DESIGN A GUIDANCE FOR WELL CONTROL IN DRILLING PROCESS

MUHAMMAD HAMZI BIN YAKUP

PETROLEUM ENGINEERING

UNIVERSITI TEKNOLOGI PETRONAS

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by

Muhammad Hamzi Bin Yakup

Dissertation submitted in partial fulfillment of

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Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750,Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the

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Approved by:

Dr. Muhannad Talib Shuker
Associate Professor
Geoscience & Petroleum Engineering Department
Universiti Teknologi PETRONAS
Bandar Seri Iskandar, 31750 Tronoh
Perak Darul Ridzuan, Malaysia

AP Dr Muhannad Talib Shuker

Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2011

CERTIFICATE OF ORIGINALITY

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

MUHAMMAD HAMZI BIN YAKUP

ABSTRACT

This report focused on well control aspects and well control issues happened in oil and gas industry. The objective that will be achieved through this project is to design a guidance for control the well during drilling process that describes well control activities and system to ensure minimal operational time and risk exposure to personnel, process, production and equipment. The scopes of study for this project revolved around simulate the well control scenario and evaluate the performance of different kind of well control procedures during kick and blowout. The area of study involved fundamental principles of well control, kick causes, kick indicators, shut-in procedures, well control equipment and procedures. After running the simulation, the result obtained were analyzed and discussed. The investigation revolved around effectiveness of driller's method, time for execution the whole kick-killing procedure, kill rate, flow check analysis, estimate circulation density and kick tolerance. The project methodology and activities have been designed to achieve the objective. The required simulation software and equipment also have been described in this report in methodology part. The project simulation work design and procedures were explained. All the result data, analysis, findings and lastly some recommendations presented at the end of this report.

ACKNOWLEDGEMENT

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INTRODUCTION

1.1 BACKGROUND OF STUDY

Over the years, well control technologies have been developed vastly in order to drill the well with highest priority on safety at minimum cost and high profit return. Many research papers, journals and well control manual handbooks had been produced in order to develop improved well control methods and approaches to avoid undesired incident which is blowout. Industry has taken great technologies strides in drilling, producing and working over wells in deep water. As water depth increases, the problems we face become more acute and new problems arise. Any companies that involved in deep water drilling operation would certainly take great priority on safety and failure to control the well during drilling would be a disaster for them. If large blowout happens, it will reflect bad image of the company and followed by worst case scenario which is an oil spill.

Most people assume that blowouts are assumed to be one of the major contributors to risk in offshore activities. Risk in offshore activities is normally related to loss of human lives, pollution of the environment and loss of material assets. Regarding loss of material assets, blowout seems to be a major contributor to the total risk. Out of 118 blowouts (not including blowouts from external causes) that occurred in the U.S. GoM and the North Sea from 1980-1994, 14 of the installations were categorized as total loss or severely damaged. Of these 14 blowouts, 12 blowouts ignited while two did not. The fire itself was the main cause of the damages for these 12 incidents. The two blowouts that did not ignite caused a subsea crater which causes one installation to sink and the other to tilt.

In terms of pollution of the environment, none of the blowouts in the North Sea or the U.S. GoM OCS from 1980-1994 involved large releases of oil/condensate into the sea. The most severe incidents were reported with 10 m^3 (63 bbl) of oil to the sea, some few cubic meters of oil to sea and large sheens.[6]

Large release incidents caused by blowouts have occurred during other periods and in other areas. Before blowout incident in Gulf of Mexico, the blowout in Nigeria in January 1980 was the most serious incident of all. The oil polluted islands and channels of the Niger delta with 30,000 tons (220,000 bbl) of crude oil, ruining the food supplies for thousands of Nigerian fishing people. It was claimed by the Nigerian government that 180 people died to pollution of the drinking water. The operating company, Texaco stated however that detailed studies found no evidence whatsoever of any fatalities directly resulting from the blowout or the oil spill.

The most remembered well control failure happened recently is oil spill in Gulf of Mexico. The impact of the spill continues even after the well was capped. It is the largest accidental marine oil spill in the history of the petroleum industry. The explosion killed 11 men working on the platform and injured 17 others. It was estimated that 53,000 barrels per day (8,400 m3/d) were escaping from the well just before it was capped.

According to Robert D. Grace (2003), in the field there is a considerable lack of understanding about the mechanics of a threatened blowout and practically no knowledge of how to kill one. This is clearly illustrated by the usual statement that "nothing happened except that all of a sudden, the well was blowing gas"[7]. Thus, right well control methods with better understanding on well condition are really important to prevent any unnecessary incident happens because even the small thing that we take for granted can cause serious problem and unexpected tragedy.

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[6] Per Holand,1997.Offshore Blowouts Causes and Control, Gulf Publishing Company, Texas
[7] Robert D. Grace,2003,Blowout and Well Control Handbook, Elsevier Science, USA

1.2 PROBLEM STATEMENT

Different drilling problems confront the operator on a day-to-day basis. One of the toughest problems is well control. Many factors have to be taken into consideration for well control operation. During the majority of operations associated with drilling, it is very challenging to maintain control over the fluids that occur in the pore spaces of formations being penetrated by the well. These fluids can be subject to extreme pressures and temperatures in-situ although these are not pre-requisites for the fluids to cause well control problems.

Failure to maintain control over these fluids can result in a spontaneous and rapid flow of the fluid into the well bore. The rate of flow is determined by the degree of imbalance between the wellbore and reservoir pressures combined with the permeability of the reservoir. In its initial stages, such a flow is called a kick.

When such a flow is not controlled and deteriorates in an uncontrolled manner, then blow out will happen. Blow out can have a very visible environment impact and are very damaging for the operator. The initial stages of a blow out can also be very hazardous to personnel and cause major damage to equipment in the vicinity of the well.

1.3 OBJECTIVES AND SCOPE OF STUDY

1.3.1 Objectives

The objective of this research is:

- To design a guidance or manual for well control during drilling process that describes well control activities and system to ensure minimal operational time and risk exposure to personnel, process, production and equipment

1.3.2 Scope of study

The scope of study revolved around well control during drilling stages for vertical shallow well environment and condition. The project consists of 3 stages where first stage is to study and understand the well control principles and methods through reading materials. Second stage is to conduct drilling simulation using provided software in laboratory to analyze the well control methods. Last stage is to design well control guidelines based on study and results of simulation programme. The area of study involved the following aspects:

i. Fundamental principles of well control
ii. Causes of kick
iii. Kick indicators
iv. Shut-in procedures
v. Methods of well control
vi. Well control equipment
vii. Surface BOP control systems

1.4 PROJECT RELEVANCY AND PROJECT FEASIBILITY

1.4.1 Project relevancy

The study and research on this topic is very relevant with current oil industry where well control becoming more important after worst oil spill and blowout incident ever happened in Gulf of Mexico on 20th April 2010. This serious incident happened due to failure in well control during drilling process and lead to major losses of life and money. There will be well control problems as long as there are drilling operations anywhere in the world. From year to year, well control problems becoming more complicated as the drilling operations locate at more challenging reservoir and extreme environment such as high temperature and high pressure (HPHT) well and deep water. Further study and research in well control system would helps in better understanding on kick causes, advanced detection and better prevention.

1.4.1 Project feasibility

The project is planned and scheduled to be completed in 2 semesters. The approach that the author planned to use is by using simulation to analyze some well control procedures. The investigation revolved around effectiveness of driller's method, time for execution the whole kick-killing procedure, kill rate, flow check analysis, estimate circulation density and kick tolerance. Studies and researches are conducted since the first semester, while the simulation conducted in the second semester.

CHAPTER 2

LITERATURE REVIEW

Well control is defined as the management of the dangerous effects of unexpected high pressures on the surface equipments of drilling rigs searching for oil and gas. Well control is an integral part of the well planning process, be it for a new well or a reentry. To understand well control, pressure relationship should be understood well. The pressure that we deal with daily in the oil industry includes fluid, formation, friction and mechanical. The first line of defense for well control is having the correct mud weight in the hole. To ensure having the correct mud weight, it is necessary to know the formation pressure. Therefore, pressure indicators must be monitored. Pressure indicators are key parameters for kick prevention. In contrast, kick indicators mean that formation fluid has entered the wellbore, a kick has occurred and the first objective of prevention was not met. The function of well control can be conveniently subdivided into three main categories, namely primary well control, secondary well control and tertiary well control. These categories are briefly described in the following paragraphs.

2.1 TYPES OF WELL CONTROL

2.1.1 Primary Well Control

It is the name given to the process which maintains a hydrostatic pressure in the wellbore greater than the pressure of the fluids in the formation being drilled, but less than formation fracture pressure. If hydrostatic pressure is less than formation pressure then formation fluids will enter the wellbore. If the hydrostatic pressure of the fluid in the wellbore exceeds the fracture pressure of the formation then the fluid in the well could be lost. In an extreme case of lost circulation the formation pressure may exceed hydrostatic pressure allowing formation fluids to enter into the well. An overbalance of hydrostatic pressure over formation pressure is maintained, this excess is generally referred to as a trip margin.

2.1.2 Secondary Well Control

If the pressure of the fluids in the wellbore fails to prevent formation fluids entering the wellbore, the well will flow. This process is stopped using a blow out preventer to prevent the escape of wellbore fluids from the well. This is the initial stage of secondary well control, containment of unwanted formation fluids.

2.1.3 Tertiary well control

Tertiary well control describes the third line of defence where the formation cannot be controlled by primary or secondary well control (hydrostatic and equipment). However in well control it is not always used as a qualitative term. 'Unusual well control operations' listed below is considered under this term:

a) A kick is taken with the kick off bottom.
b) The drill pipe plugs off during a kill operation.
c) There is no pipe in the hole.
d) Hole in drill string.
e) Lost circulation.
f) Excessive casing pressure.
g) Plugged and stuck off bottom.
h) Gas percolation without gas expansion

2.2 INDICATIONS OF A WELL KICK [8]

2.2.1 Increase in the rate of penetration

A marked increase in the rate of penetration may indicate either a change in the type of rock being drilled or a reduced differential between the mud pressure and the pore pressure. Normally, the mud density is controlled so as to maintain a slight over-pressure relative to the pore pressure of the formation being drilled if this pressure is known. If the bit enters a formation in which the pressure is higher than expected, the over-pressure may be completely eliminated and a flow may occur.

The effect of the pressure differential on the rate of penetration is shown in the following Figure 1. Such a flow may be small and hardly detectable when circulating, indeed, the fractional pressure losses in the annulus may be such that the formation pressure is controlled and the flow only occurs when pumping stops. The state of equilibrium of the well must therefore be rapidly restored before drilling any further into the overpressured section or into a highly permeable formation which could yield a significant flow.

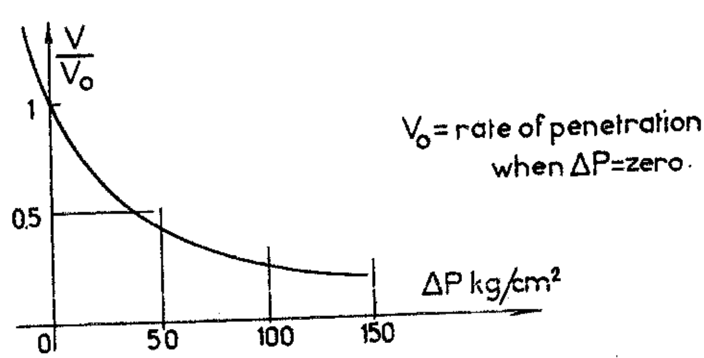


Figure 1: Rate of penetration in shales as a function of differential pressure

[8] Editions Technip,1981,Blowout Prevention and Well Control,Imprimerie Nouvelle,Paris

2.2.2 Hole takes less mud than normal when tripping

When pulling out of the hole, if the volume of mud pumped to keep the hole full is less than that normally required, formation fluids(water, oil or gas) have been produced into the wellbore. The mud volume normally required is equal to the volume of drill pipe already pulled out or slightly greater than this if there is some mud filtration loss.

This flow since it was not apparent when the pumps were stopped before starting to trip is the result of the piston effect caused by pulling the drill string out of the hole. This effect is greatest at high tripping speeds, when the clearance between the hole and the drill collars is small, when the mud viscosity is high and when the mud viscosity is high and when the bit and stabilizers are balled-up.

The flow may cease while the string is stationary or if the piston effect is reduced. However if gas has entered the wellbore, it will continue to rise and will eventually expand and force some mud out of the hole, which may then cause the well to become unstable. Even if the flow is water, a sufficient quantity may be produced into the wellbore to initiate instability.

2.2.3 Lost circulation

Mud in circulation may be lost to the formation due to:

(a) Excessive mud filtrate loss either in a very permeable formation or when the mud pressure is highly overbalanced
(b) Fracturing of weak formations caused by high mud weight or dynamic overpressure due to excessive circulation rate or running pipe too quickly
(c) Fill-up of air or gas-bearing fractured zones.

The following points should be noted:

(a) Although the overpressure caused by annular friction may give rise to lost circulation, the hydrostatic mud pressure may be lower than the pore pressure and a flow may occurred after circulation has stopped.

(b) A drop in the fluid level in the annulus will reduce the hydrostatic mud pressure across the entire open-hole section and may cause a flow.

(c) In a reservoir of high relief the mud weight required to control the well at the top of the structure may cause lost circulation at a greater depth since the reservoir pressure gradient is less than that of the mud. This effect is most pronounced in gas reservoirs.

2.2.4 Gas-cut mud

A gas-cut mud is often an indication of a flow and it is imperative that the bottom-hole conditions causing the gas-cutting are understood. As the gas rises in the annulus it expands slowly until it approaches the surface. At this point expansion takes place rapidly and causes a reduction in the mud weight. However, even though the mud weight may be appreciably reduced this does not necessarily mean that a blow-out will occur. As the major part of the gas expansion takes place close to the surface, the reduction in bottom-hole pressure is normally quite small.

It is however important to be aware of the reduction in bottom-hole pressure, the magnitude of which can be estimated using Figure 2.

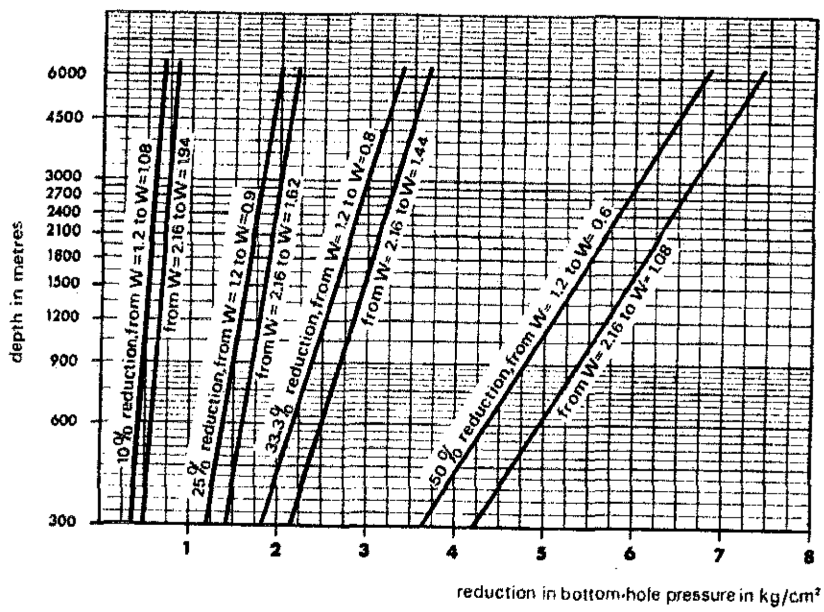


Figure 2: Reduction in hydrostatic mud pressure due to gas cutting

Gas cut mud may be a result of one or more of the following causes:

(a) Drilling through a permeable gas-bearing formation using mud of the correct weight

In this case no flow occurs but gas released from the cuttings causes the mud to become gas-cut. The amount of gas-cutting produced depends on the wellbore diameter, the rate of penetration, the mud density and the formation porosity and pressure. The problem may become serious if the rate of penetration is high. The gas released from the cuttings may then be of sufficient quantity to cause a significant reduction in bottom-hole pressure and thereby cause a flow.

(b) Drilling through a shale containing high pressure gas

As shale is practically impermeable, gas is only released from the cuttings and the freshly exposed wall of the hole and observation of the flow line with the pumps shut off will generally show that no flow has occurred. An increase in rate of penetration and hole and hole instability problems are very often associated with this type of formation especially when the hydrostatic mud pressure is lower than the pore pressure. If a permeable gas-bearing lens is encountered within the shales, a flow or gas bubble may occur. These observations may be used as a guide in the calculation of the minimum mud weight required to drill the next permeable formation, in addition to aiding in the selection of the depth of the next casing seat.

(c) Making connections and tripping

A gas bubble often appears at the end of the first cycle of the mud after tripping or making a connection. This gas known as "trip gas" or "connection gas" is either the result of swabbing the hole or of gaseous diffusion across the mud-cake. It should be noted that the latter phenomenon is not affected by the degree of overbalance (excess of mud pressure over formation pressure) but becomes more significant as the amount of oil in the mud increases.

The small volumes of gas observed after tripping, making a connection or when the pump is stopped are therefore normal occurrences, but on no account should they be ignored. The gas volumes should be carefully monitored on successive trips or connections especially if they exhibit a tendency to increase. This phenomenon may be usefully employed to indicate increases in pore pressure if standard connection and tripping practices are used.

(d) Drilling through a poor reservoir with a pore pressure higher than the mud hydrostatic pressure

The formations has a very low permeability as no gain has been detected while drilling but observation of the flow line with the pumps stopped indicates that the well is flowing slightly. Depending on circumstances drilling may continue underbalanced(providing that tripping is possible) or the mud weight may be increased.

(e) Other possible causes:

The mud may also become cut with air introduced into the drill string while making a connection or with H_2S or CO_2 formed by the decomposition of certain mud additives in hot wells.

2.2.5 Water-cut mud

If the well is drilled into a porous and permeable water-bearing formation with a pressure higher than that of the mud, a salt water flow may occur. Depending on the differential pressure between formation and wellbore and the formation permeability, the flow may be detected by a change in the chloride content of the mud, a change in its density or rheological properties or by an increase in pit level.

2.2.6 Increase in return flow rate and pit level

An increase in pit level is a certain sign of the entry of formation fluids into the well but the inertia of the circulating system or the instability of the pit level on floating rigs are often such that an increase is not always seen promptly. If the rate of flow of the returns is measured or observed at the flowline, any increase will be noted before the corresponding pit level increase can be measured and the well should immediately be shut in. If there is any doubt, observation of the flow line with the pumps stopped will confirm a suspected flow.

2.3 WELL CONTROL METHODS

2.3.2 Wait and weight method

According to Abeerden Drilling Schools, the "Wait and Weight" is sometimes referred to as the 'Engineers Method' or the 'One Circulation Method'. It does, at least in theory, kill the well in one circulation. Once the well is shut in and pressures stabilized, the shut in drill pipe pressure is used to calculate the kill mud weight. Mud of the required weight is made up in the mud pits. When ready, kill mud is pumped down the drill pipe. At commencement, enough drill pipe pressure must be held to circulate the mud, plus a reserve equivalent to the original shut in drill pipe pressure. This total steadily decreases as the mud goes down to the bit, until with kill mud at the bit, the required pressure is simply that needed to pump kill mud around the well. The choke is adjusted to reduce drill pipe pressure while kill mud is pumped down the string. With kill mud at the bit, the static head of mud in the drill pipe balances formation pressure. For the remainder of the circulation, as the influx is pumped to the surface, followed by drill pipe contents and the kill mud, the drill pipe pressure is held at the final circulating pressure by choke adjustment.

Advantages of the Wait and Weight Method

- Lowest wellbore pressures, and lowest surface pressures - this means less equipment stress.
- Minimum 'on-choke' circulating time - less chance of washing out the choke.

Disadvantages of the Wait and Weight Method

- Considerable waiting time (while weighting up) - gas migration.
- If large increases in mud weight required, this is difficult to do uniformly in one stage.

2.3.3 Driller's Method

This method requires 2 circulations. During the first circulation, the drillpipe pressure is maintained at a constant value until the influx is circulated from the well. During the second circulation, kill mud weight is pumped to the bit while following a drillpipe pressure schedule. If all of the influx is successfully circulated from the well in the first circulation then during the second circulation, the casing pressure should remain constant as the drillpipe pressure reduces from ICP to FCP. When the kill mud enters the annulus, FCP is maintained constant until the kill mud reaches surface. Figure 3 shows the drill pipe pressure graph of the two circulation method.

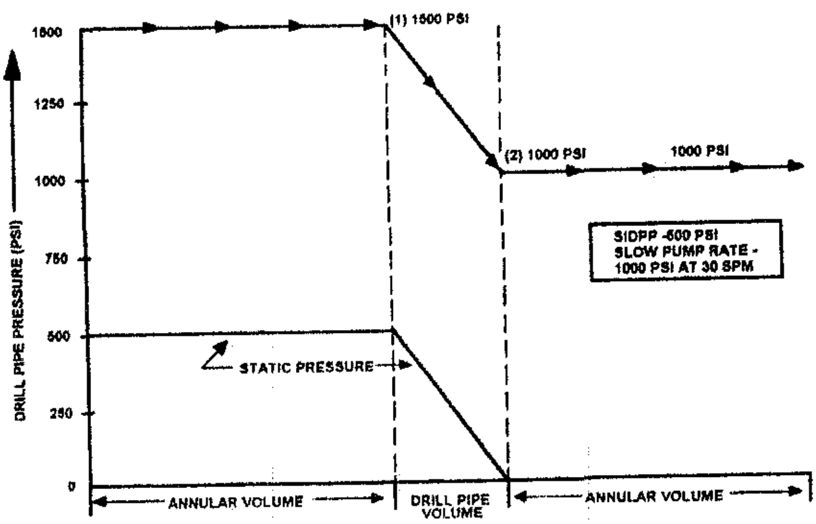


Figure 3: Drill pipe pressure graph of the two circulation method

Advantages of the Driller's method

- Less chance of gas migration
- Able to remove hydrocarbons from the well even if limited barite available on location

Disadvantages of the Driller's method

- Highest surface pressure for longest period
- More time circulating through choke

According to Lage, A.C.V.M, Nakagawa, E.Y and Cordovil, A.G.D.P.(1994),

> Both procedures are based on the same principle, the maintenance of the bottom hole pressure above the reservoir pressure but the definition of the most relevant points to be considered are procedure complexity, time requirements for execution and loads in the wellbore.

The complexity of engineer method depends on the availability of kill mud. If it is ready to pump, the execution will be as easy to implement as the driller's method. Otherwise, if kill mud is not ready for pumping, gas migration will increase well pressure. In order to avoid some consequences. pressure must be bled off during kill mud preparation. A bleeding procedure is planned in accordance to a predetermined policy based on the maximum accepted wellbore load and without permitting the entrance of any additional gas.

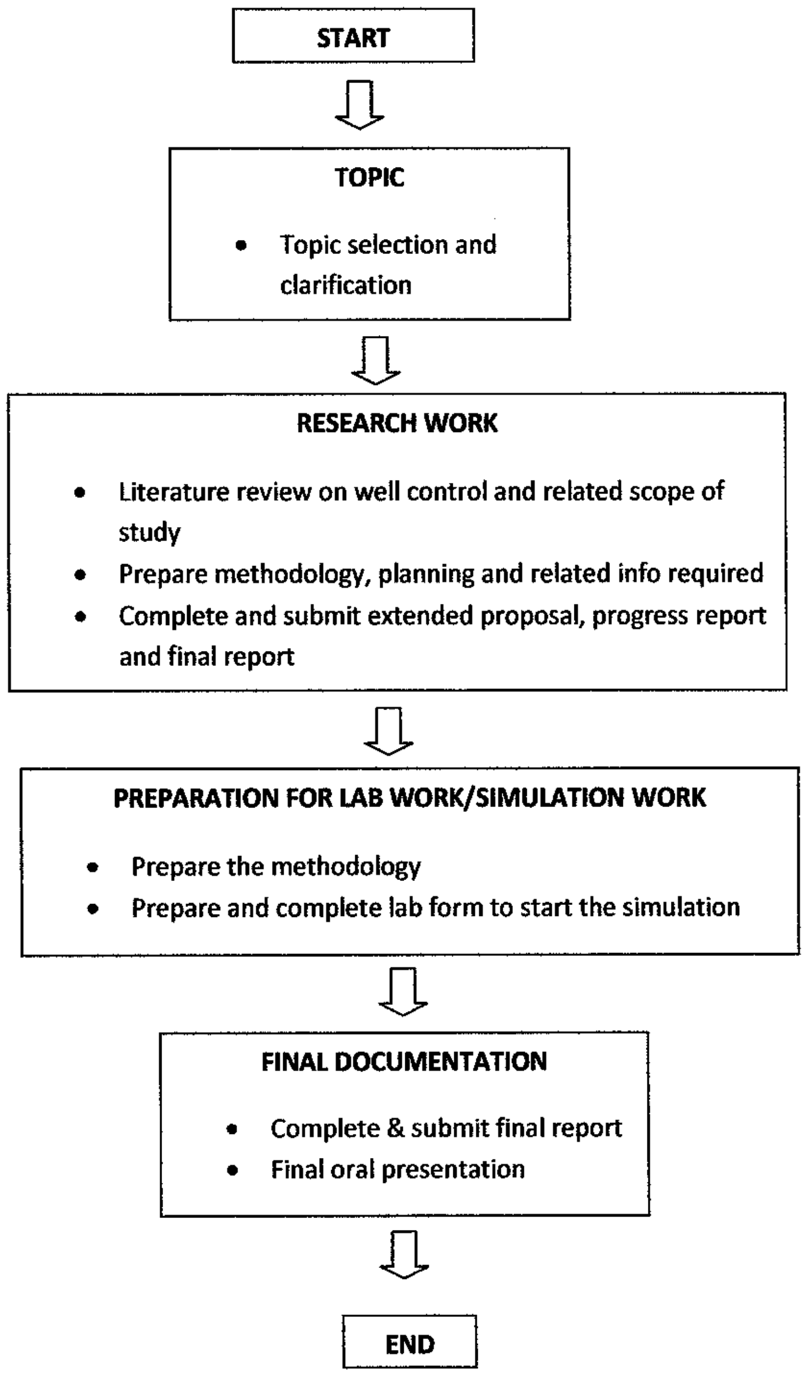
In such situation, the engineer's method is not easily implemented. As the comprehension of pressure behavior in the well is quite difficult, crew must be very well trained to execute it. In fact, as the great majority of drilling rigs do not have sufficient volume of mud tanks to keep heavy drilling fluid prepared for using in well control subjection, driller's method is usually the easiest procedure to be performed.[9]

[9] Lage , A.C.V.M.,Nakagawa, F.Y. and Cordovil, A.G.D.P,,"Well Control Procedures in Deep Water,Argentina", SPE paper 26952 presented at the III Latin America/Carribean Petroleum Engineering Conference held in Buenos Aires,Argentina,27-29 April 1994

CHAPTER 3

METHODOLOGY

3.1 RESEARCH METHODOLOGY



3.2 GANTT CHART FOR FYP

FYP 1

PROJECT ACTIVITIES	WEEK													
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Project title selection and clarification														
Work on Preliminary Report														
Extended Proposal Submission														
Further research on project (journal papers and lecturer discussion)														
Further research on project (methodology and feasibility study)														
Preparation for proposal defense presentation														
Seminar(Proposal Defense and Progress Evaluation)														
Start to work on interim report														
Submission of draft interim report														
Submission of interim report														

FYP 2

PROJECT ACTIVITIES	WEEK														
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
Simulation laboratory booking															
Simulation work continues															
Submission of progress report															
Project work continues															
Pre-EDX															
Submission of draft report															
Submission of dissertation(soft bound)															
Submission of technical paper															
Oral presentation															
Submission of project dissertation(hard bound)															

3.3 KEY MILESTONE

FYP 1

No	Activities	Date
1	Study the theoretical part of well control	W3-W6
2	Work on preliminary report	W3-W6
3	Study on the well control methods	W7-W11
4	Study on DrillSIM 500 and well control simulation	W7-W11
5	Work on project defense and progress evaluation	W7-W9
6	Work on draft of interim report	W10-W13
7	Work on interim report	W10-W14

FYP 2

No	Activities	Date
1	Work on simulation	W2-W10
2	Work on progress report	W8
3	Pre-EDX combined with seminar/Poster Exhibition/Submission of final report(Softbound)	W11
4	EDX	W12
5	Delivery of final report to External Examiner	W12
6	Final oral presentation	W14
7	Submission of final report(Hardbound)	W16

3.4 EQUIPMENT & TOOL

Below are brief descriptions on the equipment and simulation software that will be used in this project. The simulation software that is available for this project is DrillSIM 500 in university.

3.4.1 DrillSIM 500 Overview

DrillSIM 500 is one type of DrillSIM simulation model that comes equipped with a range of simulated consoles, equipment and manifold closely resembling those found on a modern drilling rig floor. The consoles are manufactured using controls and instrumentation resembling those used in operating field consoles. The DrillSIM system compute employs a mathematical model. The model simulates the operation of rig equipment and downhole characteristics in real world situation.[5] The DrillSIM simulation software is a fully integrated modular package that is designed to interact with the user actions. Several base-line exercises are supplied with the systems including:

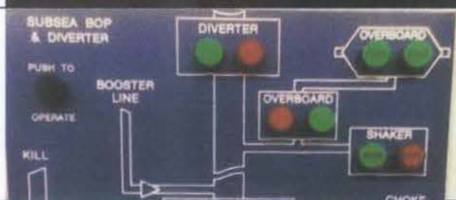
- Top drive with surface BOP
- Top drive with subsea BOP
- Kelly with subsea BOP
- Kelly with surface BOP
- Workover
- Cementing
- Top drive with motion compensator and subsea BOP
- Kelly with motion compensator and subsea BOP

3.4.2 DrillSim 500 Standard Equipment

a) Drilling controls console and gauges console
b) Surface and subsea blowout preventer and diverter
c) Standpipe and choke manifolds
d) Choke console
e) Kelly and top drive
f) Touch screen and graphics station
g) Desktop PC

[5] Drilling System Ltd, Drillsim Operators Manual

3.4.2 DrillSIM 500 consoles

1	Drilling controls console	
2	Surface BOP control console(red)	
3	Subsea BOP control console(blue)	
4	Diverter control console	
5	Remote choke control console	

3.4.3 DrillSIM 500 scope of simulation

a) Gas migration

The simulator's gas migration model enables training and experience of the hazards associated with gas migration during well control procedures.

b) Kicks while drilling

The simulator models a number of warning signs which can be recognized by the driller including:

- Pit level gain
- Flow rate increase
- Penetration increase
- Rotary torque increase
- Drill pipe pressure decrease

c) Underground blowout

The simulator provides the user with experience of the various sequences of events that would lead to underground blowout. The mathematical model dynamically monitors downhole conditions for kick influx from high pressure permeable formations and for formation fracture resulting in lost circulation.

d) Multiple kicks

The simulator will model multiple kicks to give the user experience in taking in additional volumes of kick fluid during the process of killing a well. The effect of the user's control of the rate of circulation combined with the inherent resistance to flow of the surface equipment may be sufficient to create underbalanced pressures across potentially kicking formations.

CHAPTER 4

RESULT & DISCUSSION

4.1 DATA GATHERING

For the simulation, the author has chose Gelama Merah -1 field to be used to simulate different conditions using Drillsim 500 software. Gelama Merah is a vertical exploration well located in Block SB-18-12 Offshore Sabah,Malaysia. The rig arrived at location on 29 December 2002. The well was successfully drilled from seabed at 70.1 m to 1636 m and hydrocarbon reservoir was encountered as predicted. For simulation purpose, the author has set some depth more than 1636 m to be a gas reservoir in order to simulate the kick condition. Below are details of Gelama Merah-1 used in the simulation:

GELAMA MERAH-1

Company	: PETRONAS CARIGALI SDN BHD
Location	: Offshore Sabah,Malaysia
Block/Area	: Sabah Basin
Profile	: Vertical
Rerefence depth	: Rotary table
Proposed total depth	: 1630 m TVD-SS
	1630 m MD-RKB
Actual total depth	: 1636.0 m mMD-RKB
	1635.8 mTVD-RKB

Mud properties:

Depth(m)	**1636**
Mud weight(ppg)	10.50
Funnel viscosity(cps)	30
Yield point(lb/100sqft)	27

9-5/8" Casing data:

Date	08 Jan 2002
Open hole depth	1636 m
Open hole diameter	12 ¼ in
Casing OD	9-5/8 in
Casing ID	8.681 in
Grade	L 80 BTC
Weight	47.0 ppf
Shoe depth	1570.38 m

12 ¼" Phase Leak-off test

Date	02 January 2003
Depth test(MD)	556 m
Depth test(TVD)	556 m
Shoe depth(TVD)	550.76 m
Mud weight	9.2 ppg
Applied pressure	430 psi
EMW	13.75 ppg

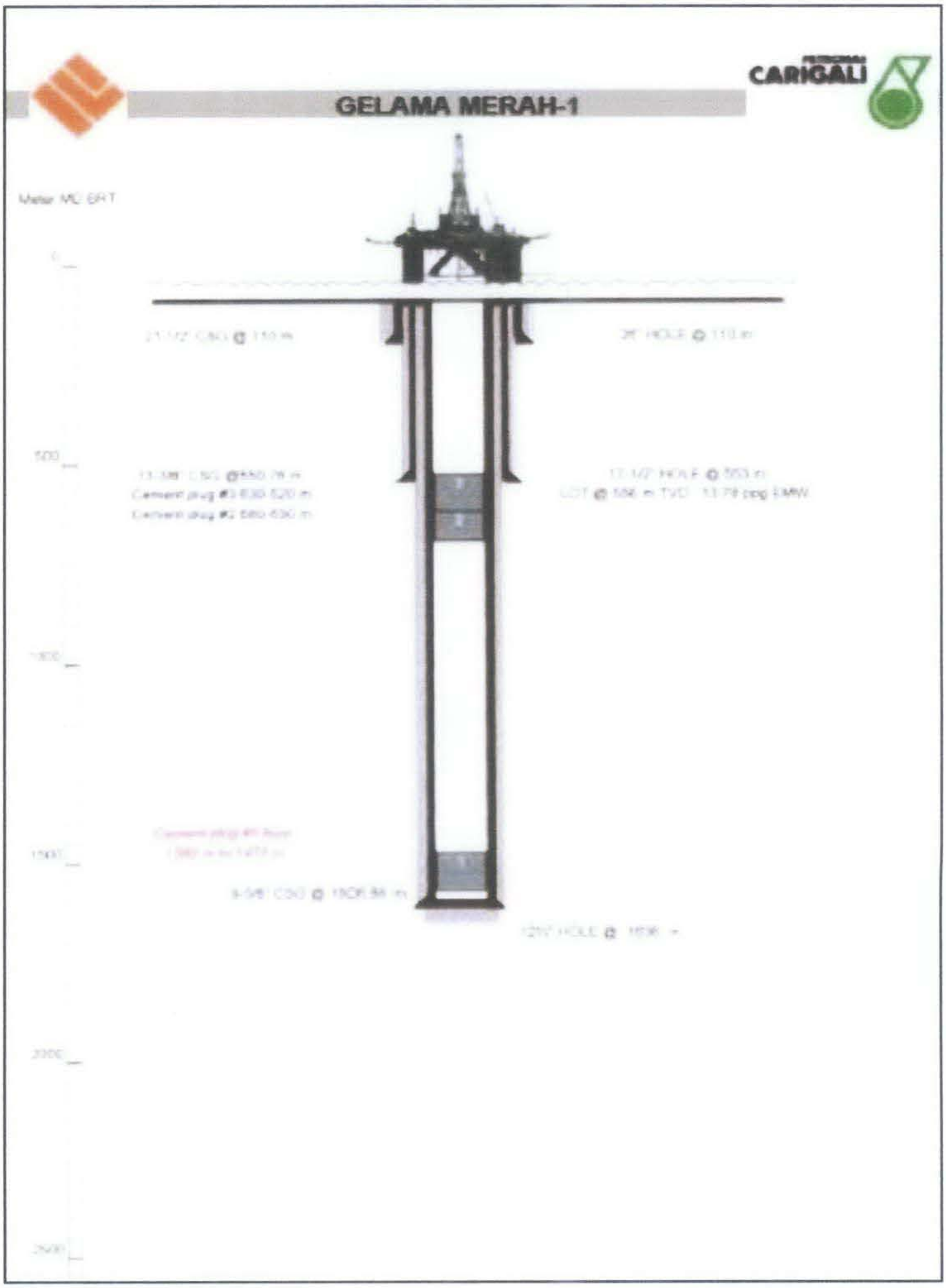


Figure 4: Gelama Merah-1 Wellbore Diagram

4.2 SIMULATION WORK RESULTS & DISCUSSIONS

Simulation 1: To study the gas migration issues when BOP is open during kick

Case 1: Kick during drilling at high permeability gas formation at 1637.5 m depth

Formation permeability	70 md
Kick zone depth	1637.5 m
Volume of kick	248.5 bbls
Time period before kicks reach surface	12.53 min
Average migration rate	10.525 bbls/min

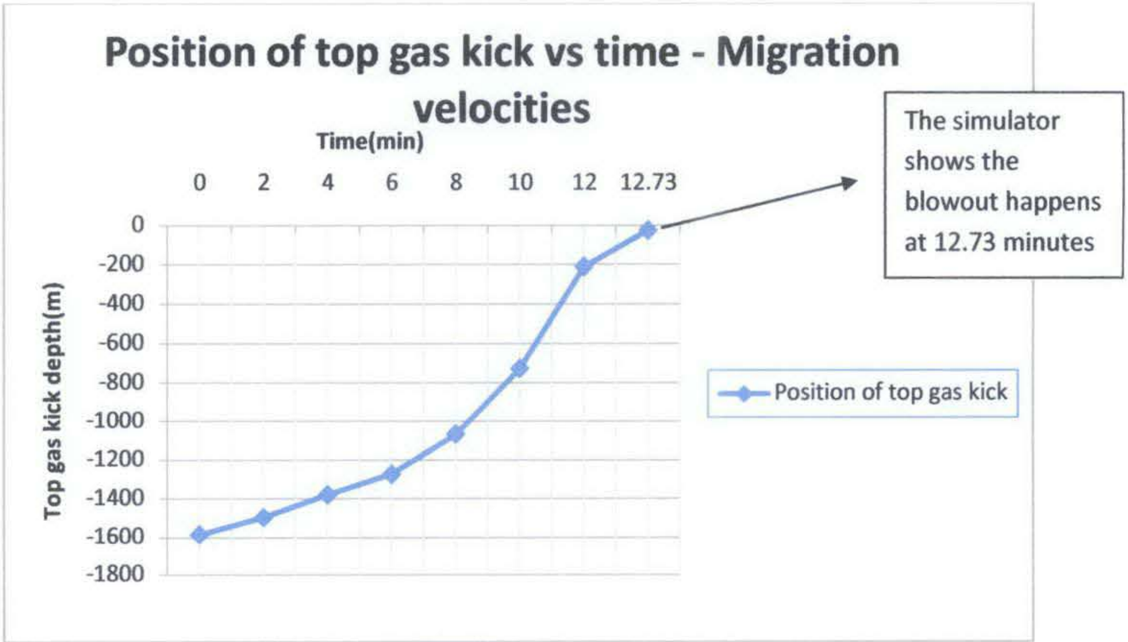


Figure 5: Position of top gas kick versus time for 70 md gas formation

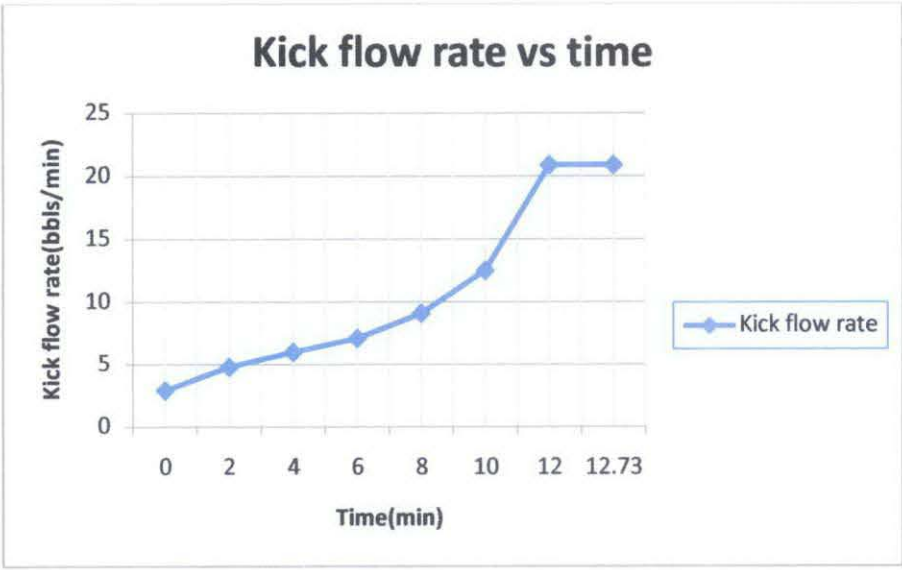


Figure 6: Kick flow rate versus time for 70 md gas formation

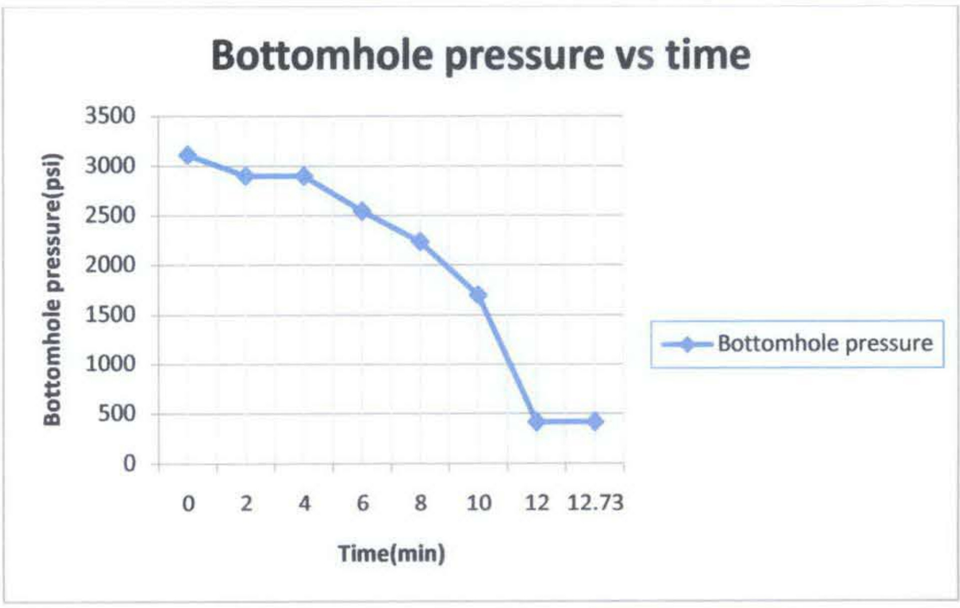


Figure 7: Bottomhole pressure versus time for 70 md gas formation

Case 2: Kick during drilling at low permeability gas formation at 1637.5 m depth

Formation permeability	20 md
Kick zone depth	1637.5 m
Volume of kick	237.4 bbls
Time period before kick reach surface	16.53 min
Average migration rate	7.19 bbls/min

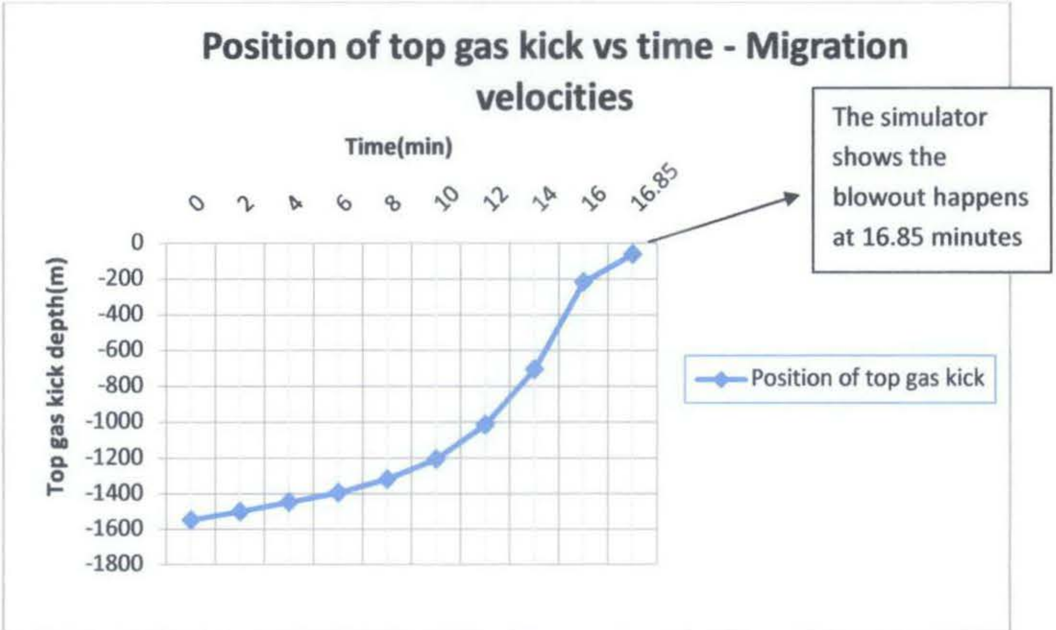


Figure 8: Position of top gas kick versus time for 20 md gas formation

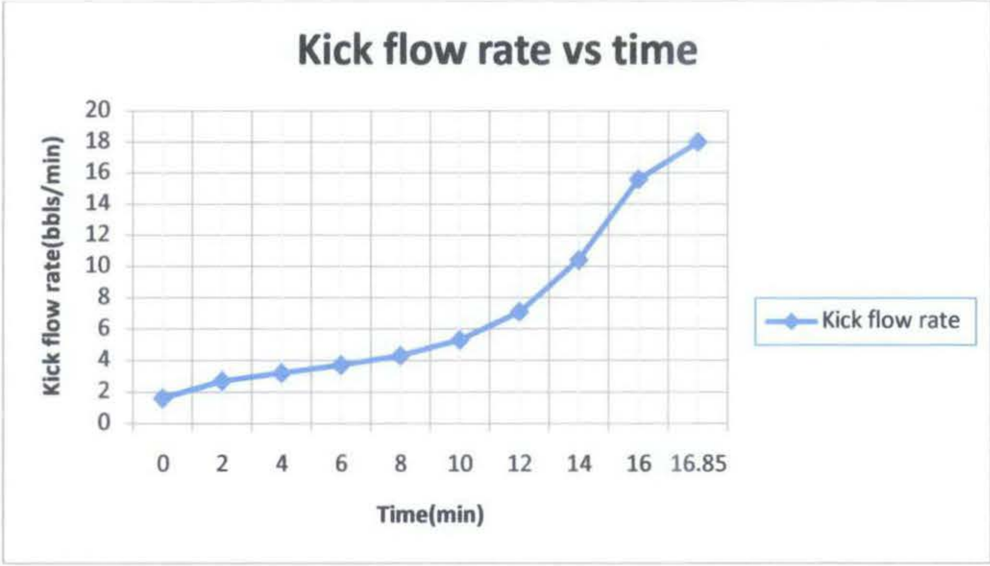


Figure 9: Kick flow rate versus time for 20 md gas formation

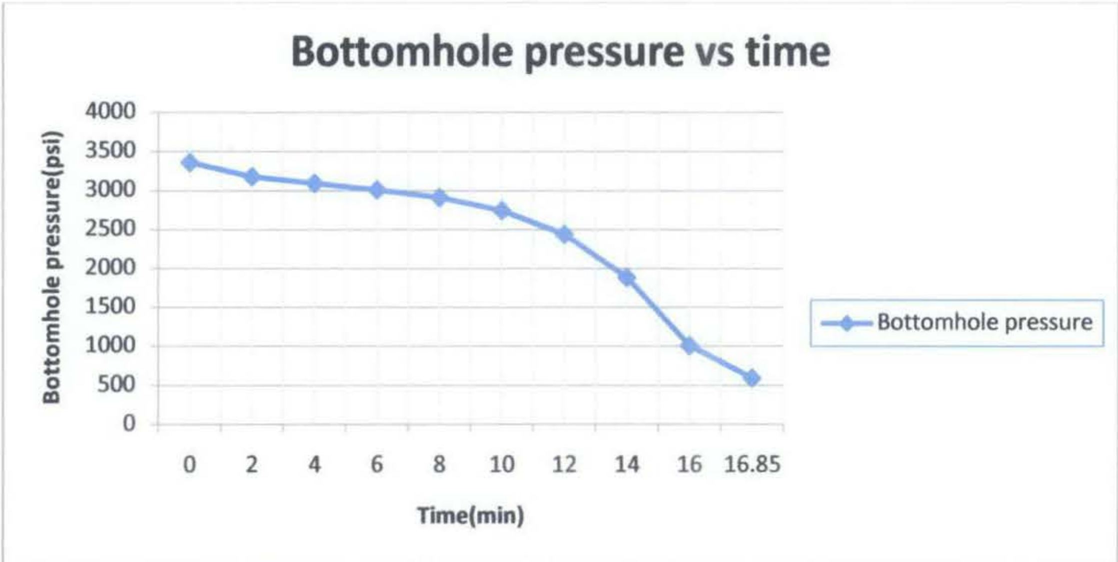


Figure 10: Bottomhole pressure versus time for 20 md gas formation

Discussion:

In case of an influx of gas in water based mud, one has to be aware that the kick will migrate and expand on its way upwards. Free gas expansion will lead to a reduction in bottomhole pressure which again can result in larger influx volumes.

An important part of the simulation was to evaluate how fast the gas would migrate to surface and the consequences for the operational procedures.

In case 1:

In Fig. 5, we have shown the position of the gas front of a 248.85 bbls kick migrating upward. It took around 10 to 12 minutes before the kick was at surface. Based on Fig. 7, within this period of time, the bottomhole pressure reduced drastically. At 12.73 minutes, the simulator shows the well experienced blowout.

In case 2:

In Fig. 8, we have shown the position of the gas front of a 237.4 bbls kick migrating upward. It took around 14 to 16 minutes before the kick was at surface. Based on Fig. 10, within this period of time, the bottomhole pressure reduced drastically. At 16.85 minutes, the simulator shows the well experienced blowout.

These numbers seemed large at first sight and caused some discussions. Gas migration depends on various factors like gas volume fractions, geometry and so on. Hence, they may vary from case to case and it is not easy to generalize. The relatively large gas migration velocities made it clear that BOP had to be closed quickly if well control incident was suspected. Higher permeability gas formation would lead to faster kick migration to surface and caused blowout. In the simulation, difference time period between low and high permeability gas formation is just 4 minutes.

Simulation 2 : To study the gas migration and pressure effects when BOP is closed during kick

Case 1: Kick during drilling at high permeability gas formation(70 md) at 1639 m depth

Figure 11: Casing shoe pressure versus time for 70 md gas formation

Case 2: Kick during drilling at low permeability gas formation(20 md) at 1639 m depth

Figure 12: Casing shoe pressure versus time for 20 md gas formation

Discussion:

If a kick is taken and the BOP is closed in, well pressures will build up until the kick has migrated to BOP. Fig. 11 and Fig. 12 show a same trending which is the simulation of the pressure build up at the casing shoe for a low and high permeability gas formation.

For case 1:

It showed that the casing exceed fracture pressure in 80 minutes of shut-in.

For case 2:

It showed that the casing exceed fracture pressure longer than case 1 which is in 410 minutes or more than 6 hours shut-in.

Both results showed that the casing shoe pressure could exceed casing shoe fracture pressure if the well was kept shut in too long before the well kill operation was initiated. Therefore, the well should not be kept too long especially for high permeability gas formation.

Simulation 3: To study and compare different kill pump rates and their effect to the annulus pressure at casing shoe and kick circulation time

For this case, the Driller's method has been chosen to be carried out to compare the different kill pump rates and their effect to casing shoe pressure and kick circulation time. 3 reducing pump rates are chosen which are 1/3, ½ and 2/3 of normal circulating rate, 90 SPM. The results obtained are pressure at casing shoe during 1st circulation. For this time, the formation permeability is set to the same value which is 70 md.

Simulation procedures using Driller's method:

1) Surface instrumentation monitored. Once "positive" kick detected, step 2 is followed.
2) Pick up off bottom and space out (tooljoint is ensured not to across the ram). Rotary stopped.
3) Pump 1 and pump 2 stopped. BOP' annular or upper ram is closed. BOP upstream choke valve is opened.
4) Shut in drillpipe pressure(SIDPP) and shut in casing pressure(SICP) are measured and recorded. Final pit gain recorded. The remote choke is adjusted to maintain the SICP constant while the pump brought up to desired circulation rate simultaneously. 3 desired reducing pump rates for 3 cases are 30 SPM, 45 SPM and 60 SPM.
5) When the casing pressure is stabilized, the new circulating drill pipe pressure is recorded. The remote choke is adjusted to maintain the initial circulating drill pipe pressure constant until the influx or kick is out.
6) Once influx out, pump stopped and remoke choke closed completely while maintaining the last casing pressure constant.

Case 1: 30 SPM(1/3 of normal circulating rate)

Time (min)	Top kick depth (metre)	Annulus pressure at casing shoe (psi)
0	1556.22	3622
10	1216.81	3859
20	1079.91	3883
30	662.4	3884
40	372.57	3865
50	91.13	3808
60	0	3891

Case 2: 45 SPM(1/2 of normal circulating rate)

Time (min)	Top kick depth (metre)	Annulus pressure at casing shoe (psi)
0	1554.51	3621
10	1200.7	3877
20	806.39	3909
30	396.14	3814
40	9.14	3616
50	0	3892

Case 3: 60 SPM(2/3 of normal circulating rate)

Time (min)	Top kick depth (metre)	Annulus pressure at casing shoe (psi)
0	1554.53	3621
10	1181.01	4049
20	676.81	4042
30	158.85	4011
40	0	3951

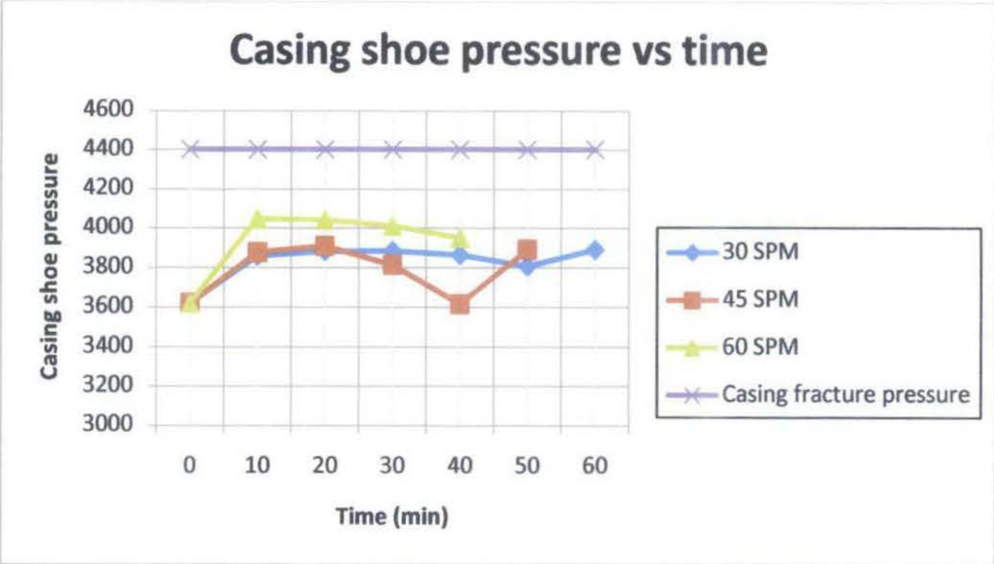


Figure 13: Casing shoe pressure versus time for different kill rate

Discussion:

From the simulation, it can be seen that the time to circulate out the kick is decreasing when the circulation pump rate is increasing. 2/3 of normal circulating rate which is 60 SPM circulate out the kick in just 40 minutes less 10 minutes than 45 SPM. However, eventhough this rate circulate out the kick in a very short time compared to others, the maximum casing shoe pressure using this rate, 4049 psi is very near to casing fracture pressure,4403 psi compared to 30 SPM and 45 SPM where both maximum casing shoe pressure are 3891 psi and 3909 psi. It is not usually desirable to operate the mud pump at a fast rate while circulating a kick for the following reasons:

a) The circulating pressure at the fast rate plus the shut in drill pipe pressure might exceed the rating of the pump
b) The time to react to a sudden change in pressure or to some other situation that may develop is reduced. Less control over the well kill operation results.

c) If kill weight mud is being pumped, the drilling crew may not be able to mix barite fast enough to maintain proper weight

From this, we can concluded that 30 SPM and 45 SPM are the safer kill rate pump than kill rate pump which more than half of the normal circulating rate. Pumping kick out at about one half the normal pump rate is the maximum rate that should be used. The casing shoe that exceeds the casing fracture pressure would lead to loss circulation and the worst case scenario which is underground blowout. Between 30 SPM and 45 SPM, 45 SPM could be the ideal kill rate to circulate the kick faster and safely.

CHAPTER 5

CONCLUSION & RECOMMENDATIONS

To design well control guidance, many factors have to be considered. The guidance perhaps becomes useful for offshore personnel to control the well pressure and handle kick. Different types of well would have different ways to overcome the problems during drilling activities. It also depends on the environments of the well. The environments would be high concentration of H_2S, high pressure and temperature, shallow gas and deep well. For this project, the environment chosen is vertical shallow well where Gelama Merah field is chosen to be used for drilling simulation. There are many journals and research papers that proposed new methods and evaluate conventional methods in oil and gas industry. Some of the methods have been implemented and were proven effective to control the well. To evaluate the methods, simulation software is needed to obtain the results under different kind of situations and kicks. The results will indicate the effectiveness and complexity of the tested methods. All the data result from the simulation have been presented in this report. The results findings have been analyzed and discussed. At the end of this project, the simulation results assist the author to come out with critical analysis and helpful recommendations. Drilling simulator which is Drillsim 500 used for simulation is a very helpful software and equipment that helps the author to understand more about well control theory and practical. Here are some conclusions and recommendations regarding well control issues and procedures based on simulation result using real field data which is Gelama Merah 1:

a) Kick prevention is definitely the best well control method. The knowledge on kick behavior is very important to select the best well control method in order to handle the kick safely. Equivalent circulating density must always stay within the operating window. This can be achieved with efficient drilling hydraulic practices.
b) Pit volume is still the best kick indicator. It is possible to detect small swab kicks if very tight pit level policies are followed.

c) Driller's method has some advantages than Wait & Weight method. Control duration is longer for driller's method but problems are taken one by one. First, the gas is evacuated from the well and then a kill mud is possibly displaced in order to control the bottom hole pressure. In a situation with an extremely narrow margin between the pore and the fracture pressure such a in deep water drilling, it is definitely a safer procedure.
d) Flow check should be avoided for the sake of minimizing influx volumes and its consequences over the pressure profile in the open hole section during displacement of the gas out of the well.
e) The well should be closed as quickly as possible when kick is detected in whatever situation or in case of any doubt without any flow check. Higher permeability gas formation would lead to faster kick migration to surface.
f) There was a potential for fracturing at the shoe if the well was kept shut in too long before the well kill operation was initiated. The study showed that one could not wait too long before initiating the kill procedure since migrating gas kicks under closed in condition could lead to excessive pressure build up.
g) For kill rate, ½ of the normal pump rate is the maximum rate that should be used for pumping kicks out of the well. More than this rate could probably lead to loss circulation and underground blowout if the drilling crew does not properly handle the kick.

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