Drilling Fluid Design for Hydrate Well

by

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9946

Progress report
submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Petroleum Engineering)

JANUARY 2011

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the Geoscience
and Petroleum Engineering Programme
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APRIL 2011

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CERTIFICATION OF ORIGINALITY

This is certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and the original work contained herein have not been undertaken or done by unspecified sources or person.

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ABDUL RAZAK BIN MOHAMED AFFANDI

ABSTRACT

Gas hydrate research in the last two decades has taken different directions ranging from ways to understand the safe and economical production of this enormous resource to drilling problems. Gas hydrates are ice-like structures of a water lattice with cavities, which contain guest gases. Gas hydrates are stable at low temperatures and high pressures. The quantity of energy trapped in gas hydrates all over the world is about twice the amount found in all recoverable fossil fuels today[1]. Thus, a careful drilling practice used in conjunction with a drilling fluid is a must to evade the various problems encountered in the course of a drilling operation through gas hydrate formation.

This report contains five chapters which are the introduction, literature review methodology, results and discussions and the conclusion. In the first chapter, the introduction explains about the background study, problem statement and also the main objectives of the project. The main objective of the project is to design a drilling fluid for hydrate well. The second chapter of this report stated the theory and literature review of the gas hydrates and drilling fluids. This report concentrates around the literature review on the history of hydrate research, properties, characteristics, types of structure for hydrate, and the stability of gas hydrates. The literature review is taken mostly from journals of many previous studies about gas hydrates formation encountered during drilling operation. Next, the third chapter explains about the methodology of the project. Under the methodology section, the author includes a project activities flow chart and also explains about the tools required to execute the project. The related equipment for the test procedure involves mixer, mud balance, viscometer, HTHP and API filter press. The mud properties such as density, plastic viscosity, yield point, gel strength and filtration rate will be measured through the experiment in the laboratory. This project will be carried out in two semesters. The milestone for the project work is presented nicely in a Gantt chart. Lastly, the conclusion states the planned activities for the project and its feasibility within the scope and time frame.

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CHAPTER 1
INTRODUCTION

1.0 INTRODUCTION

1.1 Background Study

Gas hydrate is a combination of hydrogen and water that is frozen into an ice. The crystalline structures form a cage-like structure that surrounds gas molecules; build a solid substance with a high gas density. Gas hydrates form in normally two types of geologic environments, in permafrost regions (where cold temperatures dominate) and beneath the sea in sediments of the outer continental margins (where high pressures dominate) [5]. Gas hydrates can form at temperatures above the freezing point of water. While methane (the chief constituent of natural gas), propane, and other gases are included in the hydrate structure, methane hydrates are the most common.

Throughout the world, oil and gas drilling is moving into regions where safety problems related to gas hydrates may be expected. Furthermore, the major efforts to develop technology are currently made by countries with limited domestic resources or growing energy demand in the future. Accordingly Japan, South Korea, India, China and the United States are the countries with the largest hydrate research and development programs. As a result, it is likely that some commercial production will commence by 2020 and expand to other locations over the following decade.In order to evade the gas hydrate problems to the drilling operations or equipments, optimum drilling fluid selection and design must be considered to be a key focus area to maximize the open area to flow and associated well productivity, also comply with the planned lifetime and production targets [7].

1.2 Problem Statement

Drilling of an oil or gas well can be described as a sequence of operations or drilling activities, each performed to achieve a demanding task. There are various problems encountered in the course of a drilling operation through gas hydrate formation especially in offshore. Some of possible problems encountered during drilling through gas hydrate formation are explained below [1]:

- Choke and Kill-line plugging: This causes difficulty in the use of the lines during well circulation.
- Plug formation at or below the blow out preventers (BOP): Well-pressure monitoring below the BOPs becomes impossible or difficult.
- Plug formation around the drillstring in the riser, BOPs or casing: Makes the drillstring movement a problem.
- Plug formation between the drillstring and BOPs: This causes problems in the full closure of the BOPs when necessary.
- Plug formation in the ram cavity of the BOPs: Causes difficulty in opening the BOPs fully.

Moreover, hydrate formation could result the drilling mud to lose its rheological properties, affecting the flow. In worst case, the solid plug could completely block the fluid movement. Another issue, after formed a hydrate plug, is estimating how long it would take for dissociation, by means of depressurization, heating or chemical additives. A rapid liberation of gas when hydrate crystals dissociate could result, if not controlled, in devastation of the rig equipment, because there is a great amount of gas inside the solid. One cubic meter of hydrate could liberate one hundred seventy cubic meters of gas [9]. In addition, there is a risk about the velocity of the plug, when it is pushed out of the line.

1.3 Objectives

- To design a drilling fluid for a gas hydrated well.
- To evaluate an effect of hydrate inhibitors into the drilling fluid.
- To measure the rheological properties of designated drilling fluid

1.4 Scope of Study

The project scope can be divided into two stages whereby the first stage is the study of the theories behind gas hydrate formation and types of drilling fluid as well as the method used in estimating the properties of drilling fluid. The second stage is to design particular drilling fluid based on the data and properties of gas hydrate from research conducted.

1.4.1 The Relevancy of Project

This project is relevant to the study of advance drilling engineering as it focuses on the design of drilling fluid which deals with gas hydrate research. This project is also in phase with the recent technology used in enhancing methane hydrate that will become new energy source for the future.

1.4.2 Feasibility of the Project within the Scope and Time frame

The project will be conducted starting with the collection of related materials such books, journals and technical papers specifically on gas hydrate formation. Research will be done from time to time as to get a better understanding on the subject. This project will then focus on the drilling fluid design using equipments and chemicals provided at laboratory. Based on the activities stated above, given 5 months for the researches and studies to be done as well as experiment activities and for the other 5 months for the finalization of the design, the author feels that the project can be completed within the given time frame.

CHAPTER 2
LITERATURE REVIEW

2.0 LITERATURE REVIEW

2.1 Gas Hydrates

2.1.1 History of Hydrate Research

Gas hydrates are believed to have first been discovered in 1810 in the laboratory of Sir Humphrey Davy, who cooled an aqueous solution saturated with chlorine gas below 9°C to yield a crystal/ice like material [1].

In 1940's, Soviet investigators hypothesized the existence of natural methane hydrates in cold northern climates. Later, Katz and co-workers summarized an impressive amount of work. By 1950 there was a large database available concerning hydrates but knowledge of hydrate structures was still limited. Von Stackelberg studied hydrates using x-ray diffraction and identified the hydrates as clathrates. Claussen proposed structure I and II in 1951.

Müller soon verified these structures by x-ray analysis of several gas hydrates in 1951. In 1959, van der Waals and Platteeuw were the first scientists to calculate the conditions of hydrate formation. Later on in the early 1960's, Soviets recognized methane hydrate as a possible energy source. They discovered and produced the first major hydrate deposit in permafrost. In the 1970's, a bottom simulating reflector was drilled and was found to be associated with the base of hydrate stability.

Research has increased in the 1980's, and new instrumental methods were introduced in the research, such as Nuclear Magnetic Resonance spectroscopy, vibrational spectroscopy and Raman spectroscopy. With the help of Nuclear Magnetic Resonance techniques, Ripmeester et al identified a new hydrate structure, structure H, in 1987.

2.1.2 Properties and Characteristics of Gas hydrates

Hydrates are part of a group of substances known as clathrates because they consist of "host" molecules (water) that form a lattice structure that acts like a cage to entrap "guest" gas molecules [4].

Gas hydrates are clathrates that are formed under the suitable conditions of temperature and pressure. Clathrates are complexes formed between two chemicals in which one type of molecule completely encloses the other molecule in a crystal lattice. In the case of gas hydrates, hydrogen bonded water molecules form a cage-like structure that surrounds gas molecules, forming a solid substance with a high gas density [2].

Fig 2.1 Gas hydrate recovered from a core

The ice like structures orient water molecules in a polygon type of structure made up of five (pentagon) and six (hexagon) membered polygons formed by the water molecules. The polygons are combined to form a closed structure that completely encloses or traps a gas molecule within the interior and, hence, the association of the word cage. These cages can then further combine making larger cavities or cages that also enclose gas molecules [3]. A very important property of hydrate is the amount of natural gas that can be held in the lattice structure. 1cf of gas hydrates could hold as much as 170 scf of gas.

Three different structures of hydrates have been identified namely structure I, II and H. Fig 1.1 shows the three structures of hydrates. Structure II is mainly expected to form with natural gas under production conditions.

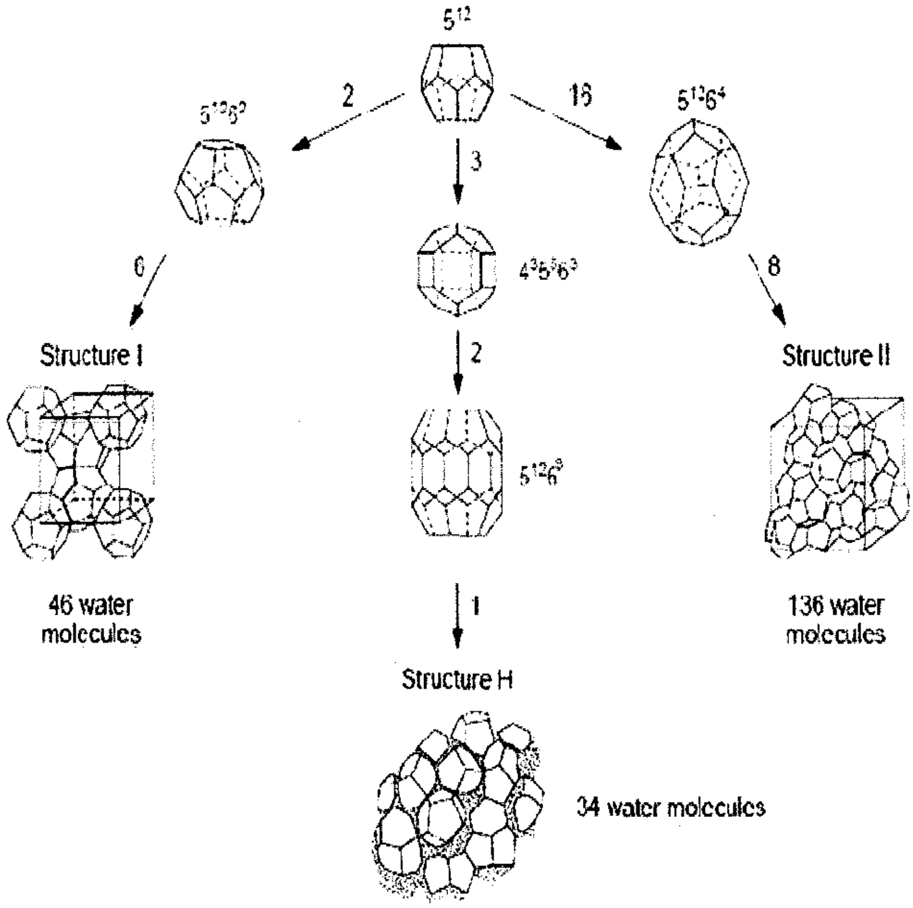

Fig 2.2 Physical structure/composition of hydrates

In structure I, there are eight cavities, two little with twelve pentagonal faces, and six large, with twelve pentagonal faces and two hexagonal faces. This is formed with light components such as methane, ethane or carbon dioxide.[9]

Structure II has twenty four cavities, sixteen little with twelve pentagonal faces, and eight large, with twelve pentagonal faces and four hexagonal faces, these large cavities, greater than that in sI, could obtain molecules such as propane or butane, which do not insert in large cavities of structure I.

The last type of structure, sH is constituted by six cavities, three small with twelve pentagonal faces, two medium cavities with three squares, five pentagonal and three hexagonal, and one large cavity composed of twelve pentagonal faces and eight hexagonal faces. This structure H is formed by heavy molecules, such as cycloalkanes, but it is necessary a support gas, as methane, in order to stabilize the reticulum. Several properties of different hydrate structures are given in Table 2.1 followed by brief descriptions of basic hydrate structures.

Hydrate Crystal Structure	I		II		H		
Cavity	Small	Large	Small	Large	Small	Medium	Large
Cavity description	5^{12}	$5^{12}6^{2}$	5^{12}	$5^{12}6^{4}$	5^{12}	$4^{3}5^{6}6^{3}$	$5^{12}6^{8}$
Number of cavities per unit cell	2	6	16	8	3	2	1
Average cavity radius, °A	3.95	4.33	3.91	4.73	3.91**	4.06**	5.71**
Coordination number*	20	24	20	28	20	20	36
Number of water molecules per unit cell	46		136		34		
Crystal type	Cubic		Diamond		Hexagonal		

Table 2.1 Properties of different hydrate structures

The hydrates of interest to the petroleum industry are formed with natural gas components. The major component of which is methane, but other components (ethane, propane, isobutane, carbon dioxide, nitrogen, and hydrogen sulfide) also form water clathrates [2].

2.1.3 Hydrate Stability

Hydrates are frozen mixtures of natural gas and water, which looks like muddy ice. Each mixture of natural gas forms at a range of pressure and temperature combinations. The environments necessary for the stability of gas hydrates are moderately low temperatures and moderately high pressures [1]. These conditions could exist offshore in shallow depths below the ocean floor and onshore beneath the permafrost.

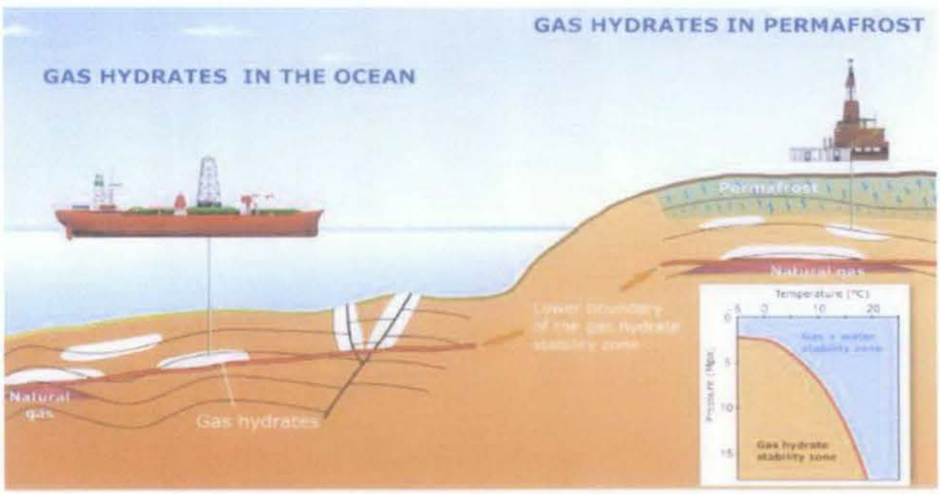

Fig 2.3 Hydrates recovery onshore from below the permafrost

The gas hydrate stability zone (GHSZ) is defined by the hydrate forming gas and by the temperature. The gas pressure is generally equal to the external pressure which is equivalent to the summation of the hydrostatic and lithostatic pressure [1]. The gas hydrate stability zone is known to have a lower base, a point beyond which gas hydrates become unstable as the depth increases. The accurate location of this point under known pressure and temperature conditions vary with a number of factors, the most important factor being gas chemistry. The various temperature and pressure profile for the 3 known hydrate structure is shown in fig 2.4.

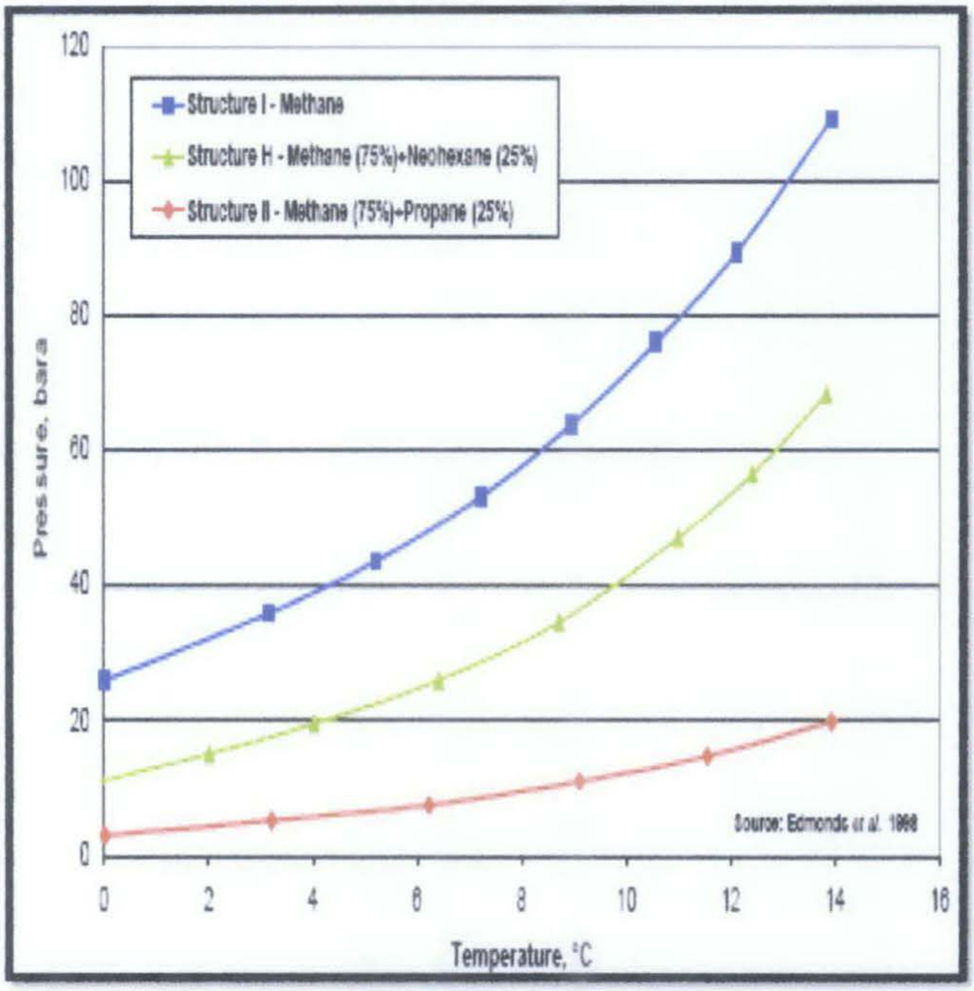

Fig 2.4 Relative stability of S1, SII and SH structures of hydrates with respect to pressure and temperature

2.2 Drilling Fluids

In the oil and gas industry, drilling fluid is the heart of the drilling process. Generally, the drilling fluid is a fluid that is used to drill a boreholes in a daily drilling operation in which the fluid is circulated and pumped from the surface, down the drill string through the bit and back to the surface via the annulus. Drilling fluids play numerous functions and encompasses all of the composition used to aid the production and removal cuttings from the borehole. Drilling fluid is also known as mud in the industry.

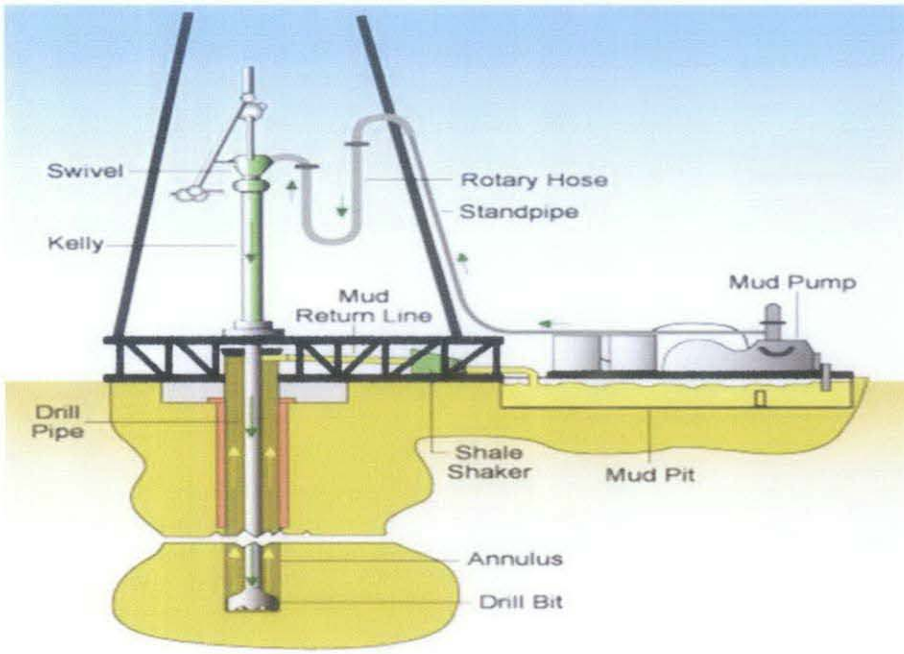

Fig 2.5 Drilling Fluid Circulation

2.2.1 Function of Drilling Fluids

Most rotary drilling methods require the use of drilling fluids. Drilling fluids perform several functions. The primary functions include cleaning the cuttings from the face of the drill bit, transporting the cuttings to the ground surface, cooling the drill bit, lubricating the drill bit and drill rods, and increasing the stability of the borehole [6].

In addition, there are a number of secondary functions. Some of the more significant secondary functions are suspending the cuttings in the hole and dropping them in surface disposal areas, improving sample recovery, controlling formation pressures, minimizing drilling fluid losses into the formation, protecting the soil strata of interest, facilitating the freedom of movement of the drill string and casing, and reducing wear and corrosion of the drilling equipment. Below are the explanation regarding drilling mud functions.

i. Transport and Remove Cuttings

Drilling cutting or rock cutting from the drill bit activities must be removed from wellbore up to the surface through the efficient circulation of drilling fluid. Its ability to do so depends on cutting size, shape, density, and speed of fluid travelling up the well. The mud viscosity is another important property, as cuttings will settle to the bottom of the well if the viscosity is too low.

ii. Control Formation Pressure

Borehole instability is caused by the unequal mechanical stress and chemical interactions as a result from processes of drilling a well. The drilling fluid must have the ability not only to stop formation from collapse but also minimize formation damage as well as having the inhibitive property to prevent clay swelling. So, if formation pressure increases, mud density should also be increased, often with barite as weighting materials to balance pressure and keep the wellbore stable. Unbalanced formation pressures will cause an unexpected influx of pressure in the wellbore possibly leading to a blowout from pressured formation fluids.

iii. Maintain Borehole Stability

Wellbore stability need to be maintain each second in drilling operation especially before the casing can be run and cemented. In short, wellbore stability requires a complex balance of mechanical and chemical factors. Thus, chemical composition and mud properties must combined together to provide a stable wellbore. Weight of the mud must be within the necessary range to balance the mechanical forces.

iv. Seal Permeable Formation

When the mud column pressure is greater than the formation pressure, mud filtrate will invade the formation and a filter cake of mud solid will be deposited on the wall of the wellbore. Mud must be designed to deposit a thin, low-permeability filter cake on the formation to limit the fluid loss inside the formation.

v. Cool and Lubricate the Drill String

Heat is generated from mechanical and hydraulic forces at the bit and when the drill string rotates while drilling and rubs against casing and wellbore. The mud help cool and transfer heat away from source and lower to temperature than bottom hole. A lubricant added in the drilling fluid improves the lubricity of drilling bit and drill string while drilling process. Poor lubrication causes high torque and drag, causing the drill string and bit to damage rapidly.

2.2.2 Types of Drilling Fluid

There were three types of drilling fluid commonly used in the drilling operation around the globe:

i. Water Based Mud

Water based mud is drilling fluid that use water as a continuous phase. A most basic water based mud system begins with water, and then clays and other chemicals to create homogenous blend water based mud. The clay is usually a combination of native clays that are suspended in the fluid while drilling, or specific types of clay that are processed. Many other chemicals are added to this mud system to achieve various effects, including viscosity control, shale stability, enhance drilling rate of penetration, cooling and lubricating of equipment.

ii. Oil Based Mud

In contrast, oil based mud is a mud where the base fluid is a petroleum product such as base oil. Oil based mud are used for many reasons, some being increased lubricant, enhanced shale inhibition and greater cleaning abilities with less viscosity. Oil based mud can also withstand greater heat without breaking down.

iii. Synthetic Based Mud

Synthetic based mud, the base fluid is synthetic oil. This is most often used on offshore rigs because it has the properties of an oil based mud, but the toxicity of the fluid fumes are much less than oil based fluid.

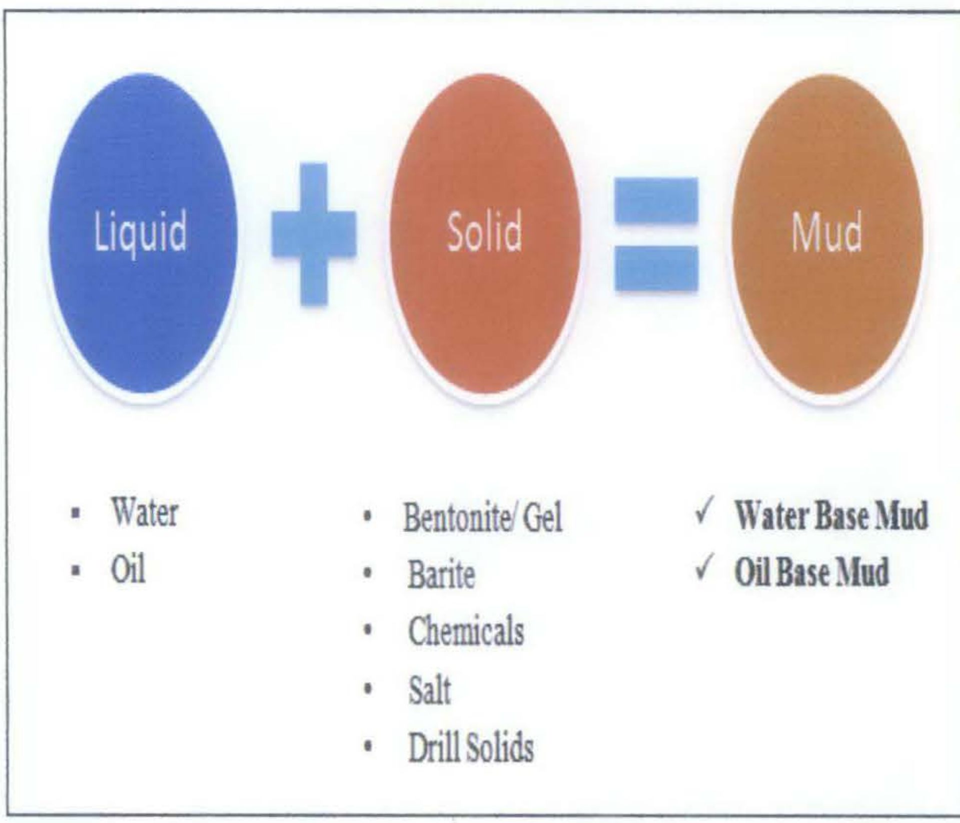

Fig 2.6 Composition of Drilling Fluids

2.2.3 Properties of Drilling Fluid

There are some basic characteristics necessary for the design of a drilling fluid. Some of them include:

1. **Density**:

   The density of a drilling fluid is a measure of weight of the fluid with respect to a known volume. The weight of a drilling fluid is usually measured with the use of a mud balance. The unit of measurement for a drilling fluid is usually pounds per gallon (ppg).

2. **Viscosity**:

   This is a measure of the tendency of a fluid to flow. It can also be described as the measure of the thickness of a fluid. The dynamic property is due to the addition of inert solids (not reacting with water) to the drilling fluids compositions. Viscosity could be measured in two ways. Funnel viscosity is checked by using a Marsh Funnel and recording the time required for a quart of the fluid to flow through the funnel. It is only a relative measure of viscosity. The second means is by using a Rotational Viscometer and is normally performed by the mud engineer. This unit of measure for this "plastic viscosity" is centipoise.

3. **Yield point**:

   This is another dynamic property of drilling fluids. Usually performed by the mud engineer and its regarded as a measure of the dynamic surface tension of the mud. Unit of measurement is pounds per 100 square feet. Gel strength is relatively compared to the yield point but it measures the static surface tension of the mud or how well it can suspend solids when not in motion.

4. **Rheology**:

Defined as the science of the deformation and/or flow of solids, liquids and gases under applied stress. Basic concepts of rheology, for instance the relationship between shear stress and shear rate, are very important to be well understood in predicting drilling fluid behaviour. The more important application of this basic concept is related to the selection and design of fluids to obtain optimum rated of circulation to transport and suspend drill cuttings, increase drilling rates and reduce hole erosion. Whether a fluid performs a specific function or not, it is attributed to the absence or presence of viscosity at the shear rate of interest.

2.2.4 Drilling fluids criteria of hydrate formation

The selection of a drilling fluid to suppress the formation of gas hydrates is specifically useful in areas where gas hydrates are likely to be formed. Most of the other requirements are more general and apply to various drilling operations. Here are some of the primary factors to be considered in the selection of a high performance fluid for ultimate performance during drilling [2]:

- Lowest density possible with maximum hydrate suppression.
- Compatibility with most common drilling fluid components.
- Provide shale inhibition for adequate borehole and drill cuttings stability.
- Compatibility with most salts to balance hydrate suppression and fluid density.
- Environmentally-acceptable.

CHAPTER 3

METHODOLOGY

3.0 METHODOLOGY

3.1 Project Workflow

The project workflow is as shown below:

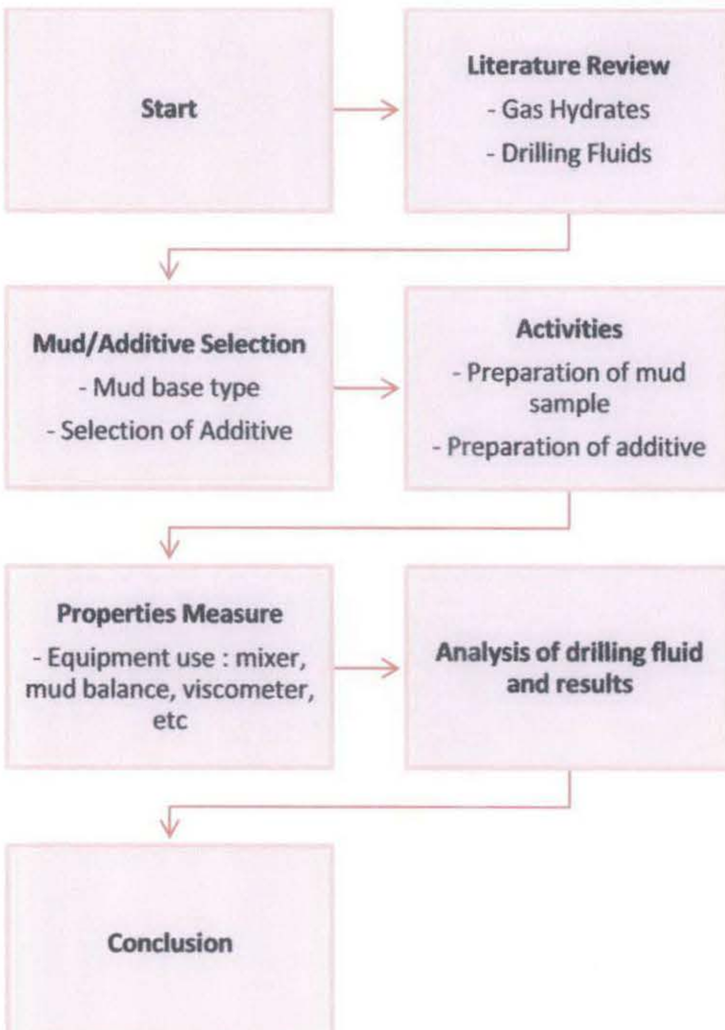

Figure 3.1: Project Activities Flow Chart

3.2 Research Methodology

In order to achieve the aim of the project, some researches had been done on several resources from books, technical papers and internet. For the first step, gathering information needs to be done on the properties, characteristics, stability, formation and location of gas hydrates. Besides that, researches about types of drilling fluid, characteristics and knowledge of the additives also significant to complete this project. After all the studies have been done, the next stage will be the experiment and systematic testing procedures applied at the laboratory.

3.3 Designing Drilling Fluids Formulation

10 lb/gal Water Based Mud

Mud Products	**Concentration (g)**
Water	300
Xanthan	1.5
Cellulose/Starch	3.5
Bentonite	30
KCL	10.5
NaCl	37.2
Diethylene glycol	18.4

Table 3.1 Proposed Fluids Formulation for Lab Testing

3.4 Drilling Fluid Tests

i. Determining Mud Weight Using the Mud Balance:

Fig 3.2 Mud balance

i. Instrument base must be set on a flat level surface.
ii. Measure and record the mud temperature.
iii. Fill the mud cup with the mud to be tested.
iv. Replace cap and rotate until it is firmly seated, ensuring some of the mud is expelled through the hole on top, to free any trapped gas.
v. Place the beam on the base support and balance it by using the rider along the graduated scale. Balance is achieved when the bubble is directly under the centre line.
vi. Take the mud weight reading

ii. Funnel Viscosity:

Fig 3.3 Marsh Funnel

i. Cover the orifice with a stopper and pour a freshly agitated fluid sample through the screen into the clean, dry and upright funnel until the liquid level reaches the bottom of the screen.

ii. Quickly remove the finger and measure the time required for the fluid to fill the receiving vessel to the one quart (946 ml).

iii. Report the result to the nearest second as Marsh Funnel viscosity and the temperature to the nearest degree.

The funnel viscosity is a good quick guide to whether the water based mud is thickening or thinning. However further analysis of rheology and solids content will be required before embarking on any treatment program.

iii. Rheology Test:

In mud rheology testing, rheometer is used. It is important to frequently monitor the mud rheology as to make sure that the mud is always within the specification as stated in the mud program:

i. Place the sample in the rheometer thermo cup and adjust the cup until the mud surface level is equal height to the scribed line on the rotor surface.

ii. Turn on the rheometer, first taking dial measurements at the top most speed (600rpm), then gradually switch to lower gear and to obtain all readings (600,300,200,100,6,3rpms).

iv. **Determining PV** – indicate the amount of solids (sands, silts) in mud. High PV means that the mud is not clean and there is a problem with the solids control equipment.

$$PV = 600\text{ rpm} - 300\text{ rpm}$$

v. **Determining YP** – indicate the carrying capacity of cuttings (usually the case is that the higher the viscosity is, the higher the YP is)

$$YP = 300\text{ rpm} - PV$$

vi. **Determining Gel Value of the mud using Rheometer:**

Fig 3.4 Viscometer

i. Stir the sample in 600rpm speed for 15 seconds. Just fefore the motor stops, slowly shift the moving gear to the lowest speed.
ii. Wait for 10 seconds. After 10 seconds has finished, turn on the 3rpm speed and record the maximum deflection of the dial. This is the 10 seconds gel reading.
iii. Repeat step one and step two, but this time, wait for 10 minutes before turning on the 3rpm speed. The maximum deflection of this reading shall give us the 10-minute gel reading.
iv. Rewrite the gel value as (dial = 10 secs) / (dial = 10 mins)

vii. Determining API filtrate using filter press:

Fig 3.5 API Filter Press

The API filtrate is a test designated to determine the mililitres of filtrate lost in 30 minutes under a 100 psi pressure. Knowing the fluid loss is important since it is bad to have mud that has a high filtrate loss because this contribute to high fluid invasion and also thick mud cakes.

i. The mud is poured into the filter press cell the filter cell then is placed in the frame. The relief valve is closed and a container will be placed under drain tube.

ii. Pressure should be adjusted at 100 psi which is supplied by compressed nitrogen.

iii. The dry cylinder is placed under the drain tube and continues collecting filtrate to the end of 30 minutes. The graduated cylinder then removed and the volume of filtrate collected is recorded.

viii. Permeability Plugging Tester (PPT) Test:

Fig 3.6 Permeability Plugging Tester (PPT)

The Permeability Plugging Tester is a modification of the standard 500ml HTHP Filter press. This instrument is useful for making filtration tests on plugging materials without the interference of particles settling on the filter medium during the heat up process. It also useful in predicting how a drilling fluid can form a low permeable filter cake to seal off depleted, under pressured intervals and helps prevent differential sticking in the loss formation.

3.5 Gantt Chart

The Gantt chart is shown as below. Noted that the Gantt chart as a guideline for the project timeline. It can be changed from time to time depending on certain circumstances.

3.5.1 Gantt Chart: First Semester

<table>
<tr><th>No.</th><th>Detail/ Week</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th><th>18</th><th>19</th><th>20</th></tr>
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</table>

3.5.2 Gantt Chart: Second Semester

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Laboratory works																				
2	Submission of Progress Report							M	●												
								I													
3	Project work continues							D													
																S	E				
4	Testing and Validation work							S								T	X				
								E								U	A				
5	Pre-EDX							M				●				D	M				
								E								Y					
6	Finalize results and findings							S													
								T								W	W				
7	Submission of Draft Report							E						●		E	E				
								R								E	E				
8	Submission of Final Report and Technical paper.														●	K	K				
								B													
9	Oral Presentation							R								●					
								E													
								A													
								K													

3.6 Project Work Progress

Referring to the project workflow and the gantt chart, the author already completed all processes of the methodology up to the lab experiment. Thus, properties of drilling fluids have been determined. Plus, the author had done research on the criteria of drilling fluids for hydrate formation, drilling fluid and additives selection for gas hydrate drilling, and learns about the procedures to conduct drilling fluid tests in the laboratory. Next, the author will analyze and discuss more about the results and findings of this experiment.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.0 RESULTS AND DISCUSSIONS

Type of mud and Inhibitor selection

Through the research, Water Based Mud is more applicable for gas hydrate drilling since Oil Based Mud contributes a lot of bridle also due to the environmental issues. Gas hydrates form when a number of factors co-exist: free water, hydrocarbon gas, cold temperatures, high pressure, and time. Cold temperatures and high pressures are typical of the near mud-line conditions in a deepwater drilling operation. Subsequently, when drilling with water-based muds, particularly on exploration wells, the risk of hydrate formation associated with a gas influx is high. The consequences of gas hydrate formation while drilling are severe, and as such, every effort should be made to ensure the risk of hydrate formation is either eliminated or significantly reduced. Thermodynamic inhibitors are used to reduce the free water content of a drilling mud, and thus suppress the hydrate formation temperature. **Sodium chloride** is the cheapest and most effective additive for thermodynamic hydrate inhibition in water based mud and as measured by molality, is one of the most effective thermodynamic inhibitors [14]. Through the research, **diethylene glycol** also suitable as an inhibitor in aqueous solution where hydrogen bonds are formed with the water molecules making it difficult for the water molecules to migrate and bond with gas to form hydrates.

Mud Properties

Mud Rheology	
Products	**Result**
Mud weight	10ppg
Rheology at ...	50°F
Density, g/cm^3	1.12
600 rpm	71
300 rpm	42
200 rpm	26
100 rpm	18
6 rpm	9
3 rpm	8
PV,cP	29
YP , $lb/100ft^2$	13
Gel 10 sec	5
Gel 10 min	7
Thickness	2
API , cc/30min	11

Table 4.1 Mud Properties

Mud Weight or Density Test

The Baroid Mud Balance is used to determine density of the drilling fluid. The instrument consists of a constant volume cup with a lever arm and rider calibrated to read directly of the fluid in ppg and specific gravity. Below are the results after density test was conducted.

Density: **9.4 ppg**

Specific gravity: **1.12 g / cm^3**

The relative density (ρ) of the drilling fluid must have an appropriate changing range. The drilling fluid can supply a definite pressure to counteract the stratums and prevent hydrates around the borehole from decomposing to keep the borehole wall stable. For a practical situation of hydrates sediment, a result of optimum relative density is in the range of 1.05–1.2 [15], according to the safe density window of drilling fluid.

Mud Rheology Test

Rheology refers to the deformation and flow behaviour of all forms of matter. Certain rheologic measurements made on fluids such as viscosity and gel strength that help to determine how this fluid will flow under a variety of different conditions.

VISCOSITY, cp						Gel Strength, lb/100ft^2	
ø600	ø300	ø200	ø100	ø6	ø3	Initial 10 sec. Gel	Final 10 min. Gel
71	**42**	**26**	**18**	**9**	**8**	**5**	**7**

Table 4.2 Rheology Test Results

Plastic Viscosity = 600 RPM reading – 300 RPM reading

= **71 – 42**

= **29cp**

Yield Point = 300 RPM reading – Plastic Viscosity

= **42 – 29**

= **13 lb/100 ft^2**

Plastic viscosity usually regarded as a guide to solids control by the relationship that exists between the Shear Stress and the Shear Rate. PV increases when the volume percent of solids or emulsified droplets increase or decrease when the size of particle decreases. PV can be affected by size distribution, shape or concentration of solids.

Yield Point is the viscosity due to the chemical attraction between the particles. The magnitude of these forces will depend on the type of their solid present, and the ion concentration in the liquid phase. It is a measure of flocculation and gives some indication of the hole cleaning ability of the mud, especially when the mud is in motion. High viscosity resulting from high yield point is caused by introduction of soluble contaminant (ions) such as salt, cement or gypsum.

YP helps evaluate the ability of mud to lift cuttings out of annulus. Thus, the high ratios of yield point and plastic viscosity would help to carry cuttings and clean the borehole.

Filtration and Wall Building

The test in the laboratory consists of measuring the volume of liquid forced through the mud cake into the formation drilled in a 30 minute period under given pressure and temperature using a standard size cell.

Test equipment: **Standard API Filter Press**
Fluid loss: **11ml**
Mud cake: **2mm**

Filtrate is an indication the amount of water lost from the mud to the formation, where by measurement is done by using a filter press. This simulates the quantity of fluid loss inside the wellbore. The solids in the mud forms as a filter cake which prevents excessive fluid loss, which the filter cake should be thin, flexible with low permeability, and have correct solids distribution. Thick filter cake reduce the effective hole diameter, and increase the chance of differential sticking.

The lower the filtrate volume the thinner the mud cakes, means that good fluid loss control in mud. The higher the filtrate volume the thicker the mud cake means we need to minimize the fluid loss.

CHAPTER 5

CONCLUSION

5.0 CONCLUSION

Diethylene glycol is suitable as an inhibitor in aqueous solution where hydrogen bonds are formed with the water molecules making it difficult for the water molecules to migrate and bond with gas to form hydrates. For a practical situation of hydrates sediments, optimum relative density is in the range 1.05-1.2, according to the safe density window of drilling fluid.

The designed Diethylene-glycol drilling-fluid system has good performance concerning shale and gas-hydrate inhibition, rheological properties and stability at low temperature. Its density is also appropriate for this application.

Drilling fluid design for hydrate wells requires a detailed study into the various parameters of the reservoir and drilling conditions. Having a systematic approach to perform the detailed study will certainly be very helpful in the process of designing appropriate drilling fluid for gas hydrate reservoirs.

The author feels that given five months for research and another five months for finalization of the design, the project can be completed within the planned time frame. Developing reliable drilling fluids for hydrate formation is important to achieve an effective drilling operation since the gas hydrate has potential to be the world energy source for future.

CHAPTER 6
RECOMMENDATION

6.0 RECOMMENDATION

When drilling in gas-hydrate-bearing formations, it is recommended that the drilling fluid have a high circulating speed to inhibit gas-hydrate decomposition and reformation. Since the heat produced by aiguilles cutting stratums can be rapidly dissipated by the drilling fluid, the drilling fluid can be renovated rapidly. This process is helpful for cooling the drilling fluid by the cold water around drill pipes in deep seas, which can help control dissociation of the hydrates around the borehole and wellbore stability.

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