بسم الله الرحمن الرحيم

Sudan University of Science and Technology

College of Petroleum Engineering and Technology

Project Title:

Three Well Control Methods Comparison

Including Application & Practices

Work over rigs; Jake S-9 Block (6)

Sudan (Case Study)

Graduation Project submitted to college of petroleum Engineering and Technology at Sudan University of Science and Technology

Practical fulfillment of the Requirements of the Degree of B.tech in petroleum engineering

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October 2018

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Signature: …………………………………………………………………

Date: ………../October/2018

الاستهلال


يا أيها الذين آمنوا إذا قيل لكم تفسحوا في المجالس
فافسحوا يفسح الله لكم وإذا قيل انشزوا فانشزوا
يرفع الله الذين آمنوا منكم والذين أوتوا العلم درجات
والله بما تعملون خبير
@AlAmoudiaama

Dedication

Every challenging work, needs self -efforts as well as guidance of elders especially those who were very close to our heart

Our humble effort we dedicate to our sweet and loving Parents

Whose affection, love and encouragement make us able to get much success and honor. Along with all hard working and respected Teachers

ACKNOWLEDGEMENT

Thanks to god first and foremost. We feel always indebted to god, the most kind and the most merciful.

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ABSTRACT

Well control problems plagued the petroleum industry since it's infancy and known as losses of valuable resources, costs increasing, environmental damages, personnel casualties. The objective of this research is to analyzes well control case study for work over rig; block-6.

Three different killing methods have been applied: Driller; W&W and concurrent methods. The formation, borehole; wellhead; rig equipment and lay out are considered as a communicating system, in which the three are influenced and restrained by each other.

Concurrent method has been applied to kill the well. It is a complex technique combining both driller and W& W methods; which it is not common in the oil industry and is the first time to be applied in the Sudan for work over rig.

التجريد

مشاكل التحكم في الابار المندلعه كانت معضله في صناعة النفط بسبب التكلفه العالية والمشاكل البيئية وفقدان ارواح العاملين.

الهدف من البحث تحليل عملية السيطرة على الابار في Work Over Rigs في مربع (6) .

طبقت ثلاث طرق مختلفة كالاتي :

- Wait and Weight
- Concurrent
- Driller

مع الوضع في الاعتبار ضغط الطبقة و معدات الحفاره و راس البئر باعتبارها منظومة متكاملة

طبقت concurrent لاخماد البئر وهي طريقة اخماد معقدة اكثر من الطريقتين الاخريتين وهي ليست شائعة الاستخدام في الصناعة النفطية وهي اول مره تطبق في السودان في الحفاره .

content

List of Figures

List of Tables

Abbreviations

P &E	Petro -Energy E & P co., ltd
GNPOC	Greater Nile Petroleum Operating Company
WNPOC	White Nile Petroleum Operating Company
CNPC	China National Petroleum Company
DQN	Dqein Company
HYD	Hydrostatic pressure
MAASP	Maximum allowable annular surface pressure
ICP	Initial circulation pressure
FCP	Final circulation pressure
BHP	Bottom Hole Pressure
SICP	Shut in casing pressure
SIDPP	Shut in drill pipe pressure
BOP	Blow out preventer
DST	Drill stem test
RFT	Repeat formation test
EOWR	End of well report
FWTR	Final well test report
EMW	Equivalent mud weight
OMW	Original mud weight
KMW	Kill mud weight
SPM	Stroke per minutes
SPR	Slow pump rate
TVD	True vertical depth

MD	Measure depth
DP	Drill pipe
HWDP	Heavy weight drill pipe
DC	Drill Collar
BHA	Bottom hole assembly
POOH	Pull out of hole
RIH	Run in hole

Chapter 1

Introduction

1.1 Introduction

In oil industry the first step is the drilling of the wells that will produce the oil. There is two type of drilling wells vertical wells and horizontal wells. Now days the drilling science is develop and growth day by day and new technology has been applied to keeping up human needs for energy that we got from oil and gas industry. Drilling wells starts by spud the rig equipment at the location of the well that spouse to be drill and drill the conductor hole then surface and intermediate then production this compartment according to casing installation.

Drilling operations is some complex procedures and full of problems like stuck pipe and low rate of penetration and hole deviation. The most dangerous problem is well control cases.

Stuck pipe is one of drilling operation problem that we face in oil industry. The stuck pipe cannot pull up cannot go down and cannot rotate. Stuck pipe has two section differential and mechanic stuck.

Low rate of penetration (ROP) is putting more weight on bit with low penetration occurs when drilling hard formation or bit selection is not suitable for the formation.

Hole deviation is means the well is take a path different than the planed path it's occur due to Bottom hole design is not proper for stabilizer position or bit type.

Well control is most danger and cost drilling operation. The purpose of well control is to ensure that fluid does not flow in an uncontrolled way from the formation being drilled into the borehole and eventually to surface this flow will occur if the pressure in the pore space of the formation being drilled is greater than the hydrostatic pressure.

Most of drilling problem has direct relationship with geological description of specific area (Sudan).

(Well Control Strategy Plan Block Vil –Dindir -Sudan (Case Study) ,shazly Sayed Ahmed, 2011)

1.2General Geological Description of Main Basin in Sudan:

There are seven Main Basin in Sudan but in this research we mention the main five that maycontain hydrocarbon as shown below

1-Blue Nile Basin:

The Blue Nile basin originated in an area of Neoproterozoic rocks aged about 750Ma that had become a peneplain, possibly during the Paleozoic era (540 - 250Ma). The basin was formed due to rifting during the Mesozoic era (250 - 65Ma). Between the Triassic and early Jurassic, about 300m of fluvial sediments were deposited by rivers and streams

2-Khartoum Basin:

The Khartoum Basin is situated in central Sudan. The basin is essentially a simple, elongated, faulted, rift basin. It is sub-divided into three sub-basins, the Dongola to the northwest, the Atbara to the northeast and the Blue Nile Sub-basin to the southeast. To the northwest, a hinge line separates the Khartoum Basin from the Uweinat High. All other basin boundaries are an onlap of the basin sediments onto pre-Paleozoic, probably pre-Cambrian basement massifs

3-Muglad Basin:

The Muglad Basin is a large rift basin located in southwestern Sudan. At its nearest point, it lies approximately 600 km southwest of the city of Khartoum.

The Muglad Basin is bordered largely by basement rocks in the north, west and southwest and by a similar intracratonic rift basin, the Melut Basin, to the east.

4-Melut Basin:

The Melut Basin is situated in central Sudan, to the south of the Khartoum Basin. It is located wholly in desert terrain, between 5°N and 14°N, and 30°E and 35°E. It is approximately 237,000 sq km in a real extent. The northern part of the White Nile flows through the northcentral part of the basin. It is a predominantly north-south orientated faulted rift basin, a northerly extension of the East African Rift Valley system. It has a single sub-basin, the Kosti, which lies in the extreme northwest. The Kosti Sub-basin shows a northwest-southeast trend in contrast to axial trend of the main basin.

5-Red Sea Basin:

Is a spreading center between two tectonic plate the African plate and Arabian plate? It extends from the dead sea transform fault system and end at an intersection with the Aden ridge and the east African rift forming the afar triple junction in the afar depression of the horn of Africa.(GANI. DS, M. G. ABDELSALAM, S. GERA and M. R. GANI, 2008, " Stratigraphic and structural evolution of the Blue Nile Basin", Northwestern Ethiopian Plateau", GEOLOGICAL JOURNAL Geol).

This topic have been selected to contribute in providing practical solutions to the oil industry in Sudan by solving one of wells control problems in Block-6, and especially no studies related to this subject was conducted in Sudan with the knowledge that this problem (well control) is one of the biggest problems facing the drilling operations and most dangerous all over the world because it have resulted in losses of valuable resources, increase drilling costs, environmental damage, increased regulations, injuries to personnel and lost of life.

The objective of this research to determine the best method to kill the well of the three methods after making calculations for all the methods.

Well control is consist of five method three method is main method other two is consider as subsidiary method.

1. Wait and weight method (main method)
2. Driller method (main method)
3. Concurrent method (main method)
4. Volumetric method (subsidiary method)
5. Pull heading method (subsidiary method)

Work over operation is the maintenance operation conduct to maintain any well deactivate for any reason such artificial problem or plugging and perforation production zoon and etc.

Our case study is blow out happen in jack field during work over operation Perforation of Abugabra formation.

Our topic includes five chapters as following:

Chapter 1: Introduction

Background about drilling & drilling problem & work over and General geological background

Chapter 2: Literature Review& Theory

Blowout accidents all over the world from 1955 to 2010 and Definitions of well control & well control method and relative equipment

Chapter 3: Data Acquisition and Methodology

Data collection and geological description of Fula basin and the goal must be achieved of three kill methods (Driller & W&W and concurrent)

Chapter 4: Results and discussion

Calculation of three kills method (Driller & W&W and concurrent)

Chapter 5: 1Conclusions and Recommendations

1.3 Problem Statement:

- One of most dangerous existing problems all over the world including selected area is well control.
- JAKE S-9 w ell in block six have been selected as case study; as it includes pressure study to determine causes of kick; kill the well by applying different three kill methods (driller method, weight and wait method and concurrent method) considering comparison between three methods.

1.4 Objective:

Main objective for this research is to perform kill selected well on minimum time and safety manner, other sub goals as following:

- ❖ Apply Driller method:
  Through calculate FCP, ICP, EMD, KMW, MAASP, String Volume, and MAMW
- ❖ Apply Wait and Weight method:
  Through calculate FCP, ICP, EMD, KMW, MAASP, String Volume, and MAMW
- ❖ Apply Concurrent method
  Through calculate FCP, ICP, MAASP, incensement of KMW per stage
- ❖ Make comparison between the three kill method
  Find out the beast method to kill the well

To apply these methods, we need special equipment's such Blow Out Preventer (BOP) and its relative equipment's. It is considered one of the main equipment at the rig side. Also, well barriers like good cement job performed & casing and well head.

out preventer limitation of pressure can contain is depend on the on shore or offshore always of shore blow out preventer is higher pressure contain than on shore blow out preventer due to deep depths of offshore wells

After finish drilling operation the next step is producing oil from the well this step is known as completion operation in case the well is need maintenance is known as work over operation.

Chapter 2

Literature Review& Theory

2.1 Literature Review

Blow out wells is rare occurrence but some time happensThe following table explain off shore blowout accidents all over the world, thus prove the importance of well control due to large damage in equipment and manpower (46 cases, 22 persons killed in 1955& 2010) as table.

Year	Rig Name	Rig Owner	Type	Damage / details
1955	S-44	Chevron Corporation	Sub Recessed pontoons	Blowout and fire. Returned to service.
1959	C. T. Thornton	Reading & Bates	Jack up	Blowout and fire damage.
1964	C. P. Baker	Reading & Bates	Drill barge	Blowout in Gulf of Mexico, vessel capsized, 22 killed.
1965	Trion	Royal Dutch Shell	Jackup	Destroyed by blowout.
1965	Paguro	SNAM	Jackup	Destroyed by blowout and fire.
1968	Little Bob	Coral	Jackup	Blowout and fire, killed 7.
1969	Wodeco III	Floor drilling	Drilling barge	Blowout
1969	Sedco 135G	SedcoInc	Semi-submersible	Blowout damage
1969	Rimrick Tidelands	ODECO	Submersible	Blowout in Gulf of Mexico
1970	Storm drill III	Storm Drilling	Jack up	Blowout and fire damage.
1970	Discoverer III	Offshore Co.	Drillship	Blowout (S. China Seas)
1971	Big John	Atwood Oceanics	Drill barge	Blowout and fire.
1971	Unknown	Floor Drilling	Drill barge	Blowout and fire off Peru, 7 killed.
1972	J. Storm II	Marine Drilling Co.	Jackup	Blowout in Gulf of Mexico
1972	M. G. Hulme	Reading & Bates	Jack up	Blowout and capsize in Java Sea.
1972	Rig 20	Transworld Drilling	Jack up	Blowout in Gulf of Martaban.
1973	Mariner I	Sante Fe Drilling	Semi-sub	Blowout off Trinidad, 3 killed.
1975	Mariner II	Sante Fe Drilling	Semi-submersible	Lost BOP during blowout.
1975	J. Storm II	Marine Drilling Co.	Jackup	Blowout in Gulf of Mexico.

1976	Petrobras III	Petrobras	Jackup	No info.
1976	W. D. Kent	Reading & Bates	Jackup	Damage while drilling relief well·
1977	Maersk Explorer	Maersk Drilling	Jackup	Blowout and fire in North Sea
1977	Ekofisk Bravo	Phillips Petroleum	Platform	Blowout during well workover.
1978	Scan Bay	Scan Drilling	Jackup	Blowout and fire in the Persion Gulf.
1979	Salenergy II	Salen Offshore	Jackup	Blowout in Gulf of Mexico
1979	Sedco 135F	Sedco Drilling	Semi-submersible	Blowout and fire in Bay of Campeche Ixtoc I well.
1980	Sedco 135G	Sedco Drilling	Semi-submersible	Blowout and fire of Nigeria.
1980	Discoverer 534	Offshore Co.	Drillship	Gas escape caught fire.
1980	Ron Tappmeyer	Reading & Bates	Jackup	Blowout in Persian Gulf, 5 killed.
1980	Nanhai II	Peoples Republic of China	Jackup	Blowout of Hainan Island.
1980	Maersk Endurer	Maersk Drilling	Jackup	Blowout in Red Sea, 2 killed.
1980	Ocean King	ODECO	Jackup	Blowout and fire in Gulf of Mexico, 5 killed.
1980	Marlin 14	Marlin Drilling	Jackup	Blowout in Gulf of Mexico
1981	Penrod 50	Penrod Drilling	Submersible	Blowout and fire in Gulf of Mexico.
1985	West Vanguard	Smedvig	Semi-submersible	Shallow gas blowout and fire in Norwegian sea, 1 fatality.
1981	Petromar V	Petromar	Drillship	Gas blowout and capsize in S. China seas.
1988	Ocean Odyssey	Diamond Offshore Drilling	Semi-submersible	Gas blowout at BOP and fire in the UK North Sea, 1 killed.
1989	Al Baz	Sante Fe	Jackup	Shallow gas blowout and fire in Nigeria, 5 killed.
1993	Actinia	Transocean	Semi-submersible	Sub-sea blowout in Vietnam. .
2001	Ensco 51	Ensco	Jackup	Gas blowout and fire, Gulf of Mexico, no casualties
2002	Arabdrill 19	Arabian Drilling Co.	Jackup	Structural collapse, blowout, fire and sinking.
2004	Adriatic IV	Global Sante	Jackup	Blowout and fire at Temsah
2007	Usumacinta	PEMEX	Jackup	Storm force rig to move, causing well blowout on Kab 101 platform, 22 killed.

2009	West Atlas / Montara	Seadrill	Jackup / Platform	Blowout and fire on rig and platform in Australia.
2010	Deepwater Horizon	Transocean	Semi-submersible	Blowout and fire on the rig, subsea well blowout, killed 11 in explosion.
2010	Vermilion Block 380	Mariner Energy	Platform	Blowout and fire, 13 survivors, 1 injured.

(Techniques for Handling Upward Migration of Gas Kicks in a Shut-In Well by J.L. Matthews and Jr. Bourgoyne)

Table (2.1) Blow out record in off shore rigs

There is some blow out happen in Sudan one of them is Tawakul-1 WNPOC's filed block 8.Another blow out happen in block 4 GNPOC Azraq field well name Azq N-45.

2.2Well ControlTheory:

Bore pressure can be defined depending on the general definition of pressure as the magnitude of the pressure in the pores of formation or pressure acting on the fluid in the pore spaces of the rock. Most of the fluids found in the pore space of sedimentary formations contain a proportion of salt and are known as brines. The dissolved salt content may vary from 0 to over 200000ppm. Correspondingly, the pore pressure gradient ranges from 0.433psi/ft (pure water) to about 0.50psi/ft. The formation pressures may be either Subnormal (less than 0.465psi/ft) or Over pressured (greater than 0.465psi/ft). (Rabia 2002, John Ford 1999).

Usually well control problems are linked to abnormal-pressure; which lead to uncontrolled exit of formation fluids; therefore, well control defense lines have been divided to three stages of such operation

2.2.1 Primary Control

Pressure exerted by drilling fluid to hold back the formation fluid. Trip Monitoring is one of key success to avoid well control problems; **which** is defined as filling the hole during a trip; Driller keeps checking to see if the hole is taking the correct amount of mud; if not means two possible scenarios:

- Possible lost circulation (if much volume).
- Possible swabbing of formation fluid (if less volume).

In case of influx, the alertness in determining early warning signs in well control is of the upmost importance to wellbore safety. Careful observance and positive reaction to these signs will keep the well under control and prevent the occurrence of a well flow situation. The main warning/indicators are:

- Improper fill up or displacement during trips.
- Connection gas.
- Change of drilling parameters.
- Change of mud properties.
- Increase drill string torque and drag.
- Increase number and size of cutting and decrease in shale density.

The warning signs are to help engineers in taking corrective action before a kick takes place (not always there). However, kick indicators are:

- Decreased pump pressure/increased SPM
- Excess flow and Return flow rate.
- Pit gain and Flow from well with pumps off.
- Drilling break.

An extremely important aspect of well control is the proper selection and utilization of the blowout preventers, chokes; choke manifolds, mud-gas separators, degassers, mud-monitoring equipment and all other well control related equipment. Only with properly selected equipment, which has been correctly maintained and serviced successful well control procedures initiated. It has to be realized that the BOP is only one part of the well integrity. Wellhead equipment, casing and open hole must all be considered. Wellheads and pressure control equipment should meet the minimum working pressure requirement.

2.2.2Secondary Pressure Control

Surface equipment that is closed to stop any further entry of formation fluid. Secondary pressure control is the system, which provides the second line of defense, in the event that primary well control cannot be properly maintained. This is generally provided by the BOP system including:

A- Blind/Shear Rams - Choke and Kill Outlets

There will be at least one (1) kill and one (1) choke outlet with at least two (2) full opening valves on each choke outlet. If the BOP stack is equipped with shears rams, they shall be capable of shearing the highest grade and heaviest drill pipe used on the rig (HWDP excluded).

B- Relief Lines

At least two relief lines shall be installed to permit venting of the wellbore returns at opposite ends or sides of the rig. On land rigs a single line is acceptable.

C- Closing Unit and Accumulator Requirement

The closing unit will consist of an independent automatic accumulator unit rated for at least 20,700kPa (3,000psi) working pressure with a control manifold, clearly showing 'open' and 'close' positions for preventers and the pressure operated choke line valve. It is essential that BOP operating units be equipped with regulator valves, which will not fail open causing a complete loss of operating pressure. This unit will be located in a safe area. Due to the large volume required to close the annular preventer(s) and large bore diverters (such as Hydril MSP) which can result in slow closing time, the hydraulic pressure for the initial closure of the annular preventer will be set at the maximum operating pressure during normal drilling operations. However, it must be readjusted to the manufacturer's recommended pressure after closure and/or prior to running casing, routine pressure testing and stripping operations.

D- Mud Gas Separators

An atmospheric or low pressure separating vessel for handling gas-cut returns must be provided where blowout preventers are used. It must be equipped with gas vent lines to discharge gas.

All equipment listed above is used to control the well using a method of fivekilling methods. (Aberdeen Sch 2002, Neb 2009, Chevron center 1994)

2.2.3Tertiary Control

Techniques to control a blowout and fire accidents. In the event that secondary control cannot be properly maintained due to hole conditions or equipment failure, certain emergency procedures can be implemented to prevent the loss of control. These procedures are referred to as "Tertiary Control" and usually lead to partial or complete abandonment of the well. Unlike primary and secondary control, there are no established tertiary well control procedures that will work in most situations. The procedures to be applied depends on the particular operating conditions which are encountered, and specific recommendations regarding appropriate tertiary control procedures cannot be given until the circumstances leading to the loss of secondary control are established. However, there are two procedures that are widely used:

- Barite plugs
- Cement plugs.

In most cases when a well control problem occurs after cement job, cement evaluation logs give a general idea of what happened during and directly after cement job. Therefore will clear cement evaluation logs. (Robert D 1994, John R. Kozicz 1999, Erik B. Nelson 1990, Jacques Jutten1988)

2.3Well Control Methods

The objective of the various kill methods is to circulate out any invading fluid and circulate a satisfactory weight of kill mud into the well without allowing further fluid into the hole. Ideally this should be done with the minimum of damage to the well. If this can be done, then once the kill mud has been fully circulated around the well, it is possible to open up the well and restart normal operations. This allows approximately constant bottom hole pressure which is slightly greater than formation pressure to be maintained as the kill circulation proceeds because of the additional small circulating friction pressure loss. After circulation the well is opened up again and the mud weight may be further increased to provide a safety or trip margin. There are four constant bottom-hole pressure kill methods in common use today which are

- Driller's Method
- Wait & Weight Method (Engineer's Method)
- Concurrent Method
- Volumetric method.

2.3.1Driller's Method:

Includetwo Circulations: 1st Circulation to clean out influx by original mud weight considering only bottom up time and 2nd Circulation to complete cycle by kill mud weight. Practice procedure for driller method as the following:

A- 1st Circulation:

1. Startups bring pumps up to kill rate holding casing pressure constant.
2. When up to speed, look at drill pipe pressure (ICP.) Hold it constant at this value for bottom up.
3. After circulation bottom up finished, shut down the pump look for pressure.

4. If annulus is clean, SICP. Will now read same value as SIDPP, If annulus is not clean then SICP will be greater than SIDPP.

B- 2nd Circulation:

1. Startup Bring pumps up to kill rate holding casing pressure constant.
2. When kill mud reaches at rotary table, re-zero stroke.
3. When up to speed maintain casing pressure constant until kill mud is at the bit.
4. With kill mud at bit. Switch to drill pipe pressure (FCP) and hold constant until kill mud returns at surface.
5. It may be preferred to use the Wait and Weight procedure for the 2nd circulation. This is in case of any influx that was not cleaned out in the 1st Circulation.

2.3.2 Wait and Weight Method:

One Complete circulation with kill mud weight.

Practice procedure for driller method as the following:

1. Startup brings pumps up to kill rate, holding casing pressure constant.
2. When kill mud reach at rotary table, re-zero stroke.
3. Once up to speed the drill pipe pressure should equal ICP.
4. Allow drill pipe pressure to fall from ICP to FCP as kill mud is pumped to the bit, by using drill pipe step down Pressure schedule.
5. With kill mud at the bit hold drill pipe pressure constant at FCP. Until kill mud returns to surface.

2.3.3 Volumetric Method:

It depends on Boyle’s law; it does not kill the kicking well, but it can be used to bring the migration gas in side casing and exclude it. Situations can the volumetric method of well control is applied are:

- Bit is on bottom and drill string is plugged. (bit is fully choked)

- Bit is off Bottom and not possible to strip or pipe stuck.
- Drill string out of hole.
- Mud pump down and not available, or failure in surface line.
- Washout in the drill string.

2.3.4 Pull heading method:

To forcibly pump fluids into a formation, usually formation fluids that have entered the wellbore during a well control event. Though bull heading is intrinsically risky, it is performed if the formation fluids are suspected to contain hydrogen sulfide gas to prevent the toxic gas from reaching the surface. Bull heading is also performed if normal circulation cannot occur, such as after a borehole collapse. The primary risk in bull heading is that the drilling crew has no control over where the fluid goes and the fluid being pumped down hole usually enters the weakest formation. In addition, if only shallow casing is cemented in the well, the bull heading operation can cause wellbore fluids to broach around the casing shoe and reach the surface. This broaching to the surface has the effect of fluidizing and destabilizing the soil (or the subsea floor), and can lead to the formation of a crater and loss of equipment and life.

2.3.5Concurrent method:

It depends on gradual increase in mud weight from the original mud to kill mud weight.

- Sometime referred to as the circulate and weight method or slow weight up method.

  It involves gradually weighting up fluid while circulating out the kick.
- Additional calculations are required when tracking different fluid weights in the string at irregular intervals.

- Sometimes crew members are required to record concurrent method data even if this is not the method intended to be used.

Circulate out kick while gradually increasing mud weight (same as wait & weight method except you will follow DP pressure vs. mud weight schedule as you weight – up your mud) only used insufficient weighting material is at rig site, till kill mud weight; which is calculated as the following:

2.4Kill Method Equations:

$\text{A} - \text{Kill Fluid Density} = \left(\frac{\text{SIDPP}}{\text{TVDX 0.052}}\right) + \text{Current Drilling Fluid Density}$..2.1

Above weighting process have been processed to equalize formation pressure through two pressure values; initial circulating pressure which is calculated as the following

B- Initial circulation pressure (ICP) = Dynamic Pressure Loss + SIDPP ……2.2

C-Final Circulation Pressure (FCP) =

$\frac{Kill\ Fluid\ Density}{Current\ Dilling\ Fluid\ Density} * Dynamic\ Pressure\ Los$……2.3

Considering Hydrostatic pressure to be less than fracture pressure; which is indicating by value of?

D- Max. Allowable Drilling Fluid Density =

$\frac{Leak\ Off\ Test}{0.052 * Shoe\ TVD} + Drilling\ Fuid\ At\ Test$ ……. 2.4

E- Initial MAASP = [Max. Allowable Drilling Fluid Density – Current Mud Density] * Shoe TVD * 0 .052…….…………………………….…...…….2.5

All pressure reading are integrated with fluid volume or strokes

F- Drill String Volume = Length * Capacity ……………………………….2.6

G- Pump Strokes = $\frac{Voloum}{\text{Pump Displacement}}$……………………………….….……2.7

H- Time Minutes =$\frac{\text{Pump Strokes}}{SPM}$……………………………… ………2.8

I- Kill Fluid Gradient = $\frac{\text{Current Drilling Fluid Gradein} + \text{SIDPP}}{\text{TVD}}$……………....…2.9

J- Pressure Decrease Value = $\frac{ICP-FCP*100}{E}$……………………………….…2.10

(E = Driller String Volume)

2.5 Concurrent Advantages

1- Minimum of non-circ time
2- Excellent for large increases in mud weight
3- Mud condition can be maintained along with mud weight
4- Less casing pressure than Driller's method
5- Can be easily switched to wait & weight

2.6 Concurrent Disadvantages

1- Arithmetic is little more complicated
2- Requires more on choke circulating time
3- Higher casing and casing shoe pressure than wait & weight

2.7 General information about concurrent method

1. Is another method for killing the flowing wells
2. It kills the well in more than two circulation may be three may be more.
3. It depends on gradual increase mud weight, from the original mud to kill mud weight.
4. Every Circ Has its own ICP, FCP, &its own step down pressure schedule.
5. The well is completely killed after the last circulation.

Chapter 3

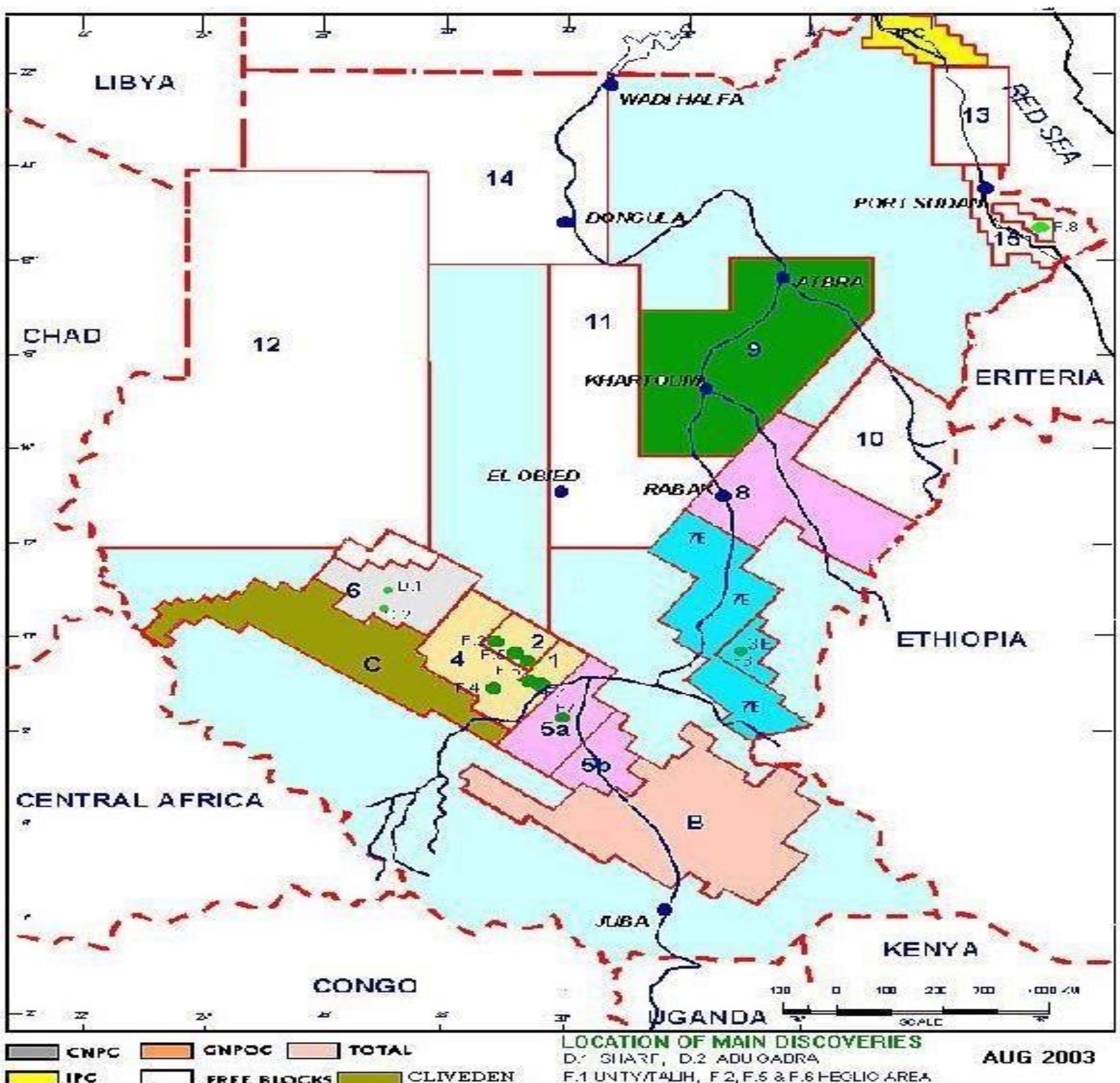
Methodology

3.1DataAcquisition

To achieve this topic objective, the following steps will be followed:

3.1Review Geological Description

The figure blow showing the blocks partition of Sudan including Block 6



❖ Figure (3.1) Sudan oil block partition (shazly Sayed Ahmed, 2011)

Block 6 is located in the muglad – sudd Rift basin in Sudan, adjacent to the Greater Nile Oil Project (GNOP) North. The block was initially operated by chevron, who withdrew from Sudan in the mid – 1980 due to civil unrest. Rompetrol, under a service agreement with Sudanese government, brought the Abu Ghabra field on-stream in1993, in 1995, Petro Energy E&P, a consortium led by CNPC, was awarded the block 6 license. the Sharaf and Greater Fula fields were developed in 2003.

The Muglad Basin

Is a large rife basin in northern Africa.The basin is situated with in southern Sudan and south Sudan .and it covers an area of approximately 120.000 km2, across the two nations. it contains a number of hydrocar-bon accumulations of various size, the largest of which are the heglig and unity oil fields . During the 1960s and 1970s, chevron made the first oil discoveries in the basin near the south Sudan and muglad. Take to gather, the muglad basin account for the majority of Sudan's known oil reserves.

The oil fields of the muglad basin are connected to port Sudan on the Red sea by the greater Nile oil pipeline which begins at the unity oil field .

General Geological Description (Fula Basin)

The Fula sub-basin is a fault-bounded depression located in the NE of the Muglad Basin, Sudan and covers an area of about 3560 km2. Eleven oilfields and oil-bearing structures have been discovered in the sub-basin. The Lower Cretaceous Abu Gabra shale's (Barremian – Aptian), deposited in a deep-water lacustrine environment, are major source rocks. Reservoir targets include interceded sandstones within the Abu Gabra Formation and sandstones in the overlying Bentiu and Aradeiba Formations (Albian – Cenomanian and Turonian, respectively). Oil-source correlation indicates that crude oils in the Aradeiba and

Bentiu Formations are characterized by low APIs (<22°), low sulphur contents (<0.2%), high viscosity and high Total Acid Number (TAN: >6 mg KOH/g oil on average). By contrast, API, viscosity and TAN for oils in The Abu Gabra Formation vary widely. These differences indicate that oil migration and accumulation in the Fula sub-basin is more complicated than in other parts of the Muglad Basin, probably as a result of regional transtension and inversion during the Late Cretaceous and Tertiary.

The Aradeiba-Bentiu and Abu Gabra Formations form separate exploration targets in the Fula sub-basin. Four play fairways are identified: the central oblique anticline zone, boundary fault zone, fault Terrance zone and sag zone. The most prospective locations are probably located in the central oblique anticline zone.

(GANI. DS, M. G. ABDELSALAM, S. GERA and M. R. GANI, 2008, " Stratigraphic and structural evolution of the Blue Nile Basin", Northwestern Ethiopian Plateau", GEOLOGICAL JOURNAL Geol).

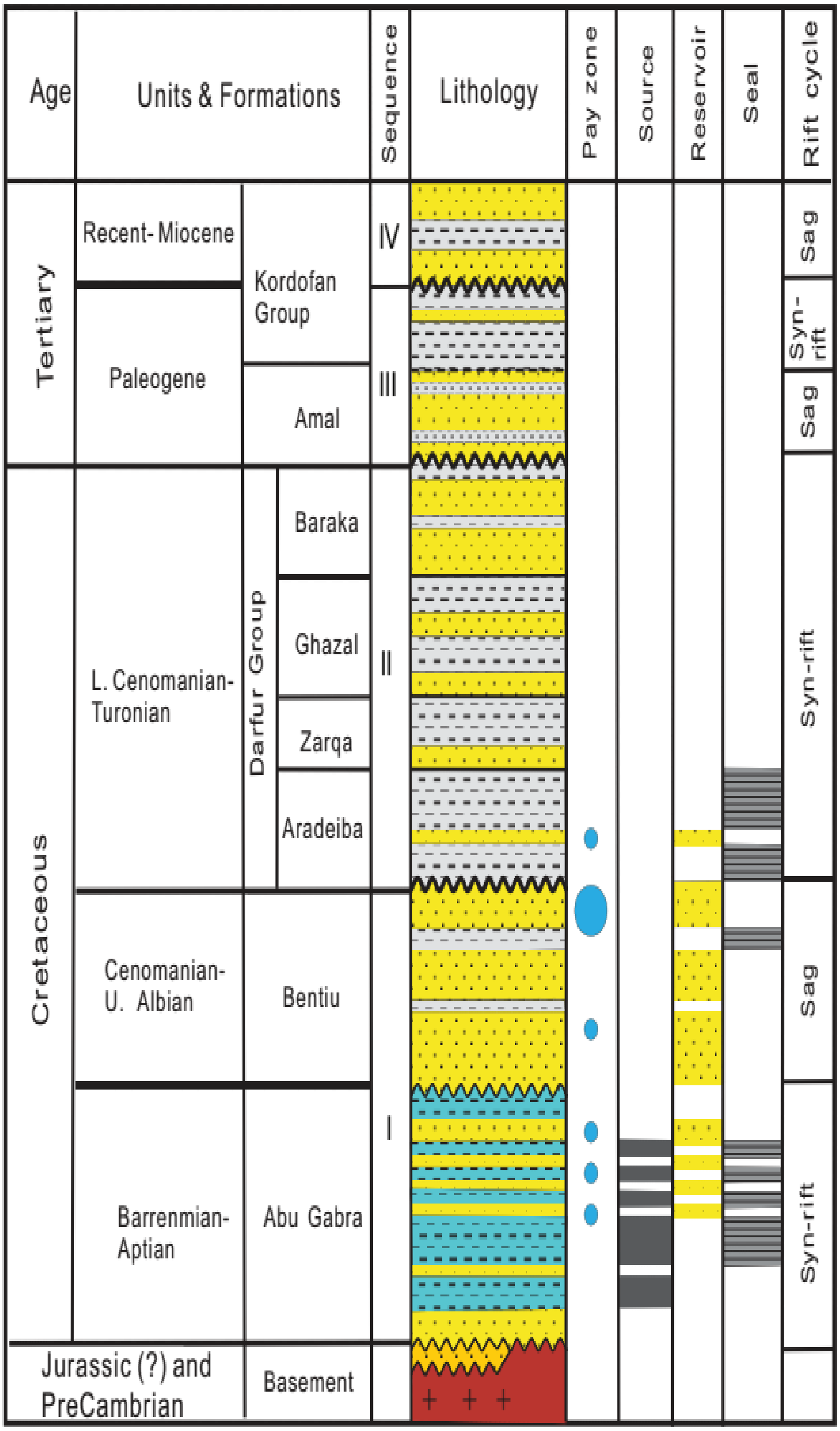


Figure (3.2) Muglad Basin Formation Type (Dr John , 1999)

Block-6 is part of Muglad basin, Block 6 generally the formation can be divided into classification from top to bottom as follows:

- Amal Formation
- Baraka Formation
- Ghazal Formation
- Zarqa Formation
- Bentiu Formation
- Abu Gabra Formation

1- Amal formation:

This is pure unconsolidated, medium to very coarse sandstone. Has high peremplaty may cause loss of circulation, it located between 540 to 650 m has thickness about 380 m .

2- Baraka Formation:

This formation contains sandstones and shale, has gray color , soft minor firm , sticky, blocky clay stone with interceded unconsolidated fine to coarse sandstone, problems cause mud making , tight interval caving . it located between 824 to 1031 m and thickness about 377m.

3-Ghazal - Zarqa Formation:

They are containing shale and sandstones, gray color, soft, minor firm, sticky, blocky clay stone with interceded unconsolidated fine to coarse sandstone, problem cause mud making, tight interval caving. it Located between 824 to 1031 m and thickness about 377m.

4- Bentiu Formation:

This formation is containing sandstone with shale, medium to very coarse sandstone with interbedded gray color, firm blocky clays tone. Problems cause mud leaking, tight, caving. Its Located at 1408 m and thickness about 1530m.

5- Abu Gabra Formation:

This formation the upper part contains sandstone interbedded with shale, its located at 2938 m, and thickness about 395 m.

the lower part is shale with sand , its located at 3605 m , and thickness about 144 m , this formation is poor to well consolidated &very fine to coarse &dirty sandstone and dark , salty clay stone and pure , dark gray color , brittle shale . Problems cause mud leaking deviation building,

(Dou Lirong, Cheng Dingsheng and Wang Jingchum 2013).

3.3Drilling and kick data:

3.3.1 Formation data:

Bentiu interval (1437.0-1463.0m).

Formation pressure 1575PSI

Current mud weight 8.3 PPG

3.3.2 Casing Information:

Data	Specification	Size of top flange	Pressure Range	Color	Manufacturer
Casing head	9-5/8”×11’’	11’’	5000psi	Red	Daqing

Table (3.1): Casing Information

3.2.3 Well Completion Profile:

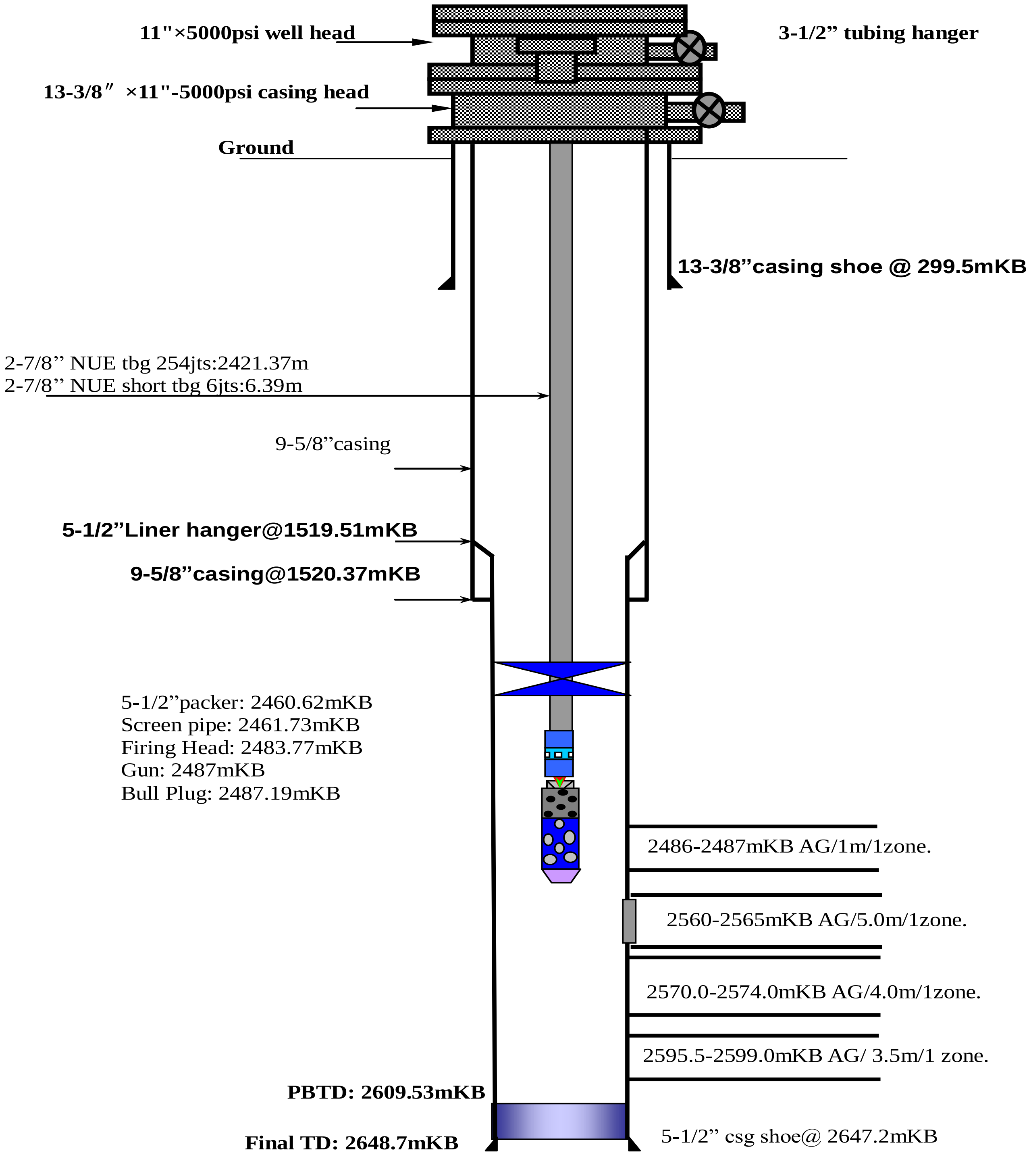


Figure (3.3) Well Completion Profile (Petro-energy , Oct 2016)

3.4Kick data:

1- Pump out put & SPM=0.8bbl/stk
2- MW= 8.3PPg
3- SIDPP=350psi
4- SICP=450psi
5- Bit gain=3bbl
6- Dynamic loss=320psi

3.5Appling killing methods

3.5.1 Driller Method

-Determine EMW, MAASP

-Calculate Volumes

- Calculate Kill Mud Weight

- Calculate ICP & FCP

3.5.2 Wait and weight Method:

-Determine EMW, MAASP

-Calculate Volumes

- Calculate Kill Mud Weight

- Calculate ICP & FCP

3.5.3Concurrent Method:

-Determine EMW, MAASP

-Calculate Volumes

- Calculate Kill Mud Weight

- Calculate ICP & FCP

Daily Report ForJaksSouth – 9

After rig DQ54 finish Jake South-7 workover well, move out to do workover operation on Jake South-9, and the workover objective (Perforate new zone (Bentiu 1437-1463mKB)) to be added to perforated zones (Bentiu: 1485.7-1513.1 AG: 2486.0-2487.0 2570.0-2574.0 2595.5-2599.0) and rig start operation as the following sequences.

Rig move to Jake-S-9 on Oct 21 and rig up

12:00 on Oct 23, RIH TCP to 1463m

15:00 on Oct 23, finish depth correlation

15:00-17:30, normally circulate till fresh water returns

17:30-17:40, CNLC drop bar and perforate Bentiu:

17:40-19:30, Observer wellhead, no flow out

19:30, Open BOP; POOH one joint of tubing and 3 joints of pup joint

19:50, when break off the second tubing thread, strong blowout occurred suddenly. Stop operation and rig crew try to close the manual BOP, but failed due to high pressure. Then rig crew evacuate from the well site.

Chapter 4

Results and discussion

4.1Kill Method Calculation

4.1.1Driller & Wait and Weight Method

Surface Leak-Off-Test = 1200 Psi

Drilling Fluid Density = 9.6 ppg

Maximum Allowable Drilling Fluid Density = Drilling Fluid AT Test+

$\frac{\text{Leak Off Test}}{0.052 * \text{Shoe TVD}}$

Maximum Allowable Drilling Fluid Density = $9.6 + \frac{1200}{0.052*4983} = 14.2$ ppg

Initial MAASP = [Maximum Allowable Drilling Fluid Density – Current Density]

* Shoe TVD * 0 .052

Initial MAASP = [14.2 – 8.33] * 4983 *0 .052 = 1529 Psi

-Calculate Volume, ICP, FCP &KillFluid Density

Kill Fluid Density = $Current\ mud\ weight + \frac{SIDPP}{TVD*0.052}$

= $8.33 + \frac{350}{8685*0.052} = 9.2$ ppg

All above mentioned values will be include in kill sheet driller & wait and weight

WELLNAME: Jack-S-09 **UNITS:** US **DATE:** 26-Aug-18

FORMATION STRENGTH DATA:

SURFACE LEAK-OFF PRESSURE FROM
FORMATION STRENGTH TEST (A) 1200 psi

DRILLING FLUID DENS. AT TEST (B) 9.6 ppg

MAX. ALLOWABLE DRILLING FLUID DENSITY =

(A) psi / 0.052 / Shoe TVD + **(B) ppg** = **(C) ppg**

1200 / 0.052 / 4983 + 9.6 = **(C)** 14.2

INITIAL MAASP = [(C) ppg - Curr Dens] x Shoe TVD x 0.052

= 14.2 - 8.33] x 4983 x 0.052

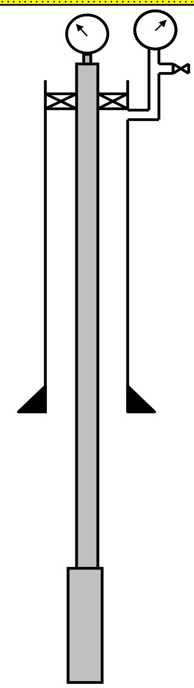
= 1529 psi

CURRENT WELL DATA:

DRILLING FLUID DATA
DENSITY 8.33 ppg
GRADIENT 0.43316 psi/ft

CASING & SHOE DATA
SIZE 9 5/8 - "5.5 in
M. DEPTH 4983 ft
T.V. DEPTH 4983 ft

HOLE DATA
SIZE 9.625-5 1/2 in
M. DEPTH 8685 ft
T.V. DEPTH 8685 ft



PUMP No. 1 DISPLACEMENT	PUMP No. 2 DISPLACEMENT
0.08 bbl / stk	0.08 bbl / stk

SLOW PUMP RATE DATA	DYNAMIC PRESSURE LOSS PUMP No. 1	DYNAMIC PRESSURE LOSS PUMP No. 2
30 SPM	320 psi	psi
SPM	psi	psi

PRE-RECORDED VOLUME DATA:	LENGTH ft		CAPACITY bbl/ft		VOLUME bbl	PUMP STROKES strokes	TIME minutes
Tbg 2 7/8"	8685	x	0.006	=	52.11		30
		x		=	+	VOLUME / PUMP DISPLACEMENT	PUMP STROKES / SLOW PUMP RATE
		x		=	+		
DRILL STRING VOLUME			(D)		52.11 bbl	(E) stks 651	22 min
Tbg / 9 5/8" ..	4983	x	0.066	=	328.9 +		
Tbg / 5 1/2"	3702	x	0.015	=	55.53		
Cgs HOLE VOLUME			(F)		384.4 bbl	4805 stks	160 min
		x		= (G) +		stks	min
TOTAL ANNULUS VOLUME	(F+G)=(H)		384		bbl	4805 stks	160 min
TOTAL WELL SYSTEM VOLUME	(D+H)=(I)		437		bbl	5456 stks	182 min
ACTIVE SURFACE VOLUME	(J)		3		bbl	38 stks	
TOTAL ACTIVE FLUID SYSTEM	(I+J)		440		bbl	5494 stks	
SURFACE LINE VOLUME					bbl	stks	

CALCULATIONS CAN BE MADE USING EITHER DRILLING FLUID DENSITY OR DRILLING FLUID GRADIENT.

KICK DATA: **Jack-S-09**

SHUT IN DRILL PIPE PRESSURE	SIDPP	350	psi
SHUT IN CASING PRESSURE	SICP	450	psi
PIT GAIN		3	bbl

1 bbl = 42 US gallon

KILL FLUID DENSITY

SIDPP / TVD / 0.052 + CURRENT DRILLING FLUID DENSITY

350 / 8685 / 0.052 + 8.33 ppg= 9.2

KILL FLUID GRADIENT

CURRENT DRILLING FLUID GRADIENT + SIDPP / TVD

0.43316 + 350 / 8685 = 0.4735 psi/ft

INITIAL CIRCULATING PRESSURE (ICP)

DYNAMIC PRESSURE LOS + SIDPP

Pump 1						
30	320	+	350	=	670	psi
0	0	+	350	=	350	psi

FINAL CIRCULATING PRESSURE (FCP)

KILL FLUID DENSITY / CURRENT DRILLING FLUID DENSITY x DYNAMIC PRESSURE LOSS

9.2 / 8.33 x

30	320	=	**353**	psi
0	0	=	**0**	psi

FINAL CIRCULATING PRESSURE (FCP)

KILL FLUID GRADIENT / CURRENT DRILLING GRADIENT x DYNAMIC PRESSURE LOSS

0.4735 / 0.43316 x

320	=	350	psi
0	=	0	psi

(K) = ICP - FCP = 670 - 350 = 320 psi **(K) x 100 / (E)** = 0.4916 **x 100**

30

49 psi/100 stks

SURFACE LINE STKS **0**

STROKES	PRESSURE
0	670
100	621
200	572
300	523
400	473
500	424
651	350
700	350
800	350
900	350
1000	350
1100	350
1200	350
1500	350
2500	350
3500	350
4500	350
5456	350

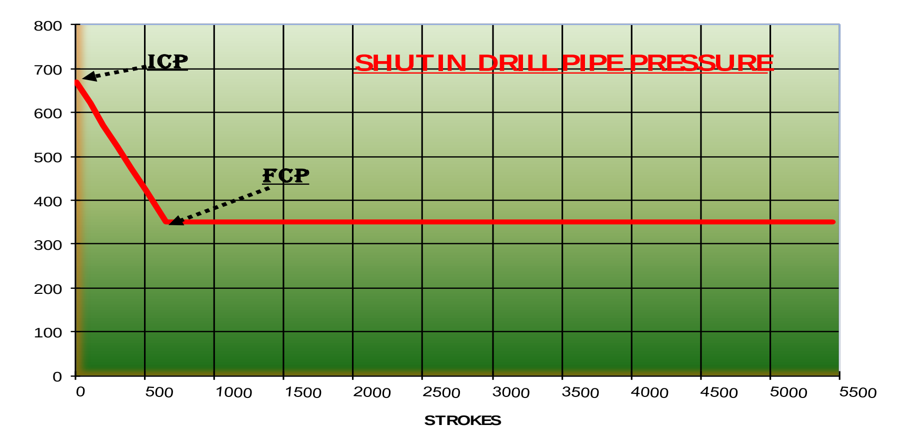


Figure (4.1) driller & wait and weight Kill Sheet

4.1.2ConcurrentMethod:

Stage One:

9.2 – 8.33 = 0.87, $\frac{o.8}{4}$ = 0.2 stage (Mud Mw increase)

MAASP = 1469 psi with kill mud 8.53 ppg

ICP = Dynamic pressure + SIDPP = 350 + 320 = 670 Psi

FCP =$\frac{Kill\ mud\ weight}{Current\ mud\ weight} * Dynamic\ prssure\ lossed$

FCP = $\frac{8.53}{8.33} * 320 = 328\ Psi$

From zero strokes to 163 stokes

Stroke gerident :$\frac{670-328}{163}$ = 2.09 Psi

Stage Two:

MAASP = 1417 psi with Mud weight 8.73 ppg

ICP = 328 Psi

FCP = $\frac{8.8}{8.53} * 320 = 331\ Psi$

With 326 strokes

Stroke gerident:$\frac{670-331}{163}$ $=$ 2.07 Psi

Stage Three:

MAASP = 1366 psi with mud weight 9.0 ppg

ICP = 331 psi

FCP = $\frac{9}{8.8} * 320 = \ \ 332$ Psi

With 489 strokes

Stroke gerident:$\frac{680-332}{163} = 2.06$ Psi

Stage Four:

MAASP = 1314 psi with mud weight = 9.13 ppg

ICP = 332 psi

FCP = $\frac{9.2}{8.9} * 320 = 331\ Psi$

With 652 stroke

Stroke gerident: $\frac{670-331}{163} = 2.08$ Psi

4.1.2.1 Barite Required

B = ($\frac{35.05*(\text{Wf}-\text{Wi})}{35.05-Wf}$) * VI

B = Amount of Barite to Add, Ibs

Wf = Desired Mud Weight, Ib /gal

WI = Starting Mud Weight, Ib/gal

VI = Starting Volume of Mud, gallons

Barite required for stage One: B= ($\frac{35.05*(8.53-8.33)}{35.05-8.53}$) * 13 = 3.43 Ibs

Barite required for stage Two: B =($\frac{35.05*(8.73-8.53)}{35.05-8.73}$) * 13 = 3.46 Ibs

Barite required for stage Three: B =($\frac{35.05*(8.93-8.73)}{35.05-8.93}$) * 13 = 3.49 Ibs

Barite required for stage Four: B= ($\frac{35.05*(9.2-8.93)}{35.05-9.2}$) * 13 = 4.7 Ibs

STROKES	PRESSURE
0	670
100	470
163	328
200	328
300	328
328	331
400	331
489	332
600	332
652	331
1052	331
1452	331
1852	228
2252	228
2652	228
3052	228
3452	228
3852	228
4252	228
4652	228
5052	228
5452	228
5494	228

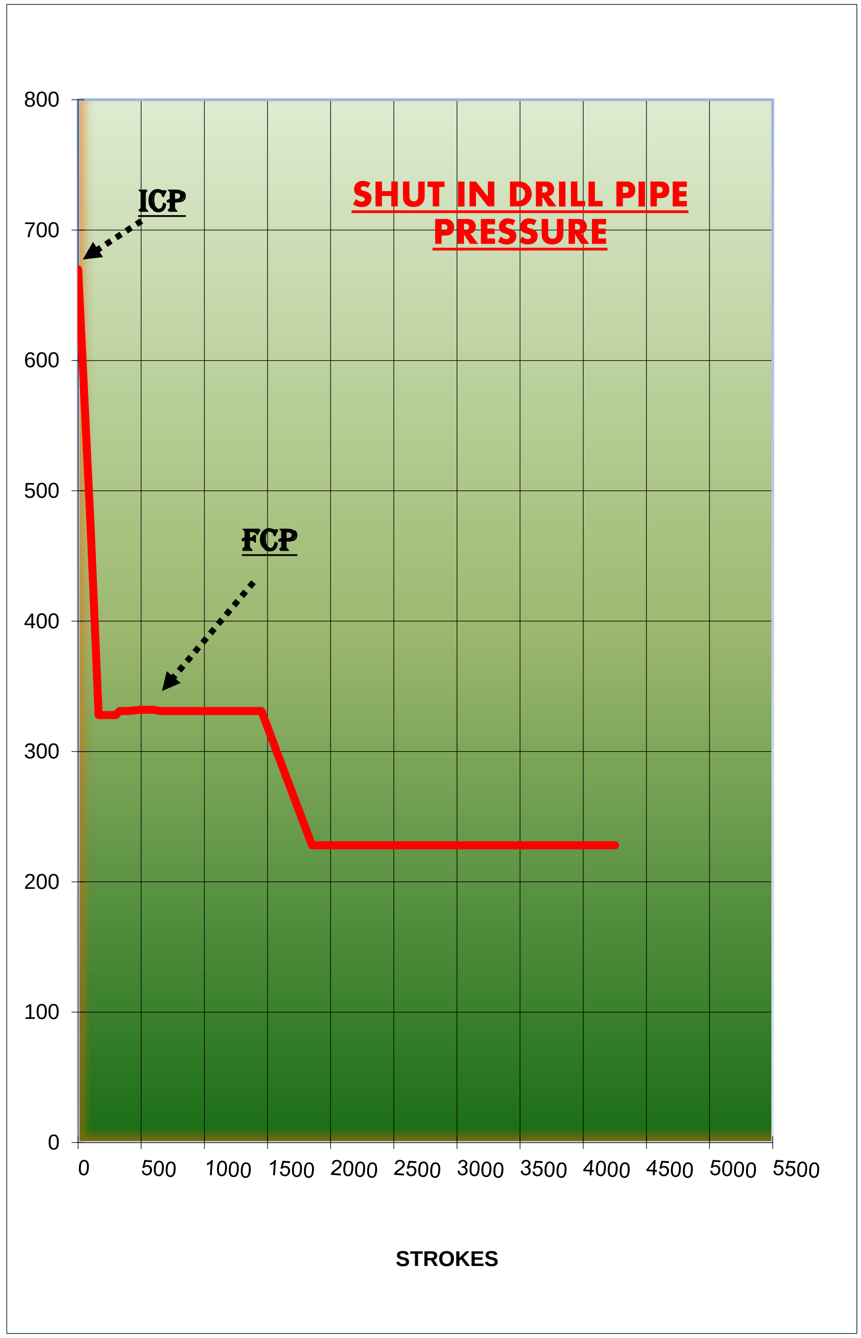


Figure (4.2) Concurrent Kill Sheet

4.2 Discussionof Killing Methods:

Driller Method has a Very few Calculation and Simple to teach and understand and reduce sticking and gas migration.

Wait & Weight has lowest casing and casing shoe pressure and Less lost circulation, has Shortest circulating time (one circ.), More time to organize crew.

Concurrent has Excellent gradually mud increase also Can easily be switched to wait and weight. And its Need special mud tanks compartment, and its Need high crew experience.

After making the comparison between driller & weight and wait & concurrent we found out the best method to apply well control is concurrent considering mud system compartment and capacities and experience rig crew.

Chapter 5

Conclusions and Recommendations

5.1Conclusions and Recommendations:

- ✓ The main purpose of this research was to analyze well control problem for Jake S-9 well; determine factors have a significant effect on choke pressures and gas-return rates for various kick scenarios.
- ✓ The variables were kick size, true vertical depth of the well, circulation kill rate, hole sizes, and kick intensity.
- ✓ The Three different well control methods have applied to kill the well: driller; wait and weight and concurrent methods; calculations have been completed to each method individually.
- ✓ The Driller's Method does offer some distinct advantages over the W&W Method. The W&W Method may be advantageous to achieve lower shoe and surface pressures. Due to gas migration and hole geometry, many times shoe pressure may not be lower at all with the W&W Method. Application of the W&W Method may even give us higher shoe pressures if the drill pipe pressure schedule is not calculated and followed properly.
- ✓ The W&W Method may be difficult to follow properly in complex, deviated wells and/or with tapered drill strings. The Driller's Method is a preferred method when hole problems are significant and any long non-circulation times could further compound the problems.
- ✓ The concurrent method is a preferred method for this study due to circulation system limitation; considering this method offer advantages for both driller and wait and weight.

- ✓ Main constrain to apply concurrent method is the low experience level of rig personnel, limited field practice with this method by a majority of experienced personnel. In addition to rig lay out limitations.
- ✓ Finally this study has covered many parts of the Jake S-9 well control problem, but there are still some questions unanswered in this endeavor, such as is there is team to integrate all field work each to other (as nitrogen injection effect to other near production well); more over all workover specs to consider killing operation needs to safe equipment's and personnel as well.

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