REVIEW OF THE CONTROL METHODS AND GUIDELINES FOR COMBATING LOSS CIRCULATION.

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CERTIFICATION

This is to certify that this project titled "REVIEW OF THE CONTROL METHODS AND GUIDELINES FOR COMBATING LOSS CIRCULATION" was carried out by EDO KESSINGTON USEMWINHIAKHIN with Matriculation number ENG1303725 in the Department of Petroleum Engineering, Faculty of Engineering, University of Benin, Edo State, Nigeria.

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DEDICATION

This project is dedicated to God almighty who gave me the wisdom, knowledge, courage and sound health to successfully complete this thesis.

ACKNOWLEDGMENT

First and foremost I would like to appreciate my supervisor, Prof. K.O. Bello for his contributions toward this thesis. It was his calm advice that gave me the needed motivation to complete this project. It has been a great pleasure working with him.

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TABLE OF CONTENTS

Title page - - - - - - - - - - i

Certification - - - - - - - - - ii

Dedication - - - - - - - - - - iii

Acknowledgement - - - - - - - - iv

Table of content - - - - - - - - - v

Abstract - - - - - - - - - - xii

CHAPTER ONE

INTRODUCTION - - - - - - - - - 1

1.1 BACKROUND TO THE STUDY - - - - - - 1

1.2 STATEMENT OF THE PROBLEM - - - - - - 3

1.3 AIM AND OBJECTIVES OF THE STUDY - - - - - 3

1.4 SIGNIFICANCE OF THE STUDY - - - - - - 4

1.5 SCOPE OF THE STUDY - - - - - - - 4

CHAPTER TWO

LITERATURE REVIEW - - - - - - - - 5

2.1 LOSS CIRCULATION STUDIES REVIEW- - - - - 5

2.2 LOSS CIRCULATION MATERIALS CLASSIFICATION - - - 9

2.2.1 CONVENTIONAL LCM - - - - - - 10

2.2.2 HIGH LOSS SQUEEZE - - - - - - 10

2.2.3 GUNK SLURRIES - - - - - - - 11

2.2.4 PRECIPITATED CHEMICAL SLURRIES - - - - 11

2.2.5 CHEMICLLY ACTIVATED CROSS-LINKED PILLS (CACP) - 12

2.2.6 CEMENT SLURRIES - - - - - - 12

2.2.7 DILIANT SLURRIES - - - - - - 12

2.3 BOREOLE STABILITY ANALYSIS - - - - - 13

2.3.1 FRACTURES AND FRACTURE IDENTIFICATION - - 13

2.3.2 MECHANICES OF FRACTURING - - - - - 16

2.4 MANAGEMENT OF EQUIVALENT CIRCULATION DENSITY - 18

CHAPTER THREE

METHODOLOGY - - - - - - - - - 22

3.1 USING LOSS CIRCULATION MATERIALS - - - - 23

3.2 WELLBORE STRENGHTENING - - - - - - 24

3.3 USING DRILLING TECHNIQUES/PROCEDURES - - - 26

3.3.1 AERATED MUD DRILLING - - - - - 26

3.3.2 FLOATING MUDCAP METHOD - - - - - 27

3.3.3 DRILLING BLIND- - - - - - - - 28

3.4 USING ADVANCES IN DRILLING TECHNOLOGY - - - 29

CHAPTER FOUR

RESULTS AND DISCUSSION - - - - - - - 30

4.1 GENERAL GUIDELINES FOR COMBATING LOSS CIRCULATION - 30

4.1.1 LOCATING THE LOSS ZONE - - - - - 32

4.1.2 ESTIMATING THE PRESSURE IN THE LOSS ZONE - - 34

4.1.3 HOW TO DETECT CROSS-FLOWS IN THE LOSS ZONE - 35

4.2 SEEPAGE LOSS - - - - - - - - 36

4.2.1 IGNORE THE PROBLEM AND DRILL AHEAD - - - 37

4.2.2 PULL UP AND WAIT - - - - - - 37

4.2.3 PRETREAT THE ACTIVE MUD SYSTEM WITH LCM - - 38

4.3 PARTIAL LOSSES - - - - - - - - 40

4.4 SEVERE AND TOTAL LOSSES - - - - - - 42

4.4.1 BLIND DRILLING (DRILLING WITHOUT RETURNS) - - 42

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS - - - - - 45

5.2 CONCLUSIONS - - - - - - - - 45

5.3 RECOMMENDATIONS - - - - - - - 46

REFERENCES - - - - - - - - - 47

LIST OF TABLES

Table 2.1: Identifying Features of Fractures - - - - - - 16

Table 3.1: Loss Circulation Materials- - - - - - - 24

Table 4.1 Seepage Loss Quick Reference Guide to Pretreat Active Mud System With LCM - - - - - - - - - - - - - - - - - - 40

Table 4,2 Partial Loss Quick Reference Guide to Pretreat Active Mud System With LCM-41

LIST OF FIGURES

Figure 1.1 Formations Where Loss Events Occur - - - - - 2

Figure 2.1 Natural and Induced Fractures - - - - - - 14

Figure 2.2 Loss from Pit Level - - - - -` - - 15

Figure 2.3 Stress Distribution in a wellbore - - - - - - 17

Figure 2.4 Leak-off Test - - - - - - - - 19

Figure 2.5 Extended Leak-off Test - - - - - - - 21

Figure 3.1 A Complete Loss Circulation Management Program - - - 22

Figure 3,2 BHA Components of Cwd Assembly - - - - - 29

Figure 4.1 Temperature Survey - - - - - - - 33

Figure 4.2 Approximate Distance to Top of Fluid Level in Wellbore - - 35

Figure 4.3 Results using LCM too large- forms a bridge on the wellbore and erodes away 39

Figure 4.4 Results of using LCM too fine- goes through the opening and does not form a bridge - - - - - - - - - - - 39

Figure 4.5 Loss Circulation Control Flow-chart - - - - - 44

LIST OF ABBREVATIONS

APWD	Annular Pressure while Drilling
bbl/hr	barrels per hour
BHA	Bottom Hole Assembly
CACP	Chemically Activated Cross-linked Pills
CDS	Casing Drilling Shoe
CwD	Casing while Drilling
DOB	Dies-Oil-Bentonite
D_{static}	Static Fluid Column above Loss Zone
EAs	Expandable Aggregates
ECD	Equivalent Circulating Density
FCP	Fracture Closure Pressure
FIP	Fracture Initiation Pressure
FIT	Formation Integrity Test
FPP	Fracture Propagation Pressure
FRP	Fracture Re-opening Pressure
ID	Internal Diameter
ISIP	Internal Shut-in Pressure
lb/bbl	pounds per barrel
lb/gal	pounds per gallon
LCM	Loss Circulation Material
LCMSS	Loss Circulation Material Squeeze System
LOP	Leak-off Pressure
LOT	Leak-off Test
M-DOB	Mud-Diesel-Oil-Bentonite

Mev	Mega-electron Volts
MRCS	Mud-Reactive-Chemical-Squeeze
MW	Mud Weight
NPT	Non-productive Time
$P_{friction}$	Annular Friction Pressure
$P_{hydrostatic}$	Hydrostatic Pressure
$P_{loss\ zone}$	Pressure in Loss Zone
PNC	Pulse-neutron Capture
PNS	Pulse-neutron Spectroscopy
P_o	Pore Pressure
PSD	Particle Size Distribution
Psi	pounds per square inch
P_{total}	Total Annular Pressure
P_w	Wellbore Pressure
R-DOB	Reverse-Diesel-Oil-Bentonite
SBM	Synthetic-based Mud
S_{HMAX}	Maximum Horizontal Stress
S_{hmin}	Minimum Horizontal Stress
STF	Shear-thickening Fluid
TD	Total Depth
TVD	True Vertical Depth
XLOT	Extended Leak-off Test
℃	Degree Celsius
ºF	Degree Fahrenheit
δ_Θ	Effective Tangential Stress

ABSTRACT

Due to the general increase in the usage of petroleum resources, drilling of oil wells are frequently done in very challenging and hostile settings. Loss of circulation has been one of the main challenge facing engineers during drilling operations. Hence there have been extensive researches done over the years in order to minimize the impact of loss circulation, however, this have led to a myriad of viewpoints as to what product and method is suitable to battle it. However, a lot of the products and guidelines available for battling lost circulation are often biased towards self-promotion for a particular service company. The purpose of this study is to develop practical guidelines that are universal and not biased towards any particular service company product and which will also serve as a reference guide for lost circulation prevention and control at the well-site for drilling personnel.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Loss of circulation can be defined as the loss of the whole or part of drilling fluid at any depth to the formation (Ferron et al. 2011), this is usually noticed as an absence or noticeable reduction of drilling fluid flow up the annulus when it is pumped down the drill string. The drilling operation may continue when the loss rate is small and partial mud returns can be maintained. However, the operation stops when losses are too large or no mud returns are experienced (Wang, 2007). Fluid loss is one of the major reasons for non-productive time (NPT) during drilling operations which causes billions incurred in losses annually to remedy negative effects caused by lost circulation such as;

1. Stuck pipe.
2. Blow-outs that can lead to loss of life.
3. Dry drilling which occurs when fluid is completely lost from the well bore without actual drilling coming to a stop. It can lead to the destruction of the drill bit, snap the drill string, damage the rig or even destroy the well bore itself.
4. Well abandonment to drill a new well.
5. Plugging of potential productive formations. (Howard and Scott, 1951)

Loss circulation will happen when the hydrostatic pressure caused by the drilling fluid in the wellbore exceeds the pore pressure of the formation and also, when there is the presence of a sub-surface pathway that transport the fluid into the formation (Osisanya, 2011), lost circulation formations can be identified to some extent, based on how fast the drilling mud is being lost and

how drilling is affected once the formation starts losing mud. There are four basic types of formations that lead to losses and these are classified as;

1. Natural fractures (unsealing faults).
2. Induced fractures (formations prone to faulting e.g shale).
3. Cavernous formations (limestone, dolomite formations).
4. Permeable unconsolidated formations (sand and gravel beds, reef deposits).

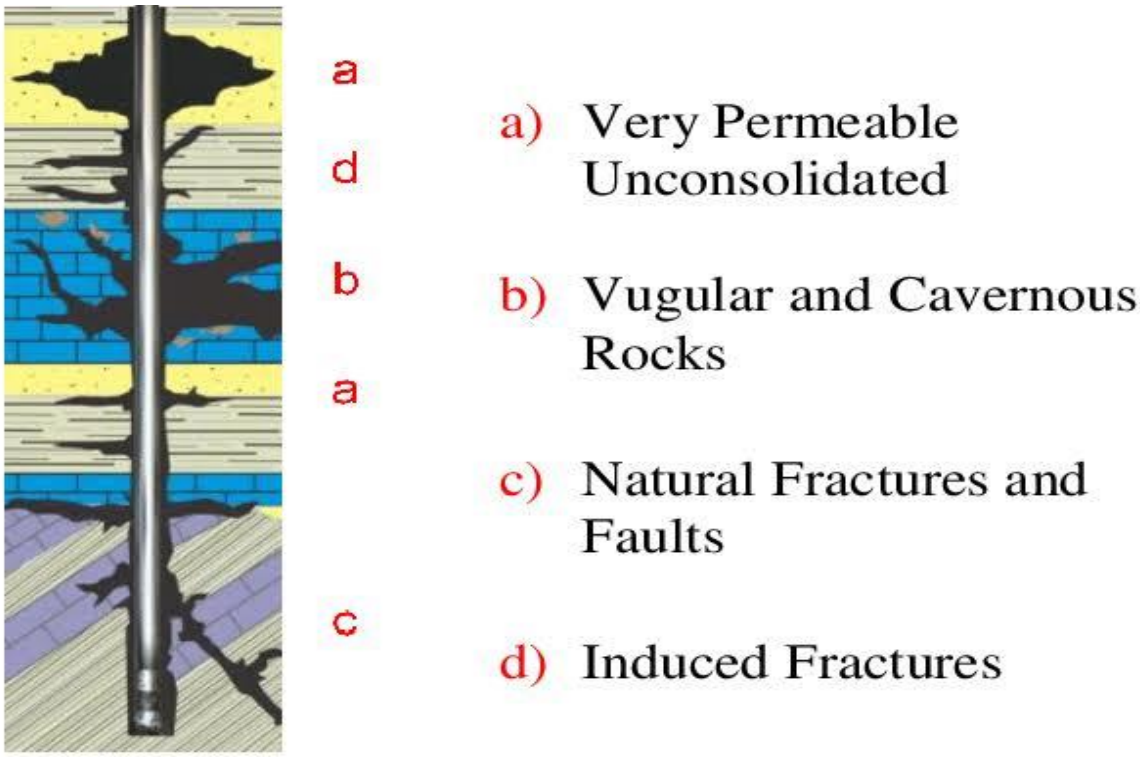

Figure 1.1: Formations where loss events occur.

Generally circulation loss can be categorized based on the loss rate (bbl/hr) and it is the criteria for presenting the treatment methods for negating them, these categories are as follows;

1. Seepage (1-10 bbls/hr).
2. Partial (10-500 bbls/hr).
3. Severe (greater than 500 bbls/hr).

The history of the first application of loss circulation control is not very clear. Early loss circulation materials were often chosen because they were available in close proximity to the drilling sites and were inexpensive such as sawdust, ground shells, shredded leather and straw (Messenger 1971). LCMs were often made of leftover materials or waste from manufacturing processes. One of the earliest efforts to prevent loss circulation from occurring was by adding granular materials to the drilling fluid, was introduced by M T. Chapman in 1890(White, 1956). Since then, loss circulation materials have been widely used to reduce fluid losses into the formation. LCM's are added continuously to the drilling fluid system or spotted as a concentrated LCM's pill in order to seal naturally existing fractures or induced fractures that are produced while drilling.

1.2 STATEMENT OF THE PROBLEM

Loss circulation problems is a major contributing factor to a rigs non-productive time, due to its seriousness numerous solutions have been suggested to combat it. Thus when loss circulation problems are encountered the rig personnel use their own derived remedies which can cause more problems or solve the circulation loss temporary. This may also be due to the fact that fluid loss materials that are available are not used properly and the APIs standard procedure for laboratory testing drilling fluids was not followed.

1.3 AIM AND OBJECTIVES OF THE STUDY

The objectives of this study are as follows:

1. To review lost circulation control methods that have been applied in the drilling industry till date.

2. To provide the successes and the failures of the methods presented above in field applications.
3. To develop practical guidelines that will serve as a reference material for lost circulation control.

1.4 SIGNIFICANCE OF THE STUDY

Knowledge of the proper methods for minimizing the impact of fluid loss circulation while drilling to reduce equipment downtime and money spent on remedial operations, especially since drilling of wells is usually carried out in hostile and challenging environments. By developing these practical guidelines that isn't towards any service company, instead it will serve as a guide for loss circulation control for any drilling personnel.

1.5 SCOPE OF THE STUDY

This project will focus on the various researches done to study loss circulation events and their field applications. This includes the classifications of loss circulation and LCMs and the applications of various LCMs based on the circumstances on hand.

CHAPTER 2

LITERATURE REVIEW

To properly carry out loss circulation control a proper engineering approach is necessary to understand its mechanics (Whitfill, 2008) as it involves more than just selecting the right LCM material. Some of the approaches involved includes borehole stability analysis, modeling of equivalent circulating density (ECD), drilling fluid and LCM selections to help minimize te effects of ECD, timely application of LCM and treatments, connection flow monitoring techniques and leak-off flow path geometry considerations. This chapter discusses some of the major studies performed to better control loss circulation and also the science involved in loss circulation control.

2.1 LOSS CIRCULATION STUDIES REVIEW

Since the subject of loss circulation is very huge in its scope numerous studies have been done to counter it's effect. Some of them include Moore, (1986) noted that in shallow, unconsolidated formations where the drilling fluid may flow easily into the formation, the most common method used to prevent loss circulation is to thicken the mud. This can be finished in water-based muds with the aid of using addition of flocculating agents which includes cement or lime. He also stated that in areas with normal-pressure formations where natural fractures are common, the method used to combat lost circulation is to drill without fluid returning to the surface. The purpose is to push the generated cuttings from the bottom-hole and deposit them at the lost circulation zone instead of flow it out to surface through the annulus. However, these practices requires large volumes of water and skillful supervision as there is possibility of encountering high drill-string torque and drag which may damage the string.

Currently studies on loss circulation centered on using loss circulation materials (LCMs), specifically chemical formulations that have been validated to be very effective. These new technologies include the usage of newly developed materials and optimized combinations of conventional LCM's. Hamburger et al. (1983) of Exxon Production Research Company developed a Shear-thickening Fluid (STF) which was tested successfully in 10 different wells that experienced severe loss circulation. A STF is a multi-component system consisting of a water-swelling material (generally clay) dispersed in an oil emulsion. The emulsion includes liquid oil, an oil-soluble surfactant, and aqueous-segment droplets containing dissolved polymer. As a result of the minimal shear encountered when it is being pumped down the drill pipe, the fluid ends as a pumpable fluid which possesses low viscosity. Yet because it passes via the drill-bit nozzles, the high shear experienced by the fluid causes it to thicken irreversibly into a viscous paste of high strength.

Nayberg, (1987) conducted a series of laboratory tests to compare the performance of conventional LCMs (granules, flakes and fibers) with a new high-performance material which is made of thermoset rubber in controlling mud loss in simulated fractured formations using both oil-based and water-based muds. From field applications, he discovered that it was very effective in controlling severe mud losses in fractured formations. Vidick et al. (1988) also conducted a research into the use of internally activated silicate solution. Laboratory tests indicated that this solution possess a low viscosity initially but after some time which is dependent on its design and temperature, it's viscosity increases rapidly to form a gel. This gel is strong, and does not produce free water as a function of time. A high pressure experimental set up was used to plug cores of different permeabilities and different fluid saturation. It was found that the gel formed

by this solution could withstand differential pressures greater than 1500 psi per foot of plugged formation.

Yet other studies have been conducted on the use of specially formulated reactive materials (squeeze systems) for use as LCMs. This squeeze systems (LCMSS) were successful in their use in wells were conventional methods with materials failed (Sweatman et al. 1997). Data from field trials indicated that losses were cured in wells having temperatures ranging from below 80F to over 325F, highly vugular or channel zones, weak zones that are easily fractured by oil-based and water-based drilling muds and other extreme conditions. Bruton et al. (2001) conducted studies on Chemically Activated Cross-linked Pills (CACP). These were activated via means of cross-linking agents borehole temperature and time. When set, they produce a substance noted as rubbery, spongy, and ductile. The setting time is fully controllable by using either a retarder or an activator based upon the thief formation or bottom hole temperature. More studies and trials have shown that these pills are not bio-degradable thus, caution should be exercised when using them.

Suyan et al. (2007) researched the use of a innovative sealant system consisting of an elastomer in combination with cross-linking polymers, activator and bridging agents which provided a quick and reliable control of loss returns. Due to their low intial viscosities they can be placed in the loss zone before getting gel activated near the wellbore to set and form a stiff, rubbery gel stick with formation sediments to prevent further losses. Its composition can be altered to produce strong cross-linked polymeric gel of various densities (8.6ppg – 14ppg) and temperature range (45oC – 120oC). Due to the addition of accelerators or retarders during mixing eliminates premature setting inside the drill string while pumping by controlling the setting time. . Another innovative work was completed by Darugar et al. (2011) where they

studied the use of single-sack fibrous pills as LCMs. This product does not require activators, retarders, set time calculations or temperature activation. It was specifically designed for rapid mixing and pumping with minimal equipment. Lab tests shows that the fibrous pills readily removes fluids and form a sealing plug on both ceramic filter and slotted metal discs, it is also a viable solution for use in depleted sand formations. The product is suitable, and has also been tested with a wide range of fluids including freshwater, brine, and base oils.

The work by Metcalf et al. (2011) in which they investigated the successful application of a new environmentally-friendly natural polymer to control lost returns during drilling and primary cementing operations in the Permian Basin of West Texas is also worth noting. This polymer consists of 30 pounds per barrel of conventional LCMs, a natural polymer, and silicate particles. They presented instances where this material was used to cure partial to total losses in more than 100 wells during drilling and primary cementing operations after other loss return control materials/methods have failed.

Nanoparticles had been lately delivered for use in drilling fluids. Due to the small pore throat length in shale formations which makes it tougher to shape an impermeable filter cake, nanoparticles were discovered to be successful in forming a tough, dense filter cake and sealing micro cracks in shale resulting in a significant impact on wellbore stability (Riley, 2012). Forming such a filter cake will reduce fluid losses into the formation and as a result, the wellbore will be stabilized (Li, 2012). The overall performance of treated silica nanoparticles was also inspected on Marcellus and Mancos shales and it showed an effective plugging of the shale pores. The reduction in shale permeability is another way of reducing the fluid loss into the shales formations which cannot be achieved by conventional filter cake buildup. Ballard and Massam (2009) investigated the use of barium sulfate nanoparticles as a weighting agent. Zinc

nanoparticles application for lubricity improvement has been reported by Griffo and Keshavan (2007) when used as a drilling bit lubricator in the presence of other additives including silica gel.

In summary, successful control or treatment of lost circulation while drilling depends onseveral factors such as borehole temperature, pressure, depth, and size of the thief zone.

2.2 LOSS CIRCULATION MATERIALS CLASSIFICATION

LCMs are mud additives designed to ensure the fluid circulated down the hole when drilling returns to the surface for recirculation rather than disappearing into the drilled formation (Robert, 1956). An LCM should react, block fractures, and form a bridge to provide a seal in a timely manner. The seal could be temporary or even permanent. Temporary seals are used to block loss zones in pay intervals while permanent seals are used to block thief zones in non-producing intervals (Fidan et al. 2004). The various groups LCM are classifie into are as follows;

1. Conventional Loss Circulation Materials; (fibers, flakes and granules).
2. High Fluid Loss Squeezes; (diatomaceous earth or clay blends).
3. Gunk Slurries, (diesel oil bentonite).
4. Precipitated Chemical Slurries (silicate and latex).
5. Resin-coated sand.
6. Cross-linked Polymer Slurries.
7. Cements.
8. Barite Plugs.
9. Dilatant Slurries.

2.2.1 Conventional LCMs

These LCMs can be either granular, flakey, fibers or a mixture of the three. The granular LCMs prevents loss by formation of bridges on the formation face and within the formation matrix. This form of sealing is preferred because it forms a permanent bridge within the formation such that pipe movements in the wellbore cannot dislodge the particles. The effectiveness of granular LCMs depends on their particle size distribution, with larger particles first forming a bridge across or within the void and smaller particles bridging the openings between larger ones examples are graphite, coarse bentonite, calcium carbonate. Fibers are LCM that are long, slender and flexible and comes in different lengths are best suited for controlling losses in highly permeable formations because they form a mat-like bridge over the pore openings. The mat reduces the size of the openings into the formation, permitting the colloidal particles in the mud to rapidly deposit a filter cake examples are sawdust, mineral fibers, cellulouse, shredded paper. Flakey LCMs possesses a thin flat shape with large surface area, they are also designed to form a mat on the formation face, which also provides good results as muchas fibrous materials when used to treat losses in highly permeable formations. Blends of granular, flakes, and fibrous materials are used in solving actual field problems (Pilehvari and Nyshadham, 2002). Examples are mica, cellophane and cottonseed hulls.

2.2.2 High Fluid loss Squeeze

These LCMs lose water quickly by de-fluidization and deposit a thick cake of residual solid plug into the loss zone. A number of HFHS treatments are available and they are usually one sack products This method is particularly useful for halting the extension of natural or induced fractures, as the deposited solids prevent the transmission of pressure to the tip of the fractures. Optimum HFHS treatment are easy to pump through BHA and should work for different loss

events and possess high shear resistance. The two main high fluid loss pills are: 1) DiaSeal M (diatomaceous earth) and 2) Attapulgite/Calcium Carbonate (Onyekwere, 2002).

2.2.3 Gunk slurries

The gunk slurries is a combination of two or more fluids which upon making contact with the wellbore or the loss circulation formation form a very viscous plug which isolates the zone. For partial losses, improved results are achievable by using Mud-Diesel-Oil-Bentonite (M-DOB) plugs. When this mixture comes in contact with water or water-based mud, a mass with high gel strength is formed. The mixture is pumped down the drill string while the mud is pumped down throuh the annulus. M-DOB plugs have several disadvantages such as; (Pilehvari and Nyshadham, 2002):

- They are not permanent solutions (break down with time).
- They are difficult to apply in long open hole intervals.
- In case of severe losses, it becomes difficult to achieve reliable pump rate down the annulus; therefore the degree of mixing cannot be controlled.
- It does not readily develop compressive strength.

There are, however, other gunk slurries that can be used with oil-based muds. For example, Reverse-Diesel-Oil-Bentonite (R-DOB) is used for oil-based muds.

2.2.4 Precipitated Chemical Slurries

Silicate solutions and latex additives used for cementing operations can be made to precipitate and used to plug up loss zones when pumped in with a combination of calcium chloride. The ideal method is to pump a calcium chloride pill followed by the silicate or latex slurry. The

mixing of these two slurries these two slurries adjacent to the loss zone form a viscous plug which can slow and seal many loss zones (Onyekwere, 2002).

2.2.5 Chemically Activated Cross-linked Pills (CACP)

Cross-linking is the joining of two independent polymer chains by a crosslinking agent that spans or links the two chains. (Bruton et al. 2001). The merits of these pills are that they can be used to stop losses in all kinds of drilling muds. However, their main disadvantage is that they are not biologically or chemically degradable within the wellbore, thus, they must be used with cautiousness near pay zones.

2.2.6 Cement Slurries

Exceptional cement preparations like magnesium-based cements and thixotropic cements are more common (Onyekwere, 2002). Portland cements are used as LCMs only when other methods have proven ineffective, or if practice has shown it to be the way of choice (Suyan et al. 2007). Portland cement possesses particle size distributions in the 30 to 100 micron range; which should not penetrate the permeability matrix near producing zones. Rock stress can create formation fractures which then accumulate whole fluid during the cement placement process and lead to formation damage. However, using cement recipes that combine an acid-soluble additive have proven to be reliable option to reduce formation damage near productive zones (Fuller et al. 2010).

2.2.7 Dilatant Slurries

These LCMs are consists of solids and polymers that are both water soluble and insoluble and are specifically sized (Onyekwere, 2002). An example is the Shear-thickening Fluid (STF) developed by Exxon Production Research Company in 1983 (Hamburger et al. 1983). The

capability of these variety of fluids to thicken permanently when they pass through the high-shear zones in the drill bit make them fit for halting losses in any loss zone. In summary, the theories and observations raised from years of experience combating loss circulation can be summarized as follows; (Bruton et al. 2001):

1. A loss circulation material should be equally effective in sealing any unconsolidated formations, fractures (natural or induced) and vugs in hard formations.
2. It should form an effective seal under both low and high differential pressure conditions.
3. The spotted plug shear strength should be strong enough to hold the fluid column, but low enough to ensure easy removal by washing or jetting (low side-track risk).
4. The plugging seal has to resist both negative (swab) and positive (surge) pressures encountered during during drilling, drill pipe trips, and casing runsx
5. It should be workable and also possess an easily controllable set time and should be functional in oil, synthetic or water based mud systems.

2.3 BOREHOLE STABILITY ANALYSIS

To effectively prevent and cure losses resulting from borehole stability issues, it is important to understand the fundamental principles of this process.

2.3.1 Fractures and Fracture Identification

One of the hugest drilling problems now is loss circulation in fractured formations. Mud losses to a formation can occur through a fracture which was induced through drilling operations or a pre-existing natural fracture. If the loss circulation is being experienced in pre-existing fracture zone, the fracture may be made always open in which case losses to the formation may occur at mud pressures only in excess of the formation pressure. Induced fractures occur when the mud

weight, necessary for well control and to sustain a stable wellbore, surpasses the fracture resistance pressure of the formation (Majidi et al. 2011). Identification of the type of fracture responsible for the losses is an important step in combating the loss circulation problems. Figure 2.1 are examples of natural and induced fractures.

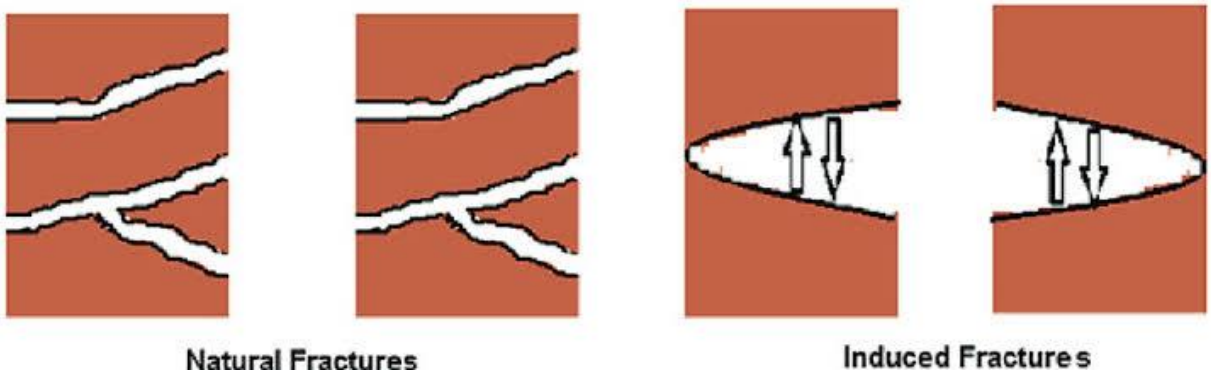

Figure 2.1: Natural and Induced Fractures

Acoustic, electrical, and optical wellbore images offer a means of discovering and differentiating natural fractures from induced fractures. The direct measurement of fluid loss flow rates and the down-hole annular pressure while drilling (APWD) can also be used as an indication of the presence of a fracture sub-surface as well as the nature of fracture (Majidi et al 2011). High resolution flow-meters can precisely measure the rate of flow of fluid into and out of the wellbore area. The characteristic response of the rate of losses can be used to interpret the fracture characteristics. A valuable method for identifying the type of lost circulating zone is the use of the plot of variation of mud pit levels. Figure 2.2 shows a qualitative response of mud losses in terms of the mud pit level changes with time.

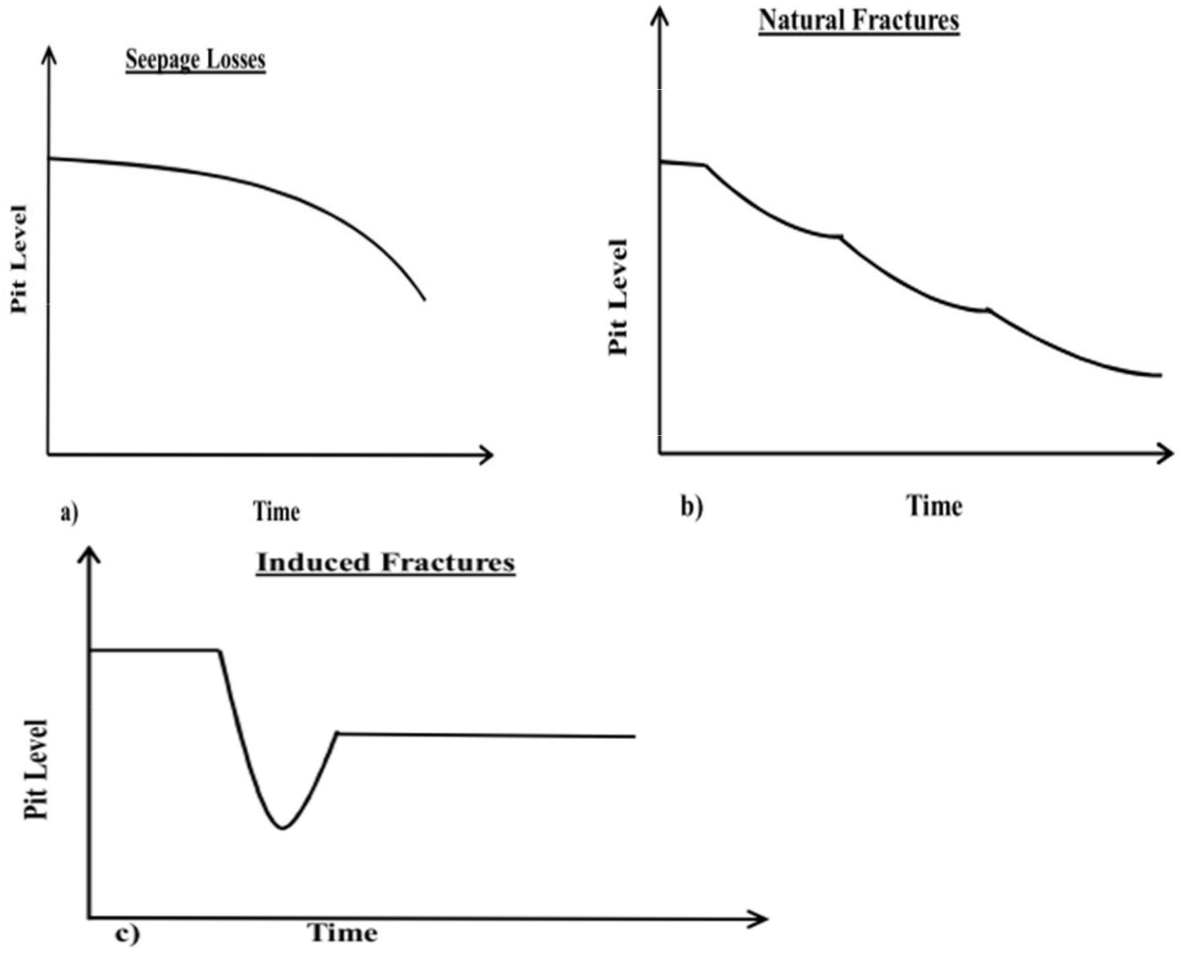

Figure 2.2: Losses from Pit Level

Seepage losses through pores are slow initially then gradually increase, whereas, losses through natural fractures are initially rapid until they decline with time. It is significant to note that fractures are not the only cause of mud losses during drilling operations and cautiousness must be exercised when estimating the causes of mud losses. The following are reasons of mud-tank level fluctuations during drilling have been provided by Dyke et al. (1995):

1. Losses through matrix permeability
2. Losses into induced and natural fractures
3. Volume change owing to temperature and pressure effects Surfaces mud losses

4. Hole collapse and enlargement
5. Change in bottom hole lithology

Table 2.1 summarizes some important identification features used to distinguish between natural and induced fractures.

Table 2.1: Identifying Features of Fractures

Natural Fractures	Induced Fractures
May occur in any type of formation.	May occur in any type of rock but would be expected in formations with characteristically weak planes such as shale.
Loss is evidenced by gradual lowering of mud in pits. If drilling is continued and more fractures are exposed, complete loss of returns may be experienced.	Loss is usually sudden and accompanied by complete loss of returns. Conditions are conducive to the forming of induced fractures when mud weight exceeds 10.5 ppg.
	Loss may follow any sudden surge in pressure.
	When lost circulation occurs and adjacent wells have not experienced lost circulation, induced fractures should be suspected.

2.3.2 Mechanics of Fracturing

Normally the weakest plane of the formation is the most susceptible to induced fractures. The requirements for fracture formation are pressure and surfaces upon which the pressure is acted upon so that the resultant forces are of ample magnitude and are applied in such a manner to part the formations (Howard and Scott, 1951). The fractures created will either be vertical or horizontal depending on the depth sub-surface. At a depth of around 2,500 feet or less, horizontal pancake fractures are generally formed because the vertical stress (overburden) is lower than the horizontal stresses. At greater depths (above 3,500 feet), vertical fractures are formed because

the overburden is higher than the horizontal stresses (Ramirez et al. 2005). Figure 2.3 shows a typical stress distribution in a wellbore.

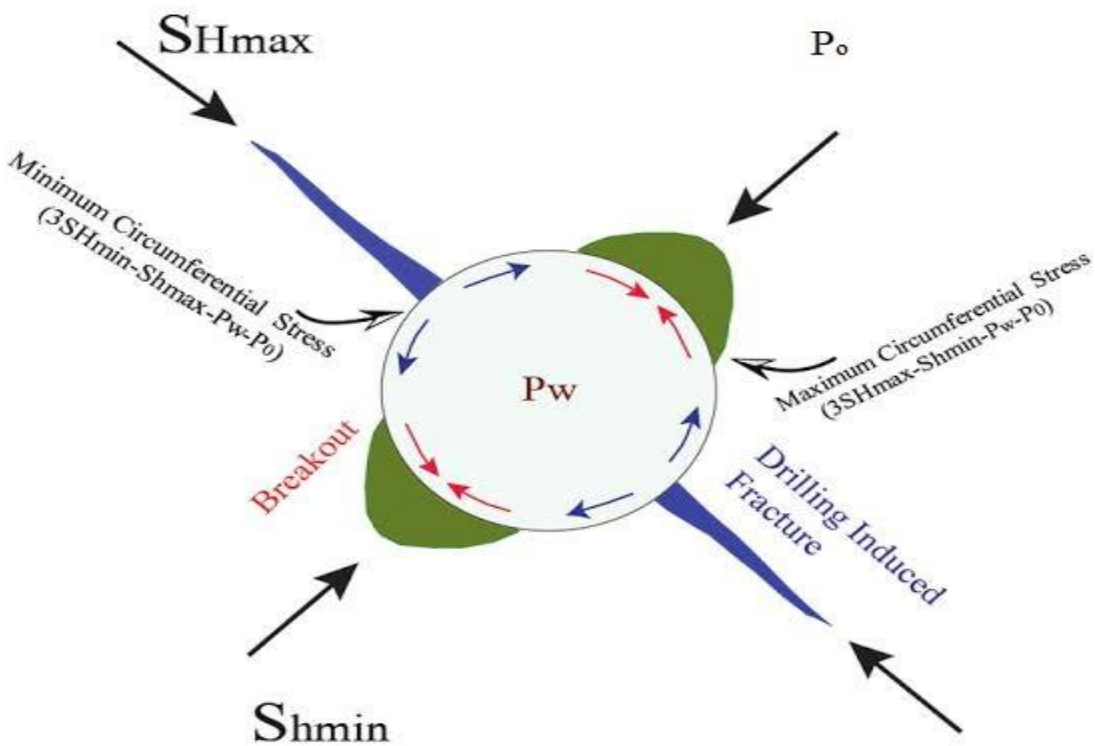

Figure 2.3; Stress Distribution in a wellbore

Where,

P_W = Wellbore Pressure;

P_O = Pore Pressure;

S_{hmin} = Minimum Horizontal Stress;

SH_{MAX} = Maximum Horizontal Stress

The minimum horizontal stresses are inherent in a particular rock and cannot be altered while the effective tangential stresses are the near wellbore stresses acting on the periphery of the wellbore which are caused by drilling operations.

2.4 MANAGEMENT OF EQUIVALENT CIRCULATION DENSITY (ECD)

In order to eliminate high ECDs drilling operations are designed to properly manage down-hole pressures that can lead to induced fractures. The control can be accomplished through manipulation of mud properties such as density, viscosity, and fluid loss. The ECD defined is the measure of the combined effect of the hydrostatic pressure of the fluid in the wellbore plus the created friction pressure while the fluid is being circulated (Metcalf et al. 2011):

$$ECD = \frac{\mathbf{P}total}{(0.052 \times TVD)} \quad \text{----------} \quad (2.1)$$

Where, PTotal $= P_{hydrostatic} + P_{friction}$

P_{total} =Total Annular Pressure

$P_{Hydrostatic}$ =Hydrostatic Pressure

$P_{friction}$ =Annular Frictional Pressure

TVD =True Vertical Depth.

To determine the value of equivalent Circulating density (ECD)the following are to be considered (Fidan et al. 2004):

1. Annular space: smaller annular area leads to higher ECD.
2. Fluid rheology: greater viscosities will rise the ECD.
3. Pump rate: the higher the rate, the higher the ECD.

Apart from the manipulation of mud properties and controlling the generation of excessive ECDs, knowledge of the fracture gradient in an area is an essential step towards fighting loss circulation during drilling operations.

The fracture gradient is gotten through a leak-off test (LOT). The LOT provides a safe method to determine the extent of pressure (equivalent mud weight) that a wellbore will tolerate without fracturing and losing fluid (Carlton and Chenevert, 1974). In this test, the borehole immediately behind the casing shoe is pressurized until fluid begins to leak into the formation which means that an induced fracture has been created. The leak-off pressure (LOP) is the first deviation from a linear pressure-volume curve as shown in Figure 2.4

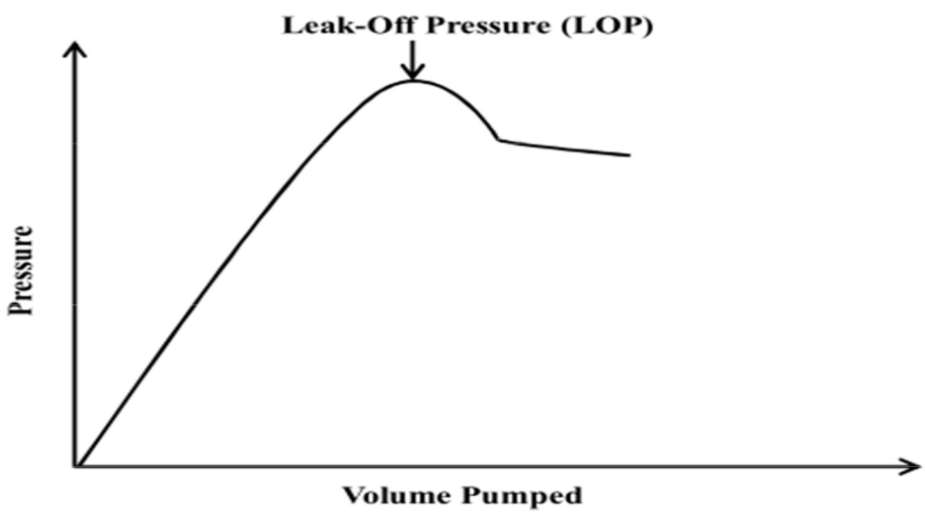

Figure 2.4 Leak-Off Test

If the value local fracture gradient is satisfactorily known at a certain casing shoe depth, a simpler formation integrity test (FIT) is often performed instead. FIT is performed by pressurizing the formation to a fixed pressure without fracturing the formation; this is used to test the integrity of the cement. Combinations of diverse LOTs are used to produce trends to be used

in the forecast of fracture gradients in other neighboring wells. However, there are limitations involved with using LOTs to generate a fracture gradient curve (Okland et al. 2002):

1. Difficulty in the interpretation of individual tests when no clear or unique deflection/deviation point exists.
2. The manual recording of data at a very low sampling rate may prevent complete data scrutiny, thus, bias towards higher interpretations may even be presented by the drilling team's eagerness to drill ahead.
3. Not all wells in the same region possess the same range of leak-Off Pressures (LOPs) since the LOPs from neighboring wells are often scattered, local trends will be subjected to significant subjective interpretations.

An extended leak-off test (XLOT) which bears remarkable parallels with the early stages of a lost circulation event can be used to overcome the restrictions associated with LOT (Okland et al. 2002). XLOT was designed mainly to measure the degree of the minimum in-situ stress (i.e. the fracture closure pressure, FCT). However, it can be used to capture other fracture events that will serve as a valuable tool in planning drilling programs to combat loss circulation. Some of the extra events captured by XLOT are:

1. FIP: Fracture Initiation Pressure
2. FRP: Fracture Re-opening Pressure
3. FCP: Fracture Closure Pressure
4. ISIP: Initial Shut-in Pressure
5. FPP: Fracture Propagation Pressure

The choice to perform an XLOT at the casing shoe should take into account both the cost of breaking the near-well barrier and the advantage of knowing what stress and FPP lies behind that barrier. The near-well barrier is the volume of rock whose state of stress is affected by the presence of the borehole, usually 1-2 hole diameters into the formation. Figure 2.5 shows an example of an XLOT showing the different events.

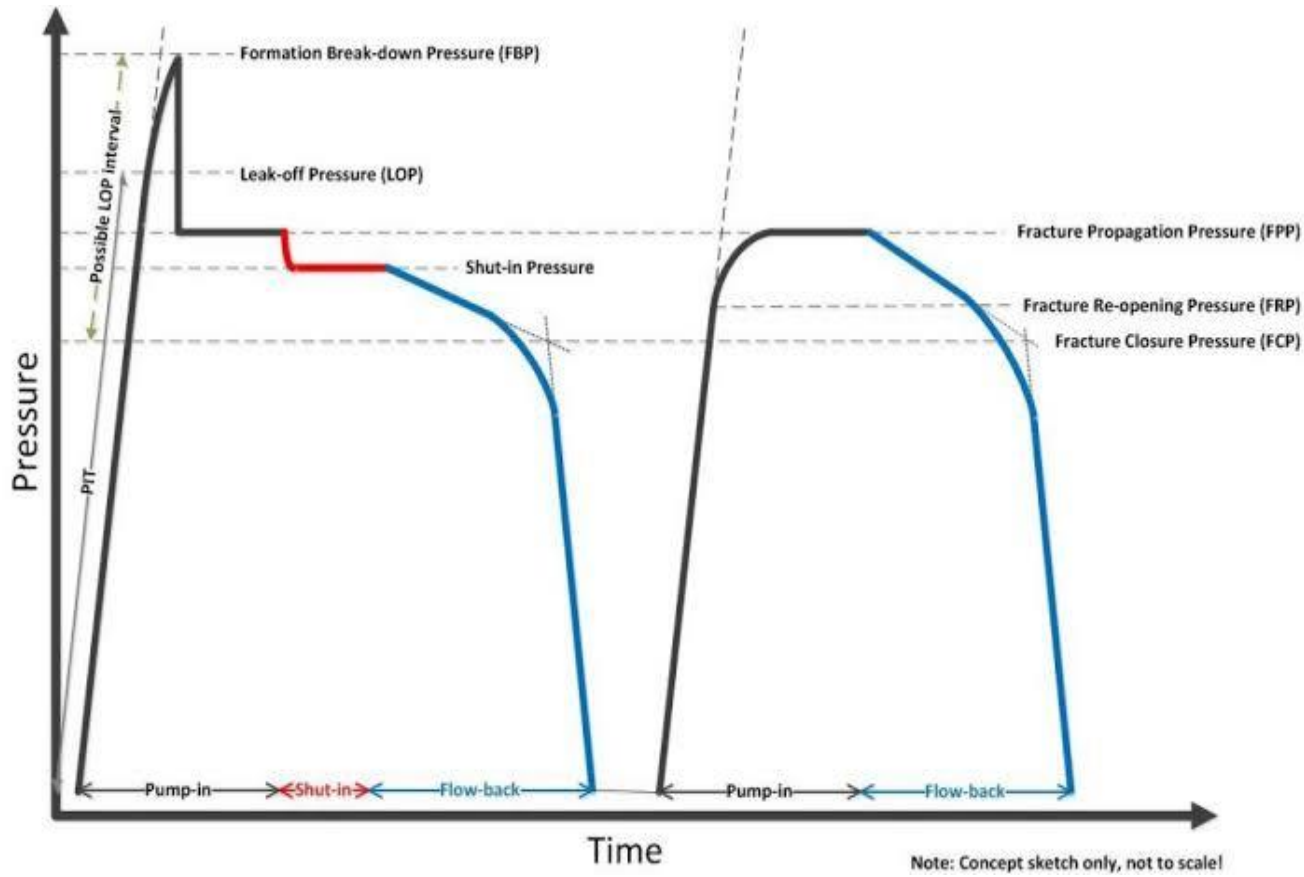

Figure 2.5; Extended Leak-off Test.

CHAPTER 3

METHODOLOGY

The various methods for dealing with loss circulation problems can either be used before the manifestation of the problem (Wang et al. 2009). The solutions are grouped into preventive and remedial approaches. This chapter highlights in detail the prevention and remedial processes for lost circulation control used in the petroleum industry today.

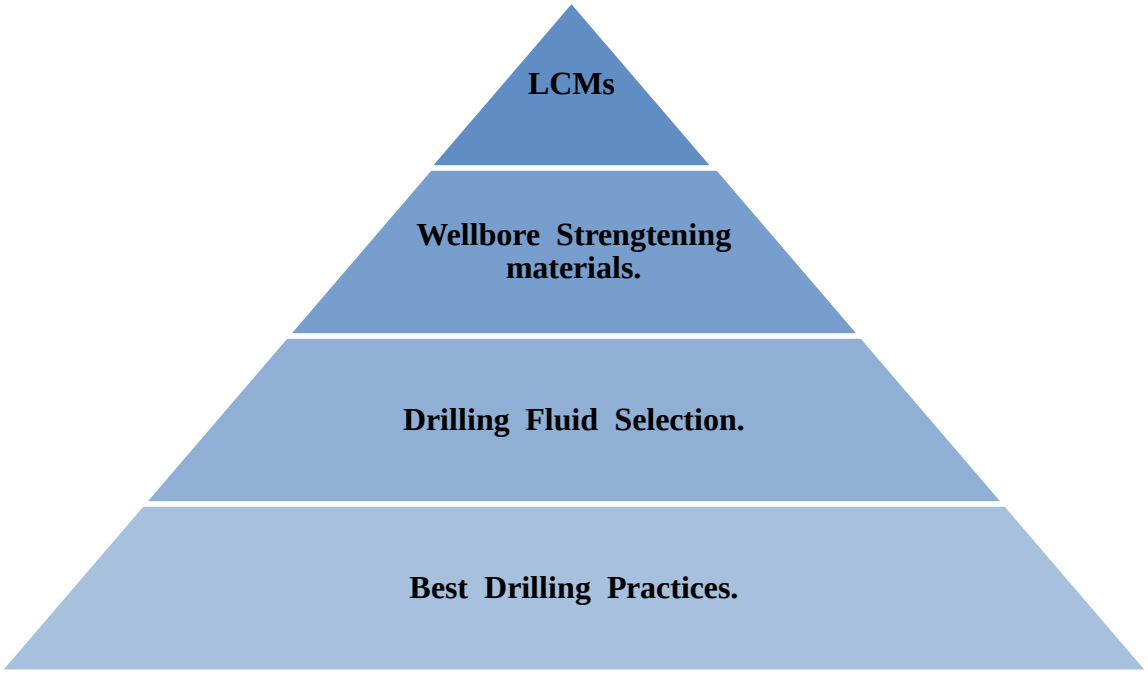

Fig 3.1; A Complete Loss Circulation Management Program.

In the figure above shows four loss circulation counter strategies. The bottom three strategies are prevention strategies which includes; Best drilling practices, drilling fluid selection and well bore strengthening materials. The last part is the remedial process of using loss circulation materials to counter fluid loss.

3.1 USING LOSS CIRCULATION MATERIALS

There is a vast range of LCM readily available for usage now for inhibiting lost circulation effects while drilling or cementing a well (Nayberg and Petty, 1986). The decision for the type of LCM to use in any given occurrence is dependent on the acquisition cost and general availability in a given area (Pilehvari and Nyshadham, 2002). They are designed to achieve two important objectives (Jiao and Sharma, 1996); To form a bridge blocking and filling in the spaces within fractures that are already existing down-hole and to also prevent the continued growth of any fractures that was be made while drilling.

Lost circulation materials can be broadly classified into the following groups;

1. Granular: these LCMs materials blocks the pores within the faulted formation matrix to ctop the continual losses into the formation, the particle size distribution of the constituent materials determines the effectiveness of the sealing.
2. Fibrous: these LCM group forms mat-like structures within the matrices to trap smaller particles and seal the formation. It is used in both OBM and WBM.
3. Flakes: flaky types of LCMs are used to plug and bridge many types of porous formations to stop the mud loss or to establish an effective seal over many permeable formations.
4. Mixtures: these are combinations of granular, flaky and fibrous materials that will penetrate fractures, vugs, or extremely permeable formations and seal them off effectively.
5. Encapsulated fluid-absorbing particles: these are materials that are highly absorbent and form spongy mass in contact with water.

Detailed classification of LCMs has been covered in chapter 2 of this thesis. From a review of various literatures on lost circulation, it can be inferred that a combination of LCMs rather than one is effective in combating losses. Table 3.1 provides some commonly used LCMs.

Table 3.1: Loss Circulation Materials.

TYPE	MATERIAL
FIBROUS	Raw cotton, Bagasse, Flax shive, Wood fiber, Bark fiber, Textile fiber, Mineral fiber, Leather, Glass fiber, Peat moss, Feathers, Beet pulp.
GRANULAR	Perlite, Coarse bentonite, Ground plastic, Nut shells, Nut hulls, Ground tires, Asphalt, Wood, Coke.
FLAKE	Cellophane, Cork, Mica, Corn cobs, Cotton-seed hulls, Vermiculite.
MIXTURE	Film, fiber and sawdust; Textile fiber and sawdust; Cellulose fiber and sawdust; Perlite and coarse bentonite.

3.2 WELLBORE STRENGTHENING

Conventional LCMs such as pretreatments, pills and squeezes often reach their extent of usefulness and become ineffective when drilling operations is carried out in deeper hole sections of depleted formations, structurally weak formations, or naturally fractured formations (Wang et al. 2005). To counter this problem, wellbore strengthening was introduced. Wellbore strengthening is the process of pluging the formation with LCMs (Kumar et al. 2010).The overall

effect of using wellbore strengthening is to increase the fracture gradient of the formation. This offers an avenue for the use of higher mud weight windows for drilling weaker and depleted formations. Wellbore strengthening methods, generally, rarely target strengthening the rock matrix but are mostly applied to (van Oort et al. 2009):

1. Enhance the near-wellbore stress, thus raising the threshold for fracture re-opening and growth.
2. Increase the formation's resistance to fracture propagation.

To achieve this chemical methods have been developed to enhance rock matrix strength in permeable and depleted formations. Other methods of wellbore strengthening exist; one of which is the stress cage approach (van Oort et al. 2009). This method aims at creating an additional hoop stress (a "stress cage") in the near-wellbore region, adding to the already existing hoop stress riser when a wellbore is created. Near-wellbore fractures of specific sizes are deliberated created and packed with specially sized LCMs in a frac-and-pack type of operation. Because of the presence of the packed LCMs, an additional tangential stress (hoop stress) is created in the near-wellbore zone, which raises the threshold for fracturing and fracture propagation. The stress cage approach can be applied while drilling into the weak zone to obtain the strengthening effect instantaneously (Wang et al. 2009). An important step in this approach involves using log analysis to identify fracture location and determine its geometry, especially its width, and then determine a mixture of particulates materials that will seal the calculated fracture width (Song and Rojas, 2006).

The key characteristics of the particulate materials that will affect their performance in the wellbore strengthening process have been provided in order of descending importance (Freidheim et al. 2008):

1. Particle size
2. Particle size distribution Concentration
3. Shape (sheroidicity/aspect ratio)
4. Others (surface texture, compressive strength, bulk density, resiliency, etc.)

Some of the particulate materials used for wellbore strengthening include sized resilient graphitic carbon and ground marble (CaCO3). Figures 3.1 and 3.2 are show images of these particulate materials.

3.3 USING DRILLING TECHNIQUES/PROCEDURES

The drilling techniques/procedures described in the following paragraphs may be used to prevent or treat lost circulation problems.

3.3.1 Aerated Mud Drilling

Aerated mud is defined as a fluid (in the form of mists and foams) consisting of liquid (usually water), air, and drill cuttings (Guo and Rajtar, 1995). Aerated muds are low density fluids that can be used to maintain a minimum overbalance while drilling probable loss zones such as depleted formations that are competent and low-pressured. Aerated mud drilling is recognized as having many advantages over conventional mud drilling; such as higher penetration rate, less formation damage, minimized lost circulation, and lower drilling cost. Foams are highly structured fluids of air bubbles contained in a continuous network of liquid films. The structured

nature of the fluid and the wide size distribution of the air bubbles means that foams have the ability to bridge a wide range of pore sizes, and even small fractures. However, foams have the following disadvantages (Reid and Santos, 2003):

1. Specialized equipment is required to generate them. This may be costly, and in offshore locations, deck space may limit the use of foams.
2. Foams are compressible and so lose some or all of their structure (and hence bridging properties) under downhole conditions. Downhole densities and rheology become difficult to predict and control.

To address the limitations of foams, a new class of aerated fluids, known as aphrons, has been developed. The aphron system is an at-balance technique that uses micro bubbles that are non-coalescing and can be re-circulated (Redden et al. 2011). Aphrons are engineered to occur within the drilling fluid without the need to inject air or gas. They exist as independent spheres where a multiple layer film encapsulates a gas or air core. This film is the key to maintaining the bubble strength that allows aphrons to function as bridging agents. A surfactant is used to produce the surface tension to contain the aphron as it is being formed, build the multi-layer bubble wall, and create interfacial tension that binds the aphrons into a network capable of creating downhole bridges.

3.3.2 Floating Mudcap Method

A Floating mudcap is a column of drilling fluid floating on the annulus side of the drillstring to hold back formation fluids/pressure. This method is used only as a final option when massive and total lost circulation has occurred and all attempts to regain circulation have failed. This is because the operation can be very expensive and hazardous. The floating mudcap method

involves pumping water down the drillstring to clean, cool, and lubricate the bit. Drilling fluid is added on the annulus side and it is weighted to exert hydrostatic pressure on top of the formation to keep the well under control. The drill water carries the cuttings into the loss zone where it disappears into the formation. The density of the drilling fluid in the annulus must be heavy enough to keep the well under control and must also be light enough to prevent any further losses.

The floating mudcap method is hazardous and requires rigorous safety procedures and only experienced crew to handle it. When the formation pressure equals the hydrostatic pressure of the drilling fluid, the well is in equilibrium. The drill water will exert an additional pressure against the fluid column which will force the drilling fluid back out the top of the column. This reduces the hydrostatic pressure which forces formation fluids to migrate into the annulus. This is a kick and needed to be handled (Redden et al. 2011)..

3.3.3 Drilling Blind

When loss zones are too large and difficult to be filled and sealed by lost circulation materials, the recommended approach is to drill blind until competent formations are encountered , after which casing is set (Redden et al. 2011). When drilling blind, it is important to maintain a pumping rate equal or greater than the pumping rate normally used to clean the hole. Otherwise, there is a risk of sticking the drillstring. Therefore, adequate source of water is a necessity when this technique is to be carried out efficiently (Canson, 1985).

3.4 USING ADVANCES IN DRILLING TECHNOLOGY

Developments in new drilling technology such as expandable tubulars and casing-while-drilling (CwD) can serve as long term methods that will mitigate the costly effects of lost circulation

while drilling (Davison et al. 2004). Expandable tubulars permit a number of mud weights to be used for different sections without losing hole size due to the telescoping effect of casing.

Casing-while-drilling employs downhole and surface components to provide the ability to use normal oilfield casing as the drillstring so that the well is simultaneously drilled and cased (Tessari et al. 1999). The casing is rotated from the surface with a top drive. Drilling fluid is circulated down the casing internal diameter (ID) and up the annulus between the casing the wellbore. The objective of this technology is to reduce the non-productive time (NPT) and the casing running times where partial and total fluid losses make conventional drilling practices difficult and expensive (Gallardo et al. 2010). Two types of CwD exist: retrievable and non-retrievable systems. The retrieval system uses a drillpipe or wireline to retrieve the bottom hole assembly (BHA) assembly attached to the casing or liner. The non-retrievable system is designed to leave the casing drill shoe (CDS) on bottom if the last section of the well is being drilled to total depth (TD) or is to be drilled afterwards to continue with the following hole sections. Figures 3.3 and 3.4 are pictures of part of the CwD assembly.

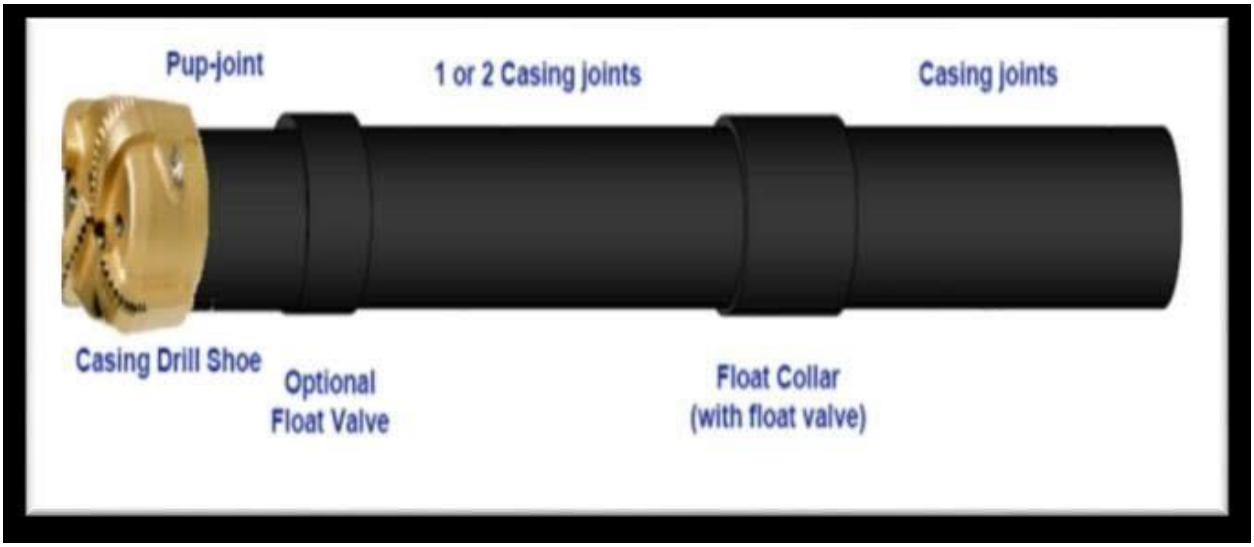

Figure 3.2; BHA Components of Cwd Assembly.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 GENERAL GUIDELINES FOR COMBATING LOSS CIRCULATION

The drilling program must include contingency plans (additional casing strings, adequate water source etc.) for known problems such as that associated with infill drilling and unknown problems such as those encountered in wildcat drilling. The following information is required about the loss zone before an effective treatment could be achieved:

1. location of the loss interval – preferably the top and bottom.
2. Estimate the pressure within the loss zone.
3. Estimate the size of the openings into the loss zone; use borehole electronic images.
4. Knowledge of The whether or not there is cross-flow into the loss zone because of the reduced pressure in the wellbore. Cross-flows into the loss zone can complicate the treatment process.

A quick economic evaluation should be made of how much investment would go into curing the lost returns problem before a decision is made to case the zone off, or side-track the loss interval or even abandon the project. It is important to reduce human error, to a tolerable minimum, as a contributing factor to lost circulation. The following drilling practices were identified as contributing to lost circulation:

1. Generation of excessive ECDs caused by high circulation rates (Prevention strategy: Use the lowest circulation rate that will clean the hole adequately).

2. Failure to break circulation frequently while tripping (Prevention strategy: Break circulation several times on the way into the hole and rotate the pipe; when on the bottom, break circulation slowly, and raise the pipe while doing so).
3. High pipe running speeds (Prevention strategy: Run pipe slowly, and above all, do not ream down rapidly with the pumps on).

Monitor downhole annular pressure and make sure that the ECD and equivalent static density (ESD) always stay within the safe mud weight window during drilling, connection, and tripping by optimizing mud weight and drilling operations. It is advisable to include properly sized LCM in the drilling mud when drilling formations that are prone to losses (depleted formations). This practice can help in preventing seepage losses and also prevent induced fractures from propagating beyond their initiation stages.

Graphitic carbon and sized calcium carbonate have proven to be effective primary LCMs if included in the drilling mud in the course of drilling through depleted and weak formations. Avoid the use of coarse LCMs that require by-passing the solids control equipment as this will result in fines build up in the mud and increase viscosity and ECD which may induce more losses.

LCMs come in many different forms; each possesses a specific advantage such as cost, availability and effect or lack of it on drilling fluid properties. However, the performance of a LCM is based primarily on its concentration, particle size distribution (PSD), and shape. Size LCMs to restrictions in Bottom Hole Assembly (BHA); consult the manufacturer or Directional Drilling Services Company if necessary.

When circulations are lost temporally due to pressure surges induced while running casing or because bottom hole pressures are exceeded while breaking circulation after a trip, it is recommended to reduce the solids content or reduce the yield point (YP) value of the drilling mud rather than using LCMs.

Overall well economics can influence whether to pre-treat the system with LCM or deal with the problem when/if the problem occurs. Get ready for well control situations when handling losses.

4.1.1 Locating the Loss Zone

Drilling through a low pressure, naturally fractured formation is normally signalled by a sudden severe loss of returns which is accompanied by a notable increase in drilling torque and relative drilling roughness. This signature is a reliable indication that the loss zone is at the bottom when no previous incident of lost circulation had occurred (Canson, 1985). When drilling through vugs, channels, and caverns, apart from the drilling conditions experienced in low pressure naturally fractured formations, the drill-string can advance to a particular depth unrestricted without taking any weight.

Since rock strength generally increases with depth, the location of an induced fracture is closer to the previous casing shoe than total depth (Ramirez et al. 2005). To accurately locate the loss zone, a temperature survey is employed. Circulation of drilling fluids will alter the static geothermal gradient in a borehole because of the injection of cooler mud (Sweatman et al. 1997). A base temperature log is run to establish the normal temperature gradient in the well under static conditions. Then a volume of mud (equal to 1000 – 1500 feet of open hole) is pumped into the hole from the surface and a second temperature log is run. The two logs are compared to determine the location of the loss zone. A cooler gradient is observed on the second log from the

surface to the point of mud exit into the loss zone. However, below the loss zone, higher temperature gradient should be observed on both logs. Figure 4.1 shows a temperature survey used to locate a loss zone.

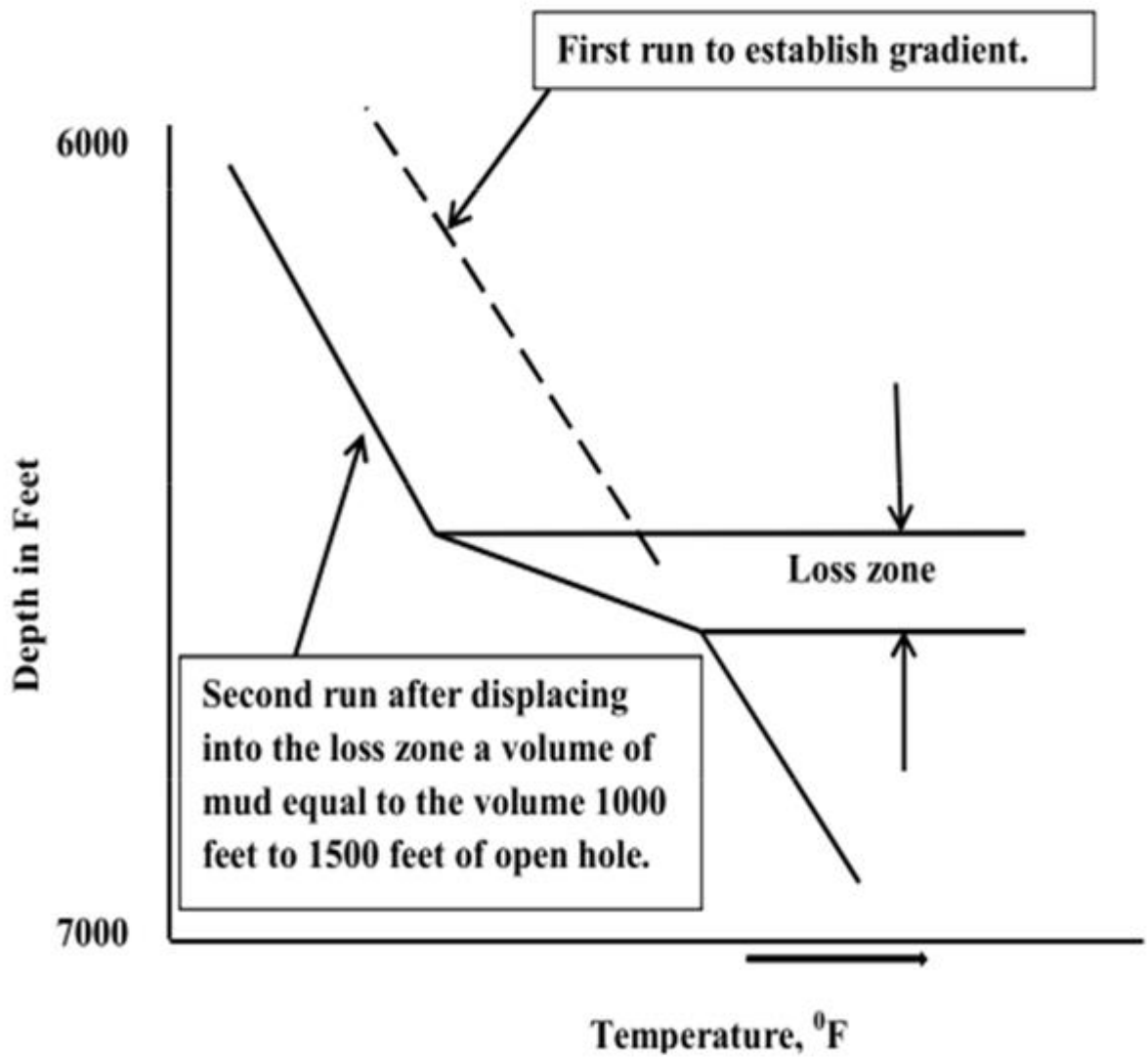

Figure 4.1; Temperature Survey

Radioactive logs, noise logs, and mechanical devices (flowmeters) can also be used to locate the loss zone (Canson, 1985). The above methods are useful when the loss zone is off the bottom of

the well. When the loss zone is at the bottom of the well, it is advisable to drill through the loss interval until the top and bottom of the loss interval can be established.

4.1.2 Estimating Pressure in the Loss Zone

This information is especially useful when total loss of returns is experienced. Without this information, the control of the flow of treatment material into the loss zone is left to trial and error work, and as such the treatment might not be successful (Canson, 1985). To estimate this pressure, knowledge of the static fluid level in the wellbore is a requirement. A number of methods are available to estimate static fluid level in the well; echometer determinations as well as counting pump strokes to fill the annulus are two of the methods used (Gray and Darley, 1980). Another method used is described below (Ferron et al. 2011):

A one inch diameter ball is formed with soft clay. A stopwatch is started when the ball is released over the wellbore and stopped when the ball hits the static fluid level in the wellbore. It is advisable that the ball does not hit the sides of the wellbore when it is released otherwise it will take a longer time to hit the fluid level. From figure 4.2, tracing the time along the vertical until it hits the curve, the distance to the top of the fluid level in the wellbore can be estimated. From this estimated distance and knowing the depth of the loss zone, the pressure in the loss zone can be estimated using a simple formula:

$$P_{loss\ zone} = D_{static\ fluid\ column} \times MW \times 0\text{-}052 \quad \text{----------(4.1)}$$

Where,

$P_{loss\ zone}$ is the pressure in the loss zone (psi).

$D_{elastic\ fluid\ column}$ is the static fluid column above the loss zone (feet).

MW is the mud weight (lb/gal).

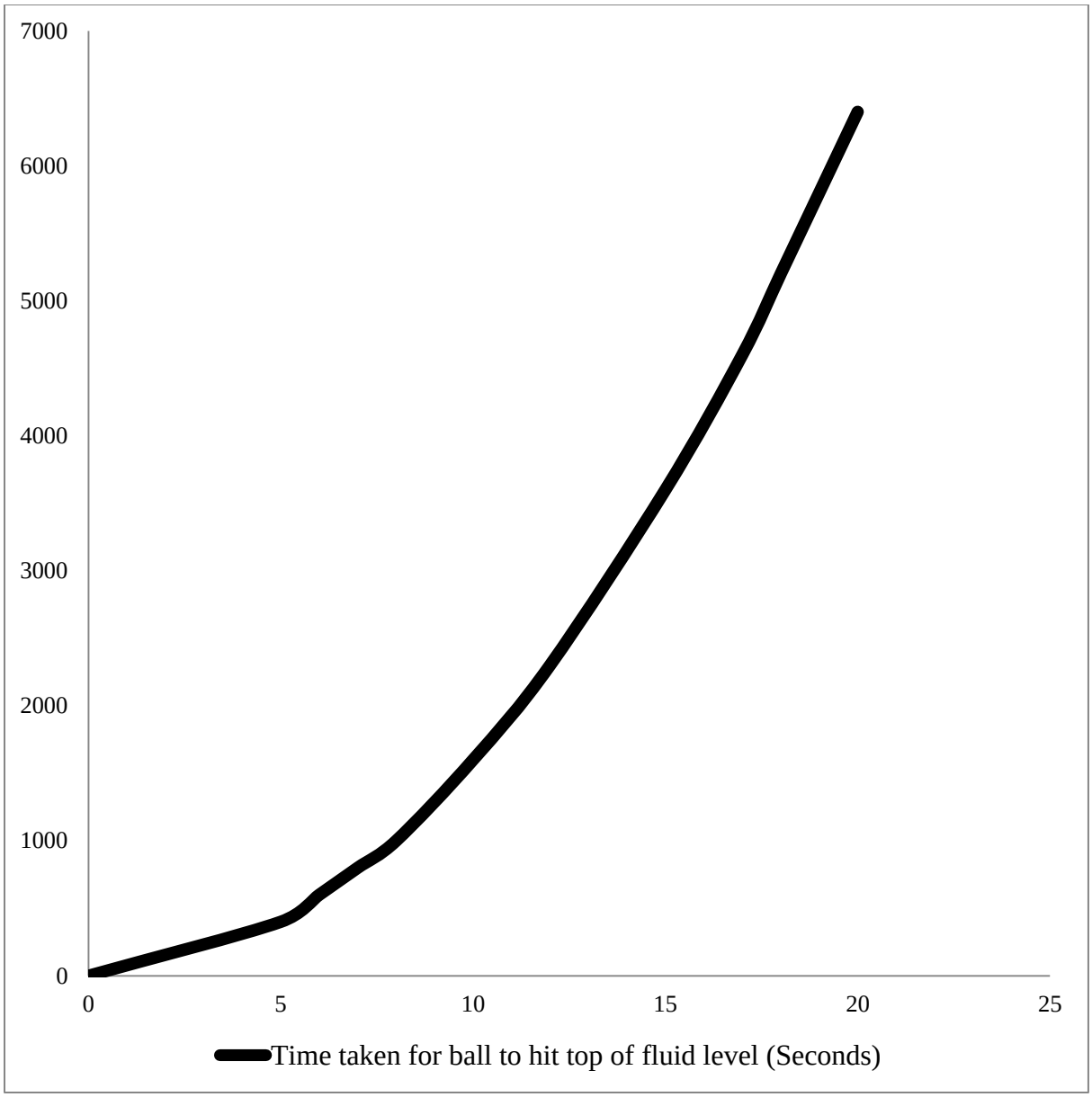

Figure 4.2: Approximate Distance to Top of Fluid Level in Wellbore.

4.1.3 How to Detect Cross-flows in the Loss Zone

One of the methods used to detect cross-flows is oxygen activation (Sweatman et al. 2004). Oxygen activation logging tools such as pulse-neutron capture (PNC) or pulse-neutron

spectroscopy (PNS) can detect down-hole water flows. When oxygen is irradiated with neutrons with energies greater than 10 MeV, the following reaction occurs:

$$16\,O + n = 16\,N^* + p \quad (4.2)$$

The nitrogen is left in an excited state which beta-decays back to the oxygen with a 7.35-second half-life. The oxygen immediately emits a gamma ray which the logging tool uses to detect oxygen activation. For water to be detected, its fluid velocity must be greater than the speed of the logging tool.

4.2 SEEPAGE LOSS

A lost circulation incident can be classified as seepage loss when the rate of loss is in the range of 1-10 bbl/hr. They occur in any type of formation. Seepage loss can be caused by a number of factors resulting from the drilling operations or it may be a perceived loss. For example, drilling through competent formations with fast drilling rates can result in perceived losses when they did not actually exist. Some of the causes of perceived seepage losses are (Ferron et al. 2011):

1. Normal displacement of drilling mud with drilled solids; a certain amount of drilling fluid is required to fill the new hole being drilled.
2. Drilling fluid retained on drill solids that have been removed from the system; the allowable upper limit is 1 bbl of fluid per 1 bbl of drilled cuttings removed.

Therefore, it is important to analyze the seepage loss based on the above factors before any treatment is commenced. Monitoring the mud level in the mud pit with floating sensors or acoustic reflectors and measuring the cumulative volume of mud lost over a period of time

provides a way of differentiating actual losses from perceived losses (Beda and Carugo, 2001). The subsequent paragraphs provide some seepage loss control techniques and guidelines.

4.2.1 Ignore the Problem and Drill Ahead.

This technique can be applied depending on the severity of the seepage loss. The technique is in two folds:

1. Depending on what stage the drilling operation is and the severity of the seepage loss, the loss may be ignored entirely. That is, when the drilling operation is good and close to a casing setting depth with an in-expensive drilling mud, simple economic analysis may dictate that the loss may be ignored entirely.
2. Ignore the problem and drill ahead with the intention that the accumulated solids would seal the loss zone and stop the seepage loss. This technique must be applied with caution as it can lead to other hole problems. For example, the accumulated fine-solids may alter the rheology of the drilling mud and render it ineffective.

4.2.2 Pull up and Wait

This technique can be used to solve seepage losses resulting from induced vertical fractures. While circulating, if the increased pressure due to circulation (ECD) is higher than the fracture initiation pressure of the formation, induced fractures may be created (Tare et al. 2001). These induced fractures open and accept fluid but when circulation is stopped many of these fractures may close and heal and the fluid is released back into the wellbore provided that the increased ECD has not exceeded the fracture propagation pressure of the fractures. The healing process can take about two hours. To reduce non-productive time (NPT), this period is normally used for rig maintenance.

4.2.3 Pretreat the Active Mud System with LCM

This technique is applied either as a preventive method (i.e. before drilling through zones that are prone to lost circulation) or as the problem arises (remedial). When pretreating the drilling fluid system with LCM, special considerations must be made to optimize the solids control equipment (Ferron et al. 2011). This is important to maintain the LCM in the fluid system. Research shows that combinations of LCMs rather than a single type give the best results in combating losses (Savari et al. 2011). Graphitic carbon and sized calcium carbonate (CaCO3) have proven to be effective primary materials when carried as a pretreatment in the drilling fluid (Whitfill and Wang, 2005). The particle size distribution (PSD) of these LCMs used depends on the permeability/pore size/ fracture width of the loss zones. Models that are available to select the optimum PSD in order to effectively form a bridge that will plug fractures and stop losses are presented

1. : Abrams' median particle size rule (Abrams, 1977): the median particle size (D50) of the bridging material should be equal or slightly greater than 1/3 the median pore size of the formation.
2. Ideal Packing Theory (Dick et al. 2000): the D90 value of the PSD should be equal to the fracture opening size.
3. Vickers Method (Vickers et al. 2006): In order to achieve minimal fluid loss into the formation, the following criteria for the bridging blend must be met:
4. D90 = largest pore size
5. D75 < 2/3 of largest pore size
6. D50 = +/- 1/3 mean pore size
7. D10 > smallest pore size

8. Halliburton Method (Whitfill, 2008): the D50 of the PSD is set equal to the estimated fracture width to offset uncertainty in the estimation. In this way, sufficient particles both larger and smaller than the estimated fracture width are present to plug a smaller or larger fracture width.

Where DX implies X % of the PSD is less than a certain diameter size. The D50 is the primary PSD used to select LCMs used for bridging and sealing pores/fractures (Kumar et al. 2010). Figures 4.3 and 4.4 illustrate the importance of getting the right PSD of LCMs for bridging and sealing loss zones.

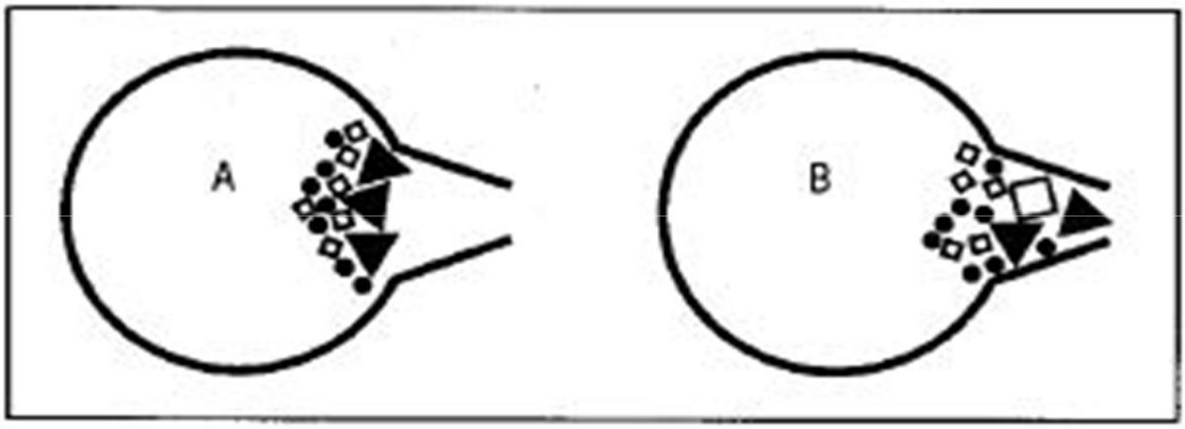

Figure 4.3; : Results using LCM too large – forms a bridge on the wellbore and erodes away; B: Proper bridging

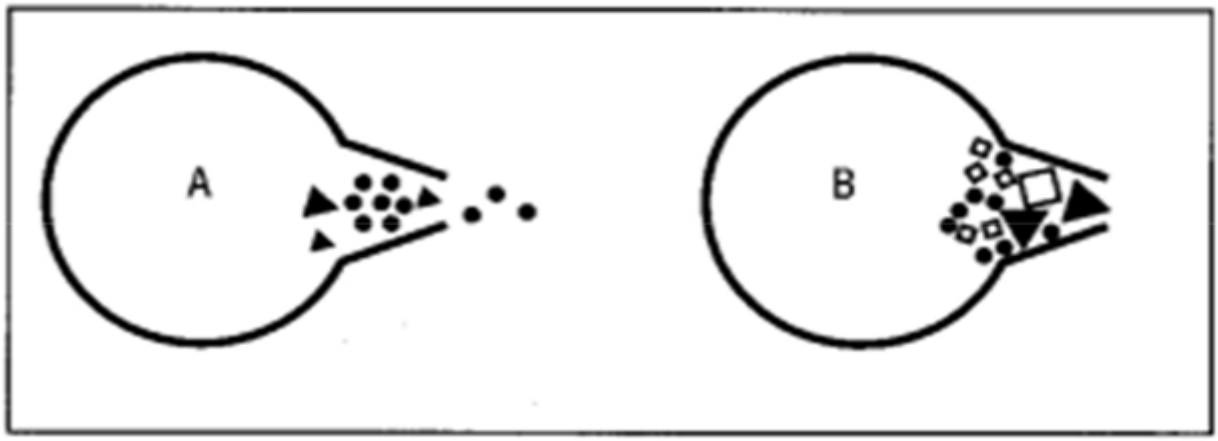

Figure 4.4; Results using LCM too fine – goes through the openings and does not form a bridge; B: Proper bridging

Higher concentration of LCMs delivered in sweeps can aid in fracture tip screen-out and prevent fracture propagation (Whitfill and Wang, 2005). As the drilling progresses, additional make-up LCMs should be added to maintain pretreatment levels. Table 4.1 provides a guideline on the amount of LCMs to be added to the mud, based on the weight of mud (Ferron et al. 2011).

Table 4.1: Seepage Loss Quick Reference Guide to Pretreat Active Mud System with LCMs

LCMs		MUD WEIGHTS (lb/gal)			
		7.0 To 12.5	12.5 To 15.0	15.1 To 17.0	17.1 +
GRAPHITIC CABORN (FINE)	LCM CONCENTRATION (lb/bbl)	5-10	5-10	5-10	5-10
$CaCO_3$ (FINE)		5-10	5-10	5-10	5-10
TOTAL LCM CONC (lb/bbl)		10-20	10-20	10-20	5-10

4.3 PARTIAL LOSSES

Partial losses occur when the severity of the loss is in the range of 10-500 bbl/hr. They occur in gravels; small, natural horizontal fractures; and barely opened induced vertical fractures (Nayberg, 1987). The use of LCMs in the mud can be used to prevent and cure partial losses in all the formations mentioned above. The guidelines discussed in the previous sections on selecting the optimum PSD of these bridging materials must be adhered to. Table 4.2 provides

guidelines on the amounts of LCMs to be added to the active mud system to prevent and cure partial losses (Ferron et al. 2011).

Table 4.2: Partial Loss Quick Reference Guide to Pretreat Active Mud System with LCMs

LCMs		MUD WEIGHTS (lb/gal)			
		7.0 to 12.5	12.5 to 15.0	15.1 to 17.0	17.1+
Fine Micro-Fiber	LCM CONC (lb/bbl)	10	10	10	10
Medium Micro-Fiber		10	10	10	10
Coarse Micro-Fiber		10	10	10	10
Fine $CaCO_3$		10	10	10	10
Coarse $CaCO_3$		10	10	10	10
TOTAL LCM CONC (lb/bbl)		30-50	30-50	30-50	30

As a note Pump sweeps as needed. Do not over treat as this can lead to a build-up of solids which will increase ECDs

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4.4 SEVERE AND TOTAL LOSSES

Mud losses are said to be severe when the rate of loss is greater than 500 bbl/hr. Total losses occur when no fluid returns is seen through the annulus. These types of losses occur in long, open sections of gravels; large, natural horizontal fractures; caverns; interconnected vugs; and widely-opened induced fractures (Nayberg, 1987). Losses into large caverns occur only at very shallow depths and are difficult to treat. Sometimes, a cure may not be possible and may require other actions (Ferron et al. 2011). Some of the actions that may be taken include: 1) Drilling Blind 2) Drilling with Aerated Mud.

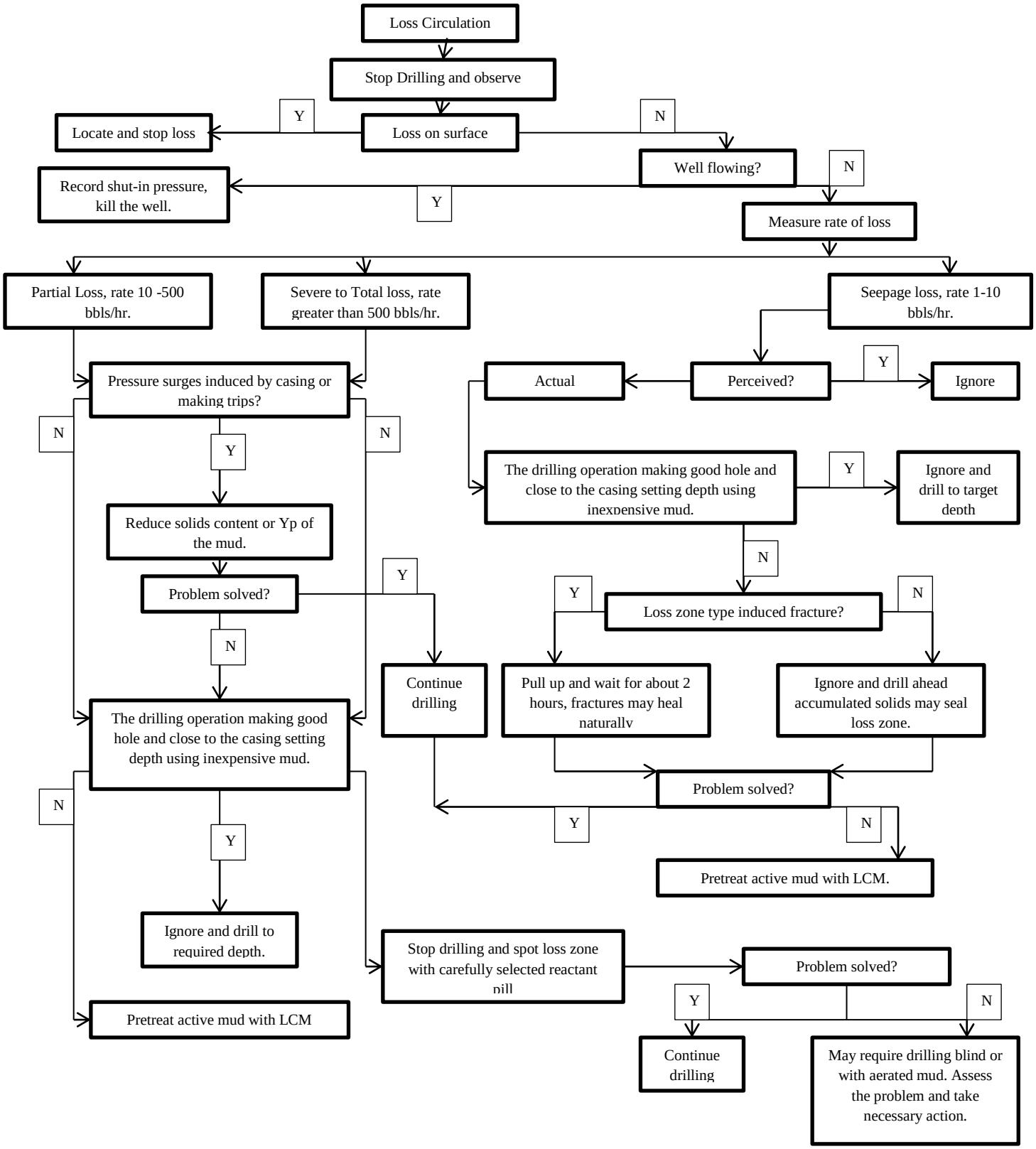
4.4.1 Blind Drilling (Drilling Without Returns)

This technique is used in severe total lost circulation events, where a cure might not be possible or where economic analysis of the treatment process is not favorable, to cross the loss zone in order to set casing. Concerns of drilling blind should include: possible stuck pipe, insufficient hole cleaning, loss of well control, sloughing formations, etc. (Johnson et al. 2000). When drilling without returns, it important to maintain a pumping rate equal or greater than the normal pumping rate used for hole cleaning. Otherwise, there is a risk of sticking the pipe string. This makes practical access to an adequate water source a necessity if the technique is to be completed efficiently (Canson, 1985).

Chemical systems that form flexible ultra-viscosity treatments may be necessary to solve the most severe lost circulation problems (Whitfill and Hemphill, 2003). The most commonly used chemical systems are Reactant Pills. These pills are used to regain circulation from either lost circulation or kicks and they have been successfully used for many years to seal off zones or pathways to underground flows allowing the flowing zone to be killed. Reactant means that the

pill's final properties will be much different after it has been spotted in the wellbore (Ferron et al. 2011). There are many pill treatments available, including cements, gunk squeezes, cross-linked gels, and graded particulates (Reid and Santos, 2003). It is important that the operator carries out a careful study in order to select a pill that will offer several technical and operational advantages.

Figure 4.5 provides a summary of the techniques and guidelines on how to combat the different types of lost circulation cases. When used in combination with the above guidelines, the problem of lost circulation will be reduced if not totally stopped.



Key:

Y = Yes, N = No

Figure 4.5: Loss Circulation control Flow-Cart.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

The problems loss circulation poses while drilling cannot be overemphasized. The huge amount of time spent in developing new ways and evolving old methods of combating it certainly prove the fact. Thus this study is made to; review the various loss circulation prevention and control techniques that have been used for drilling in the industry till date, also to note their qualitative successes and failures of these techniques during field applications and to develop a standard set of real-world guidelines that will act serve as a reference guide for loss circulation problems that may arise at the well-site.

These goals were achieved by reviewing a number of technical journals, papers, textbooks, and manuals that address the problem of lost circulation were carefully reviewed and summarized. The results of this study are real-world guidelines that are not biased towards a particular service industry product but are general to the resolution of loss circulation problems while drilling. A flow chart has also been developed that will act as a reference guide for loss circulation problems that may arise at the well-site.

5.1 CONCLUSION.

Based on this study, the following conclusions were made:

1. Successful control or treatment of lost circulation depends on several factors such as borehole temperature, pressure, depth, and size of the thief zone.

2. There are no guaranteed methods for solving lost circulation problems entirely but a lot of approaches can be used to prevent its occurrence, especially those that occur via induced fractures when drilling formations that are prone to losses.
3. Practical guidelines have been developed that when used with the accompanying flow chart will serve as a quick reference guide to prevent and minimize the problem of lost circulation while drilling.

5.2 RECOMMENDATIONS

For future work in this study area, the following recommendations may be considered:

1. The effect of lost circulation materials (LCMs) on reservoir productivity may be considered when selecting these materials for lost circulation control.
2. Since the subject of lost circulation control is very broad, a study may be conducted in a particular formation type, such as depleted reservoirs, for in-depth understanding of control measures.

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