastic viscosity, Apparent viscosity and weight of the mud from 150°C to 230°C while a decrease was noticed in both the yield point and gel strength throughout the temperature increment, this is due to the fact that at high temperature, the fluidity of the fluid generally increases while the gradual increase in pH is due to the increase in the reaction rate of substances as the temperature increases.

From the graph of plastic viscosity against temperature in Fig 4.4, it was observed that the plastic viscosity of the mud follows the same reducing trend with the weight with an increase in temperature until at a temperature of 190^{0}C was reached. At this point the plastic viscosity was steadly high but later with further increase of temperature it followed the decreasing trend till at a temperature of 210^{0}C, at this temperature, there was an increase in the plastic viscosity as the temperature get increased. It is a well known fact that mud may thin or thick with an increase in temperature and is noted here that as the mud thickens with an increase in temperature as at 230^{0}C, it is thicker four times more than it was at 150^{0}C, this is due to the drop in the shear rate.

Increase in pH causes the reduction of gel strength showing that temperature has a substantial effect on flow characteristics of drilling mud but this depends on the type of solids in the mud.

4.4.1 Possible Effect On Drilling Process

The increase in plastic and apparent viscosity of the mud due to temperature increase leads to thinning and severe thicking of the mud thereby causing flocculation of the clay platelets, also the reduction of the viscosity noticed at an increase of temperature was due to the thinning of the liquid phase of the mud. Also the reduction in the plastic and apparent viscosities with increase in temperature reduces the ability of the mud to suspend cutting and if the mud is not under circulation, the cuttings in the mud will settle with ease. At high temperature, the wall cake thickens thereby leading to damage of well and causing an increase in the rate of fluid filtration into the formation.

As the weight of mud is reduced, its hydrostatic pressure excerted in the hole, will also reduced, this is believe to have been caused by chip hold-down effect of the differential between hydrostatic and formation pore pressure though might not fall up to the extent of not being able to withstand formation pressure, also the weight reduction causes "well kick."

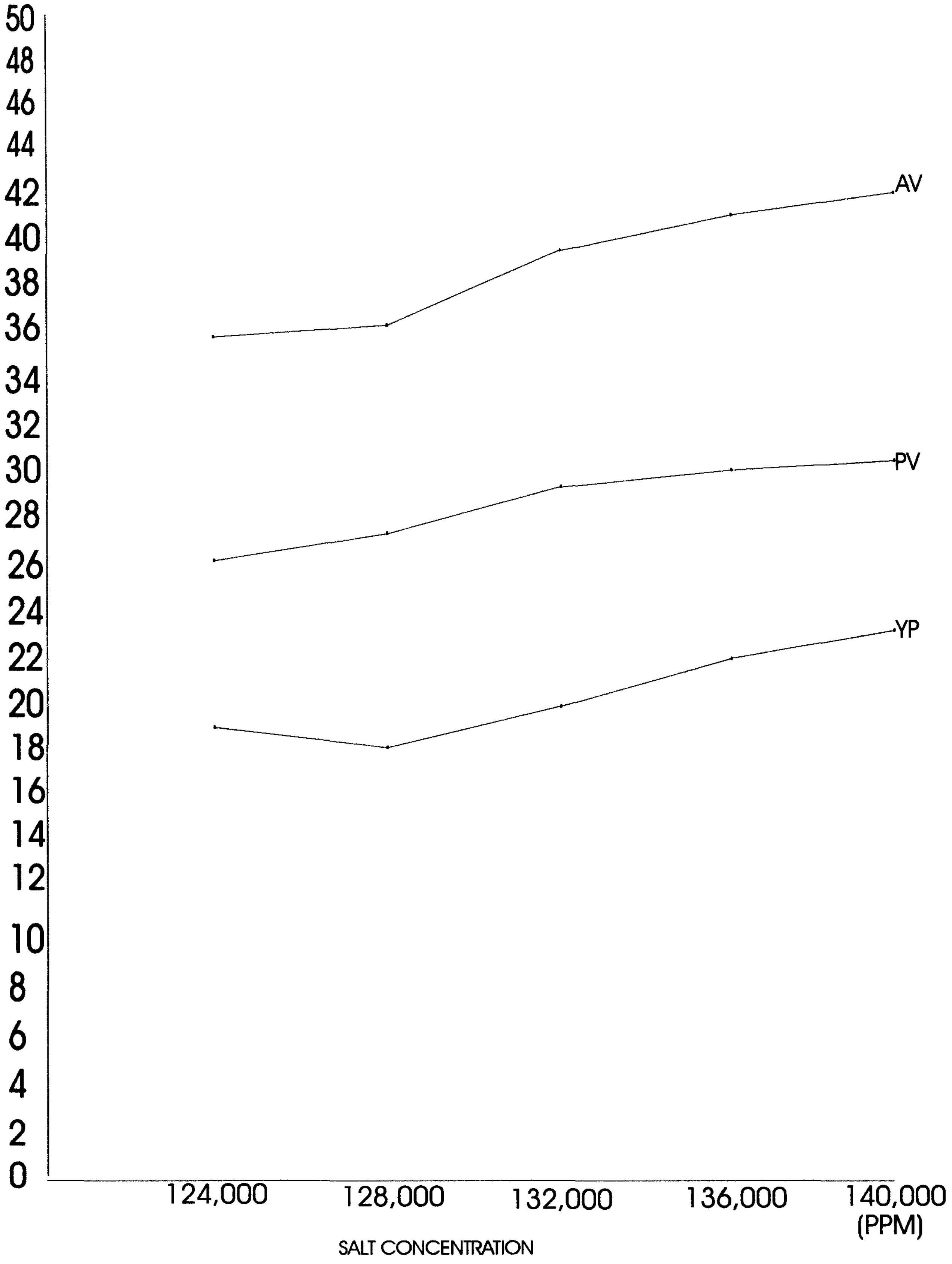


FIG.4.1 Graph of viscosity versus Salt concentration

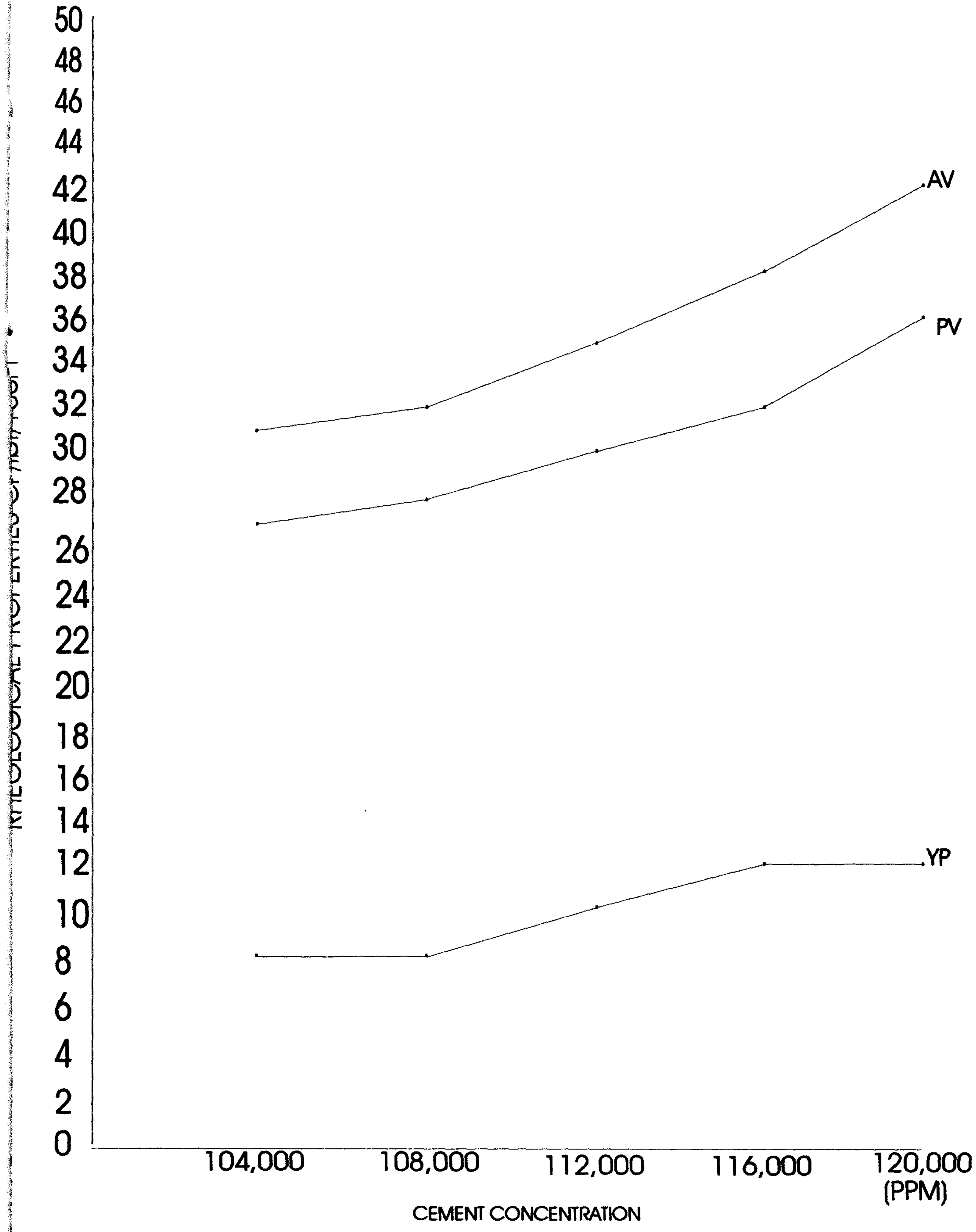


FIG.4.2 Graph of viscosity versus cement concentration

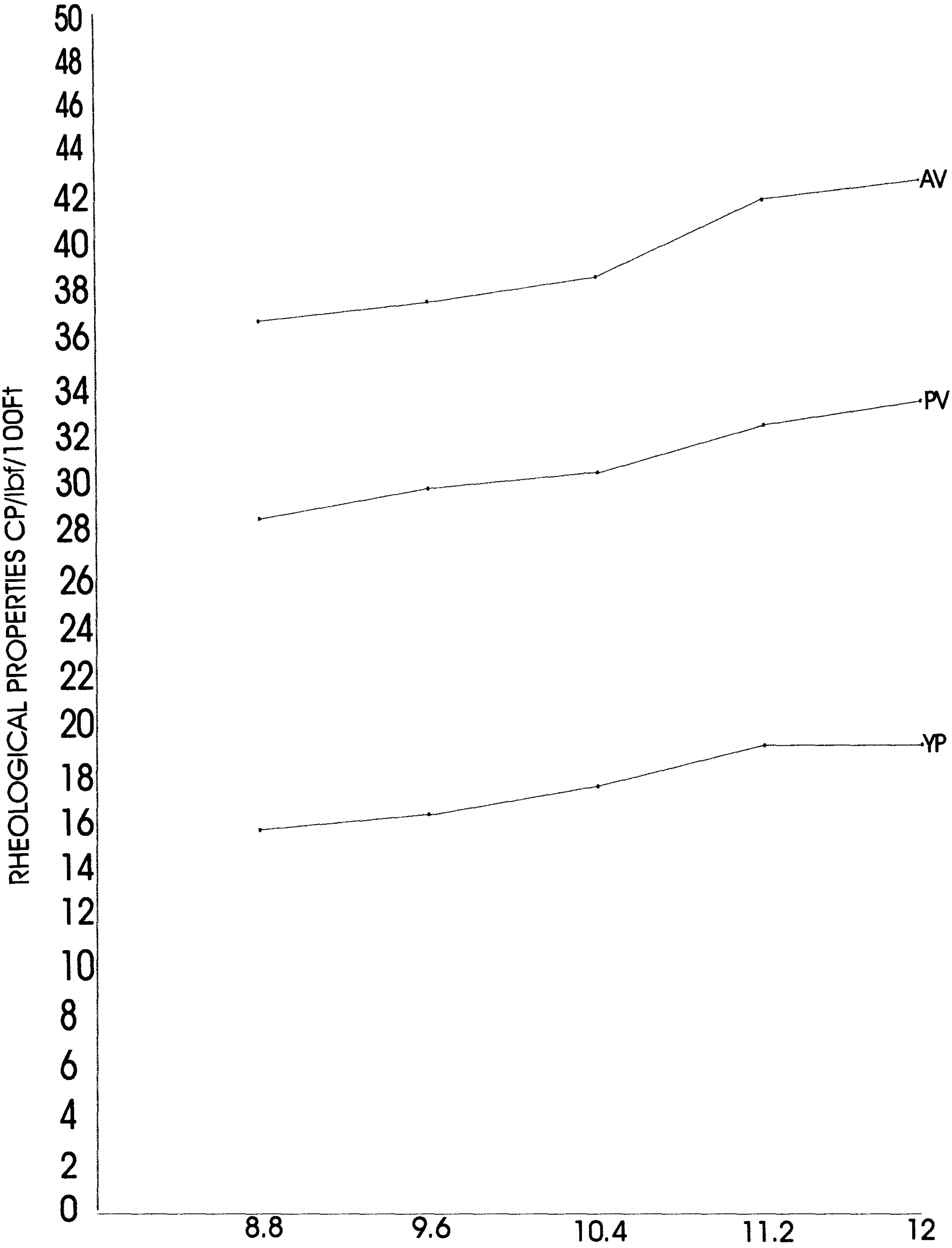


FIG.4.3 Graph of viscosity versus carbonate Volume

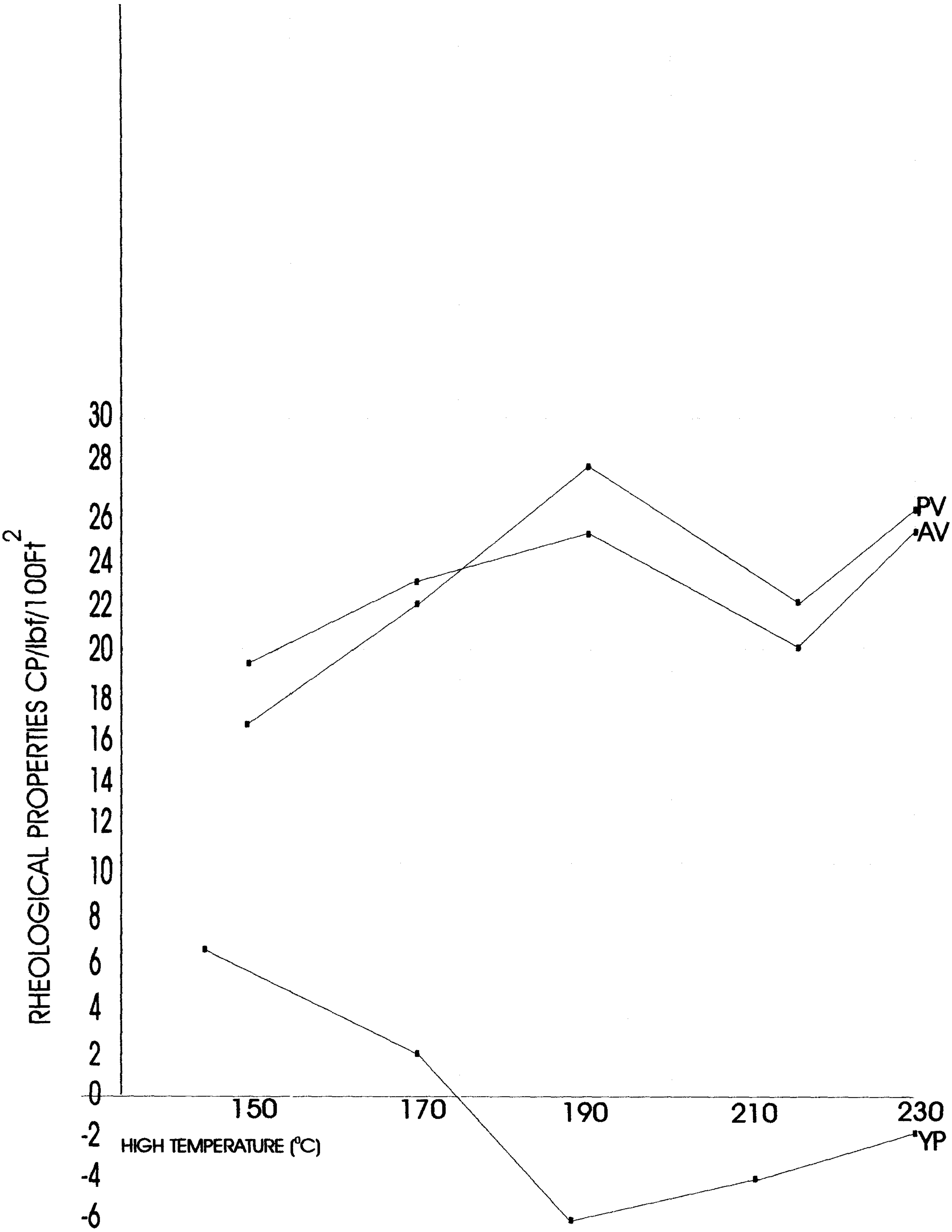


FIG.4.4 Graph of viscosity versus High Temperature

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATION

5.1 CONCLUSION

From the experimental analysis, it can be conclude that water-base lignosulfonate mud can not resist contaminate effect on the properties of drilling mud above salt concentration of 124,000ppm, 104,000,ppm concentration of cement and 8.8% per volume of calcium carbonate contamination as above these, drilling mud functions are affected leading to severe well problems such as pipe sticking, well kick, blowout, formation damaged, flocculation, sloughing of wells, and lost circulation

Since a substantial effect was observed on mud properties at high temperature, therefore lignosulfonate water-base mud are undesirable for high temperature wells as damage caused by contaminate become more pronounced with increasing temperature.

5.2 RECOMMENDATION

The mud engineer should develop pretreatment of mud so as to prevent effects of contaminant in time and therefore negate the requirement for post-corrective measure, which is time and cost intensive.

The mud engineer should adjust any of the drilling mud properties at any point in time to achieve the most suitable hole stability requirement and the set objectives.

Since the method use in the test does not in general permit the measurement of fluid properties at temperature above 230°f, the operator should therefore always measure the mud properties at the same temperature.

High PH concentrations is desirable in drilling mud to enhance hole safety, stability requirement and against contaminants effect.

Mud properties test should be carried out at room temperature.

Special mud should be generally introduce during drilling to combat specific hole problems to reduce the cost of drilling and help formation evaluation

Good solid control equipment and proper additives of water-base mud and chemicals should be provided to a high mud weight system to eliminate solid build up problems in the hole since the water dilution used as a corrective measure of solid problem is very expensive.

A complete and comprehensive mud plan must be included in the well planning process to prevent waste of time, money and resources on non productive and in diagnoses of troublesome wells.

Since water-base mud suffers thermal degradation and break down at high temperature to prevent down hole gel strength the operating temperature range of the mud should not be exceeded unless temperature-extending chemical are added in proper proportion.

Personnel on rig should wear eye goggles and protective materials, since contaminant effect could easily lead to loss of sight and lives.

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APPENDIX

CALCULATION OF RESULTS OF SPUD MUD (BENTONITE MUD)

Before Aging

Apparent Viscosity (AV)

600 Reading divided by 2

600 Reading = 23

AV = 23/2 = 11.5cp

Plastic Viscosity (PV)

600 Reading = 300 reading

600 reading = 23

300 reading = 15

PV = 23 – 15 = 8 cp

Yield Point/Stress

300 READING – PV

15 – 8 = 7 lbf/100ft^2

Marsh Funnel Viscosity

72 Sec./qt

After Aging

Apparent Viscosity (AV)

600 reading divided by 2

600 reading = 19

AV = 19/2 = 9.5 cp

Plastic Viscosity (PV)

600 reading - 300 reading

600 reading = 19

300 reading = 12

PV = 19 – 12 = 7cp

Yield Point/Stress

300 reading – PV

12 – 7 = 5 lbf/100ft^2

Marsh Funnel Viscosity

60 Sec./qt

CALCULATION OF RESULTS OF LIGNOSULFONATE MUD

Before Aging

Apparent Viscosity (AV)

600 reading divided by 2

600 reading 59

Av = 59/2 = 29.5cp

For 132,000ppm

600 reading = 78 rpm

AV = 78/2 = 39cp

For 136, 000pm

600 reading = 81 rpm

AV = 81/2 = 40.5cp

For 140,000ppm

600 reading = 83rpm

AV = 83/2 = 41.5cp

Plastic Viscosity (PV)

600 reading – 300 reading

For 124,000 ppm

600 reading = 71rpm

300 reading = 45rpm

PV = 71 – 45 = 26cp

For 128,000ppm

600 reading = 72rpm

300 reading = 45rpm

PV =72 – 45 =27cp

For 132,000ppm

600 reading = 78rpm

300 reading = 49rpm

PV = 78 – 49 = 39cp

For 136,000ppm

600 reading = 81rpm

300 reading = 51.5rpm

PV = 81 – 51.5 = 29.5cp

For 140,00ppm

600 reading = 83rpm

300 reading 53.0rpm

PV = 83 – 53.0 = 30cp

Yield Point

300 reading – pv

For 124,000ppm

300 reading = 45rpm

PV = 26cp

YP = 45 – 26 = 19 lbr/100ft^2

For 128,000ppm

300 reading = 45rpm

PV = 27cp

Plastic Viscosity (PV)

600 reading – 300 reading

600 reading = 59

300 reading = 35

PV = 59 – 35 = 24 cp

Yield Point/Stress (YP)

300 reading – PV

YP = 35 – 24 = 11 cbf/100 ft^2

Marsh Funnel Viscosity

82 Sec/ qt

After Aging

Apparent Viscosity (AV)

600 reading divided by 2

600 reading = 48

AV = 48/2 = 24

Plastic Viscosity (PV)

600 reading – 300 reading

600 reading = 48

300 reading = 30

PV = 48 – 30 =12cp

Yield Point/Stress (YP)

300 reading – PV

30 - 12 = 18

YP = 18 lbf/100 ft^2

Marsh Funnel Viscosity

70 Sec/qt.

CALCULATION OF RESULT OF LIGNOSULFONATE MUD WITH SALT (NaCl) CONTAMINATION (AFTER AGING)

Apparent Viscosity (AV)

For 124, 000ppm weight of salt.

600 reading divided by 2

600 reading = 71 rpm

AV = 71/2 = 35.5cp

For 128,000 ppm

600 reading = 72/2 = 36cp

YP = 45 – 27 = 18 lbf/100 ft^2

For 132,000ppm

300 reading = 49rpm

PV = 29cp

YP = 20 lbf/100ft^2

For 136,000ppm

300 reading = 51.5rpm

PV = 29.5cp

YP = 23 lbf/100ft^2

For 140,000ppm

300 reading = 53rpm

PV = 30cp

YP = 53 – 30 = 23lbf/100ft^2

CALCULATION OF RESULT OF LIGNOSULFONATE MUD WITH CEMENT CONTAMINANT AFTER AGING

Apparent Viscosity (AV)

For 104,000ppm

600 reading = 62rpm

AV = 62/2 = 31cp

For 108,000ppm

600 reading = 64rpm

AV = 64/2 = 32cp

For 112,000ppm

600 reading = 70rpm

AV = 70/2 = 35cp

For 116,000ppm

600 reading 76rpm

AV = 76/2 = 38cp

For 120,000ppm

600 reading = 84

AV 84/2 = 42cp

Plastic Viscosity (PV)

For 104,000ppm

600 reading – 300 reading

62 – 35 = 27cp

PV = 27cp

For 108,000ppm

600 reading – 300 reading

64 – 36rpm = 28cp

PV = 28cp

For 112,000 ppm

600 reading – 300 reading

70 – 40 = 30cp

PV = 30cp

For 116,000 ppm

600 reading – 300 reading

76 – 44 = 32cp

PV = 32cp

For 120,000 ppm

600 reading - 300 reading

84 – 48 = 36cp

PV = 36cp

Yield Point/Stress (YP)

For 104,000 ppm

300 reading - Plastic viscosity

35 – 27 =8

YP = 8lbf/100ft^2

For 108,000ppm

300 reading = 36 rpm

PV = 28

YP =36 – 28 = 81bf/100ft^2

For 112,000 ppm

300 reading = 40 rpm

PV = 30

YP = 10 Ibf/100ft^2

For 116,000 ppm

300 reading - 44 rpm

PV = 32

YP = 44 – 32 = 12 Ibf/100ft^2

For 120,000 ppm

300 reading - 48 rpm

PV = 36

YP = 12 lbf/100ft^2

CALCULATION RESULT OF LIGNOSULFONATE MUD WITH CALCIUM CABONATE ($CaC0_3$) CONTAMINANTS)

Apparent Viscosity

For 8.8%

600 reading = 72.5rpm

AV = 72.5/2 = 36.25cp

For 9.6%

600 reading = 74.0rpm

AV= 74.0/2 = 37cp

For 10.4%

600 reading = 76.3rpm

AV = 76.3/2 = 38.2cp

For 11.2%

600 reading = 82.5 rpm

AV = 82.5/2 = 41.23cp

For 12%

600 reading = 84.5 rpm

AV = 84.5/2 = 42.23cp

Plastic Viscosity

For 8.8%

600 reading – 300 reading

600 reading = 72.5 rpm

300 reading = 44.0 rpm

PV = 28.5cp

For 9.6%

600 reading = 740rm

300 reading = 45.5rm

PV = 29cp

For 10.4%

600 reading 76.3rpm

300 reading 46.5rpm

PV = 29.8cp

For 11.2%

600 reading = 82.5

300 reading = 50.5

PV = 32.0cp

For 12%

600 reading = 84.5

300 reading = 51.5

PV = 33.0cp

Yield Point

For 8.8%

300 reading = 44rpm

PV = 28.5cp

YP = 44 – 28.5 = 15.5Ibf/100ft^2

For 9.6%
300 reading = 45rpm
PV = 29cp
YP = 16Ibf/100ft^2

For 10.4%
300 reading = 46.5 rpm
PV = 29.8
YP = 16.7 Ibf/100ft^2

For 11.2%
300 reading = 50.5
PV = 32.0
YP = 18.5 Ibf/100ft^2

For 12%
300 reading = 51.5
PV = 33.0
YP = 18.5 Ibf/100ft^2

CALCULATION OF RESULT OF TEMPERATURE EFFECT

Apparent Viscosity

For 150^0 C

600 reading = 39.5 rpm

AV = 39.5/2 = 19.8cp

For 170°C

600 reading = 46rpm

AV = 46/2 = 23cp

For 190°C

600 reading = 50.0rpm

AV = 50/2 = 25cp

For 210°C

600 reading = 40rpm

AV = 40/2 = 20cp

For 230°C

600 reading = 50rpm

AV = 50/2 = 25cp

Plastic Viscosity

For 150°C

600 reading – 300 reading

600 reading = 39.5rpm

300 reading = 23rpm

PV = 16.5cp

For 170°C

600 reading = 46rpm

300 reading = 24rpm

PV = 22cp

For 190°C

600 reading = 50rpm

300 reading = 22 rpm

PV = 28cp

For 210°C

600 reading = 40rpm

300 reading = 18rpm

PV = 22cp

For 230°C

600 reading = 50rpm

300 reading = 24rpm

PV = 26cp

Yield Point/Stress

300 reading – PV

For 150°C

300 reading = 23rpm

PV = 16.5cp

YP = 6.5Ibf/100ft^2

For 170°C

300 reading = 24rpm

PV = 22cp

YP = 2Ibf/100ft^2

For 190°C

300 reading = 22rpm

PV = 28cp

YP= -6lbf/100ft^2

For 210°C

300 reading = 18rpm

PV = 22cp

YP = - 4Ibf/100/ft^2

For 230°C

300 reading = 24rpm

PV = 26cp

YP = - 2Ibf/100ft^2

CONVERSION OF GRAMS PER LITRE (g/l) TO PARTS PER MILLION (ppm) FOR SALT CONTAMINATION.

FOR 31g salt.

1ml = 1000 litres

250ml $= \frac{250}{1000} =$ 0.25lit

Grams > g/l

31g > $\frac{31}{0.25} =$ 124g/l

g/l > G/gal = 124 x 58.418 = 7243.832

G/g > ppm = 7243.832 x 17.118 = 124,000ppm

FOR 32g Salt

Grams > g/l

2g > $\frac{32}{0.25} =$ 128g/l

/l > G/gal = 128 x 58.418 = 7477.504

/g > ppm = 7477.504 x 17.118 = 128,000ppm

OR 33g of Salt

\> g/l

g > $\frac{33}{0.25} =$ 132g/l

\> G/gal = 132 x 58.418 = 7711.176

G/g > ppm = 7711.176 x 17.118 = 132,000ppm

FOR 34g of Salt

g > g/l

34g > $\frac{34}{0.25}$ = 136g/l

g/l > G/gal = 34 x 58.418 = 7944.848

G/g > ppm = 7944.84 x 17.118 = 136,000ppm

FOR 35g of Salt

g > g/l

35g = $\frac{35}{0.25}$ = 140 g/l

g/l > G/gal = 140 x 58.418 = 8171.52

G/gal > ppm = 8178.52 x 17.118 = 140,000ppm

FOR Cement Concentration

For 26g Cement

1ml = 1000 lit

250ml = $\frac{250}{1000}$ = 0.25

Grams > g/l

26g > $\frac{26}{0.25}$ = 104g/l

g/l > G/gal = 104 x 58.118 = 6075.472

G/g > ppm = 6075.472 x 17.118 = 104,000ppm

FOR 27g

1ml = 1000 lit

250ml = $\frac{250}{1000}$ = 0.25

g > g/l

27g > $\frac{27}{0.25}$ = 108g/l

g/l > G/gal = 108 x 58.418 = 6309.114

G/g > ppm = 6309.144 x 17.118 = 108,000ppm

FOR 28g

1ml = 1000 lit

250ml = $\frac{250}{1000}$ = 0.251

g > g/l

28g > $\frac{28}{0.25}$ = 112g/l

g/l > G/gal = 112 x 58.418 = 6542.816

G/g > ppm = 6542.816 x 17.118 = 112,000ppm

FOR 29g

29g > $\frac{29}{0.25}$ = 116g/l

g/l > G/gal = 116 x 58.418 = 6776.488

G/g > ppm = 6776.488 x 17.118 = 116,000ppm

FOR 30g

30g > g/l = /l
0.25

g/l > G/gal = 120 x 58.418 = 7010.16

G/gal > ppm = 7010.16 x 17.118 = 120,000ppm

CONVERSION OF caco$_3$ CONCENTRATION

$\frac{22}{250} \times \frac{100}{1} = 8.8\%$

$\frac{24}{250} \times \frac{100}{1} = 9.6\%$

$\frac{26}{250} \times \frac{100}{1} = 10.4\%$

$\frac{28}{250} \times \frac{100}{1} = 11.2\%$

$\frac{30}{250} \times \frac{100}{1} = 12\%$