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COMPARING VERTICAL AND HORIZONTAL DRILLING IN WELL CONTROL IN OIL AND GAS

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DECLARATION

Candidate's Declaration

I **ERIC TETTEH,** hereby declare that this dissertation is the result of my own original work and that no part of it has been presented for another degree in this University or elsewhere.

Candidate's Signature………………………………. Date…………………….

Supervisor's Declaration

I hereby declare that the preparation and presentation of this dissertation was supervised in accordance with the guidelines on supervision of dissertation laid down by the University of Education, Winneba.

Supervisor's Signature………………………………. Date……………………..

CHIBUDO KENNETH NWORU

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Finally, I would also like to thank my family for all help, support and patience along the way. God shower his blessing upon you and make you successful in all your endeavours

DEDICATION

I dedicate this project work to God Almighty, the author and finisher of my faith. I pray that out of this, greater opportunities are yet to come.

Finally, to my wife Rev Mrs Evelyn Tetteh and my two girlfriends Erilyn and Enna Tetteh Thank you for being there for me through it all. I owe it all to you.

ABSTRACT

A brief introduction is given to a range of well control procedures. It was found that many of the procedures rely on a set of simplifying assumptions. This is particularly true in the hand calculations for designing a well kill. This set of assumptions was used to define an analytical model. The premises of the analytical model and some of the procedures were tested in a well control simulator. The main objective of this thesis was to verify some of the well control procedures, and to shed light on their limitations. Particular attention was given to well control methods for a vertical and horizontal well. The aim of the project is using the well control simulator to compare the vertical and horizontal drilling operation in oil and gas exploration. The study involves drilling technology, well design and construction, with reference to collating and comparing data when the two-drilling simulation were performed.

Further modifications deemed necessary:

- Improved accuracy in reading of bottom hole and choke pressures.
- Implementation of additional topside parameters (pit gain, drill pipe pressure)
- A more realistic friction model.
- Changing the liquid component of the system from water to drilling fluid (altering the liquid density).

The results obtained by the kick simulator were compared to hand calculations. The main discovery was that although the hand calculations produce slight errors, the errors exclusively functions as additional safety margins with respect to downhole pressure differential.

It was also found that a gas bubble migrating in a shut-in annulus subjects the well to higher loads than the gas filled well scenario.

TABLE OF CONTENTS

CONTENTS **PAGE**

LIST OF TABLE

CONTENT **PAGE**

LIST OF FIGURES

CONTENT **PAGE**

CHAPTER ONE

INTRODUCTION

1.0 Background of the Study

Well control in short words is described as the core for human safety on board a platform or a rig. It includes a variety of elements that are in place to prevent an unwanted inflow of formation fluids. It needs to be functional in order to fulfil their purpose. Elements are made, controlled and replaced by people, it is therefore vital that the people working with them knows how they work in order to detect failure so they can be repaired or replaced as soon as possible. It is also important that everyone working in a drilling operation knows what well control is and the different scenarios that can develop if one should emerge.

Well control is of great importance during drilling and well operations. The main purpose of well control is to keep downhole pressures in the operating window between pore and fracture pressure. In the case of a well control situation where either the formation is fractured causing loss of circulation or the pressure in the well drops below pore pressure causing a kick, measures have to be taken in order to get the situation under control. When drilling vertical and horizontal wells the same basic principles of well control apply, but also other aspects have to be considered.

Oil plays a vital role in geopolitics and energy security of the world. The International Energy Agency (EIA) estimates that the three largest oil producing nations as of 2012 were Russia (with a share of 14% of world oil supply), Saudi Arabia (a share of 13.1%), and the United States (a share of 12%) (EIA, 2015). On the other hand, the Organization of the Petroleum Exporting Countries (OPEC) estimates that they controlled 81% (an equivalent of 1,206 billion barrels) of total crude oil reserves as of 2013, out of which 66% was located in the Middle Eastern countries (OPEC 2015).

Ghana started the exploration for oil and gas in 1896 in onshore Tano basin (Western Region). The wells were drilled by West African oil and fuel company and from that period several companies from the then Soviet Union, Romanian and Canadians have developed wells a total of 22 blocks in Ghana in the quest for oil ,gas and its by product. Within 2001 to 2007, exploration for commercial hydrocarbons intensified with some independent Oil Companies such as Kosmos Energy, Hess Corporation and Tullow Oil, acquiring exploration and production rights over areas in deep water. There was a shift of focus from shallow water to deep water areas which was occasioned by other deep-water discoveries made in the region and by the results of four deep water wells drilled in Ghana between 1999 and 2003. These wells proved the existence of an active petroleum system in the deep water, a fact which hitherto was unknown. Hunt Oil's WCTP-2X well encountered 14ft of light oil column. This effectively reduced the risk of petroleum generation in the deep-water areas of Ghana.

Kosmos Energy (block operator), Anadarko (technical operator), Tullow Oil and E. O. Group struck a significant (about 312ft net) column of high-grade oil in the Mahogany prospect with the Mahogany-1 well in the West Cape Three Points Licence. This is the most significant discovery crowning years of concerted effort by all. From August 2007 to 2013, 23 discoveries (Odum, Ebony, Tweneboa, Sankofa, Dzata, Owo, Teak-1, Paradise-1, Banda-1, Gye Nyame, etc) have been made. Except Ebony, all recent discoveries were made in deepwater (water depths ranging from 800 to 1600m). The Mahogany and Hyedua discoveries have been appraised and put into production as Jubilee Field.

In this thesis the basics of well control and techniques have been discussed, along with considerations by using vertical and horizontal drilling methods, and comparing the techniques used in well control operations.

1.2 Statement of the Problem

In the light of BP`s Macondo well disaster, the emphasis on technique, safety and avoiding unwanted situations have led to a tightening up of existing procedures and making new ones that compel the industry to make changes to show their motivation on safety. The focus towards the industry is high and there are no rooms for errors if they want to stay in the game. Therefore, it is important that adequate procedures exist and that high focuses on well control methods are integrated into the work culture. In this way the risk of a new BP`s Macondo can be reduced or prevented in oil and gas exploration.

Figure 1: Blowout at BP's Macondo prospect (Source: www.telegraph.co.uk)

1.3 Purpose of the study

This research seeks to compare the vertical and horizontal wells using the various techniques of well control methods. The focus of the simulations will be on circulating kicks out of the well safely and comparing the outcome.

The effect of different mud densities and kick intensities was also included for the simulations.

1.4 Objective of the Study

The main objective of the study is to study the effect of well control methods on safety in oil and gas exploration. It will also help the innovation in the drilling of hydrocarbons industry.

1.5 Specific Objectives

An extensive simulation study covering a wide range of variables will be performed.

The most important procedures are as follows:

1. Perform a “hard” shut-in when a kick is detected and confirmed.
2. Record the pressures and pit gain and start to circulate immediately using the Driller’s Method.
3. Start circulating with a high kill rate to remove the gas from the horizontal section.
4. Slow down the kill circulation rate to ½ to 1/3 of normal drilling rate when the choke pressure starts to increase rapidly.

1.6 Significance of the Study

The well control simulator will be used to validate the procedures in vertical and horizontal well control in oil and gas exploration. It will also give precise information to the industry players to help them select the right method to prevent loss and also maximizes profit and loss of life.

CHAPTER TWO

LITERATURE REVIEW

This part is categorised as follows; the over view in oil and gas exploration, the drilling technology, well design and construction, the hole drilling, the main systems of a rotary drilling rig, the hole's logging, the running, cementing and logging of casing. Loss of primary well control, signs of a kill and detection and well control methods in conventional drilling.

2.0 The over view in oil and gas exploration

Crude oil and natural gas are usually a complex mixture of hydrocarbons, non-hydrocarbons and other trace elements; they are usually stored in the sedimentary rock of deep formations (Zou et al. 2015). With the knowledge of crude oil and natural gas, we need to do something to get the oil and gas out from the deep formations. As far as we know, the only way is to drill a well. Since 1895 the first commercial oil well was drilled using the percussion drilling method (Gatlin 1960), the drilling technologies had got a great progress. According to the rock breaking method, there are two kinds of drilling methods, i.e., the percussion drilling method and the rotary drilling method, in which, the rotary drilling method is the most widely used methods (Mitchell 1995; Chen 2011; Lyons and Plisga 2016) In fact, the rotary drilling method was developed mainly due to the improvement of operational efficiency, and its development is very slow in recent years. However, only the improvement of operational efficiency is not enough, we also need more advanced technologies to drill more complex wells, such as directional well, horizontal well, extended reach well, and multi-lateral well. So, according to the characteristics of well trajectory, some very important drilling methods, such as vertical drilling, directional drilling and horizontal drilling, had been developed in recent years. Therefore, more and more unconventional petroleum resources, such as shale oil and gas (Chen et al. 2014; Liu et al. 2016a), tight oil and gas (Zou et al. 2015), coal-bed methane (Zhi and Elsworth 2016; Verma and Sirvaiya 2016) and so on, gradually be taken seriously, due to the exhaustion of conventional petroleum resources and the development of directional drilling. On the one hand, to exploit ultra-deep petroleum resources, the vertical drilling are needed, mainly due to it can help us to reduce the down-hole accidents. On the other hand, to exploit unconventional petroleum resources, more and more non-vertical wells, such as directional well, highly-deviated well, extended reach well, horizontal well and etc., are utilized. For example, the extended reach wells and horizontal wells are usually used to develop the offshore oil and gas, mainly due to the required number of platforms can be reduced (Ma et al. 2015a); the horizontal wells are usually used to develop the tight oil and gas, shale oil and gas, mainly due to the drainage area can be enlarged and it's good for multistage fracturing, as a result, enhanced oil and gas recovery (Ma et al. 2015a). Thus, the vertical and directional drilling are the key technologies for the exploration and exploitation of oil and gas resources, and they are also the very important ways to exploit deep geothermal energy and geo-resources (Elders et al. 2014), conduct international continental scientific drilling program (ICDP) (Wang et al. 2015).

In order to review and discuss the vertical and directional drilling technologies and their recent developments, Zeng and Liu (2005) reviewed the technical status and development trend of drilling techniques in deep and ultra-deep wells, Wang and Zheng (2005) analyzed the technical status of deep well drilling of Petro China and discussed the challenges that the PetroChina encountered, Wang et al. (2006) reviewed the technical status of rock mechanics of deep or ultra-deep drilling, Yan and Zhang (2013) analyzed the status of the Sinopec ultra-deep drilling technology and presented the suggestions for the Sinopec. It should be noted that, although some reviews about the deep drilling had been given by above researchers, it's very limited in number and scope. Well control is based on decades of experience from worldwide drilling operations. In the early days of offshore drilling, most wells were drilled in shallow water with simple wellbore geometries. Over the years, the boundaries of drilling have continuously been pushed towards new extremes. The wells are getting deeper along with higher downhole pressures and temperatures, the waters are getting deeper and the wellbore geometries are getting more adventurous. Yet, there has been little change in the actual well control procedures and methods in use. In the aftermath of the recent events of the Macondo well in the Gulf of Mexico, there has been an increasing focus on safety and well control techniques and methods. Great effort has been made to investigate what went wrong, and to take lessons from the tragic accident.

Standard Norway, Norsok D-010, 2014 defines well control as a; ''collective expression for all measures that can be applied to prevent uncontrolled release of well bore effluents to the external environment or uncontrolled underground flow''. A kick is defined as an "intrusion of formation fluids into the wellbore."

A kicking well may develop into a full-scale blowout, if not handled properly. This may injure or kill people, and will damage the environment and property. Keeping a well in control at all times is therefore utterly important.

In conventional drilling, either vertical or horizontal drilling, the well is controlled by balancing the formation pressure with the hydrostatic pressure exerted by a column of drilling fluid. This is called primary well control. If the drilling fluid for any reason fails to provide an overbalance against the formation, the formation fluids may flow into the well bore, i.e. a kick is taken. By the means of secondary well control, the influx can be detected, contained and removed from the well bore in a controlled manner. In this way, primary well control is re-established. Thus, well control involves: Testing and verification of well barriers, Kick prevention, monitoring and maintenance of primary barrier, Kick detection upon failure of primary barrier, Influx containment, activation of secondary barrier, Removal of influx, re-establishment of primary barrier, well control depends on both equipment and operational procedures.

Horizontal and vertical drilling are two different drilling techniques used to explore and develop oil and gas properties. Horizontal drilling has gained market share over the last few years and now the dominant form of drilling in the United State according to Baker Hughes which maintains industry data rigs. According to the schlumberger oilfield glossary horizontal drilling involves drilling a well to a predetermined depth based on seismic and other geological data and then turning the well horizontally to a set lateral length. The well is then completed and production of oil and natural gas begins, this is sometimes referred to as directional drilling.

As at April 2010, there were 749 horizontal rigs, 225 directional rigs and 502 vertical rigs drilling for oil and gas in the United States according to Baker Hughes. On the other hand, the vertical drilling involves drilling a well straight down into the earth until the drill bit reaches the formation being developed. The well is then completed and starts producing oil or natural gas.

2.1 The Drilling Technology

Around 2500 BC the Egyptians used core drilling tools (brass tubes reinforced with diamond grains) for the construction of the pyramids (Delleur, J. W., 2010).

In China, in 1700 BC, wells were manually drilled, using the percussion system with bamboo poles, to depths of up to 800 feet. They extracted oil to burn it, to evaporate brine in order to produce salt. (Totten, G.E., 2013). Wells having up to 200 feet and diameters up to 14 inches were drilled by the Chinese between 600 and 260 BC (Lynch, A. J. & Rowland, C. A., 2005). Their churn drill method of lifting and dropping a rod tipped with a metallic bit, which allowed the drilling of a hole actually grinding only its outer section, appeared in Europe only during the 12th century.

At the time of the Roman Empire, the pump drill was used extensively. Pump drills involved both the use of a vertical spindle aligned by a wood board, and a flywheel (Hall, A. R., Holmyard, E. J., & Singer, C., 1967). Starting sometime between the ages of Roman and Medieval empires, the auger, which used a rotary helical screw like today's common Archimedean screw shaped bit, was used for the drilling of larger holes.

In 1126, the Carthusian order monks achieved water drilling up to 1000 feet. Around the 13th century the first hollow-borer tip was used. The use of the churn drill method, with a stick having a piece of tubular shaped copper or other metal on its end, was more productive (Daumas, M. Ed., & Hennyessy, E. B., 1969). Before the 15th century, the brace and bit, a type of a two parts hand crank drill, was invented.

Oil wells were hand dug up to 115 feet deep, in 1594 at Baku, in Persia (Totten, G.E., 2013). The first salt drilling was performed in Germany in 1810. In Pennsylvania, in the United States, oil was produced in 1815 as a byproduct from brine wells. The first cable tool drilling was made in Europe in 1825, and twenty years later Robert Beart obtained a patent on rotary drilling methods. In Baku (then in the Russian Empire) at the Bibi-Eibat field an offshore drilling started up in 1846; near Baku, on the Aspheron Peninsula, two years later the first modern oil well was drilled, using the dry percussion system with wooden rod. In 1854, at Bobrka, Poland, the first European oil wells were drilled up to 30-50 meters depth. The first steam powered rig was built in 1856. Colonel Edwin Drake drilled the first oil well in Titusville, Pennsylvania, in 1859.

The first diamond coring was performed in 1863 in Switzerland. Berthold Pensky produces flash point testers and other oil testing equipment in 1873. The first patent on a two-cone bit was issued in 1878. The New York state required the abandoned wells' plugging, through the first formal regulation, in 1879. S. F. Bowser produced the first gasoline pump in 1885, its tank of one barrel having marble valves and wooden plungers. A. J. Arnot and W. B. Brain, of Melbourne, patented the electric drill in 1889 and four years later the drilling depths reach 2004 m (Arnot, & Brain, 1889). The first patent for horizontal drilling was issued in 1891 to Robert E. Lee, for drilling a horizontal drain hole for a vertical well. The first offshore drilling was performed in Santa Barbara, in 1897. By the end of the 19th century the hydraulic percussion drilling, in which the debris removal was done continuously by water circulation, was largely used.

In 1898, the American Society of Testing and Materials (ASTM) were founded. Captain Anthony Lucas and Patillo Higgins first used rotary drilling in their Spindle top well in Texas for drilling oil wells in 1901. The ASTM discussed the need for standards in the petroleum industry for the first time on 22 October 1904.

In 1909 Howard Hughes Sr. patented the first roller cone for the rotary rock bit. Gilbert & Barker produced curb pumps with measuring devices in 1911; while the Beman Auto Oil Can Co. was selling the "New Improved Automatic Tank."

The rotary system appeared in the early twentieth century in the U.S. The first rock bit was used in 1908. The first rotary rig using a diesel engine was built in 1925, and four year later the first use of bentonite as a drill mud was registered. In 1933 two Hughes engineers, one of whom was Ralph Neuhaus, introduced the tri-cone bit as a new drilling tool. The horizontal drilling dates back to the 1930s, as the first recorded true horizontal oil well was completed in 1929 near Texon, Texas. H. John Eastman pioneered in directional drilling in 1934, when in the company of George Failing he saved the Conroe, Texas, oil field. The Interstate Oil Compact Commission (IOCC) was formed by Oklahoma, Texas, Colorado, Illinois, New Mexico and Kansas in 1935, for the government's intervention into the industry supply-demand chain (National Energy Technology Laboratory, Office of Fossil Energy, & U. S. Department of Energy, May, 2009).

In 1947 the first modern off-shore oil well's drilling depths reached 17,000 ft, while in 1953 the first hydraulic rig was produced and commissioned. The first drill ship was launched in 1955. Drilling depths of 31,358 ft were reached in Oklahoma in 1974, while the Kola Super Deep Hole of 40,223 km is the deepest hole in Russia.

2.2 Well Design and Construction

The technologies of the wells' drilling evolved in time and the technologies used to drill oil and gas wells are similar to the conventional gas wells drilling techniques that are now considered the industry standards (Azar & Robello, 2007). In order to effectively manage the natural gas resource, and to efficiently drain it, due to the shale's low natural permeability, the vertical wells were required to be developed at closer spacing intervals than the conventional gas reservoirs, thus the spacing intervals of vertical shale gas wells are of 40 acres per well, or less.

The current oil and gas wells' drilling and completion include both vertical and horizontal wells, but the number of the horizontal wells grows as the plays mature. That is the reason for which horizontal drilling has become the preferred method of drilling in most of the exploration of oil and gas play. Horizontal wells have been used in many areas to access the remote resources from beneath the existing infrastructure, buildings, environmentally sensitive areas, or other traits that could prevent the vertical wells' use.

Once the site's location has been established, the natural gas well drilling and completing consist of several sequential activities which are largely described in the following sections.

2.3 The Hole Drilling

The preparation of the drilling fluid ("the mud") is required before starting the drilling. The drilling fluid is used to cool and grease the bits, while it is removing and transporting the cut rock fragments to the surface. The mud also compensates the formation pressure preventing the blowout of the well due to the premature entering of formation fluids into the well. The drilling fluid precludes the open hole from crack-up (Azar & Robello, 2007).

The pipes are elevated from the pipe rack (or the catwalk) with the cat line usually, or with the help of the air hoist hydraulic winch. The pipes are positioned in the mouse hole and the first drill bit is fastened to the bottom hole drill collar attached to the Kelly. The bit at the end of the drill string is gradually drooped down through the rotary table. The drilling fluid pumps start. The crew checks for leaks and breaks and only after the inspection the rotary table is employed. The sharp, chiseled bit is lowered to the bottom and the drilling operation begins: the bit is rotationally driven into the rock. The used bit is replaced according to the drilling program.

There are many different types of drill bits that facilitate the different types of formations' breakage, the three main types of drill bits being:

- The blade or drag bit, which is made out of steel and tungsten; it is suitable for unconsolidated formations.
- The steel tooth rotary bit, which was invented in the 1900s, which crushes and chips various rock formations; it is used for the majority of the drilling projects. The long-

tooth roller cone bit is preferred for softer formations while the short toothed bit was considered the best for hard ones. Aiming to improve the steel tooth rotary bit's abrasive effects, the granite and/or quartzite was recently replaced by tungsten carbide. The conventional drill bit has three movable cones containing teeth made of tungsten carbide steel and sometimes industrial diamonds. The drill bits range usually from 3¾ inches (9.5 cm) to 26 inches (66 cm) in diameters. The most commonly used sizes are 17½, 12¼, 7 7/8, and 6 ¼ inches (44, 31, 20, and 16 cm).

- The diamond and polycrystalline diamond bits (Figure 1), which have a layer of industrial diamonds over the carbide insertions. These bits are used to crush the hardest formations, because they are harder than all the conventional steel tooth rotary bits.

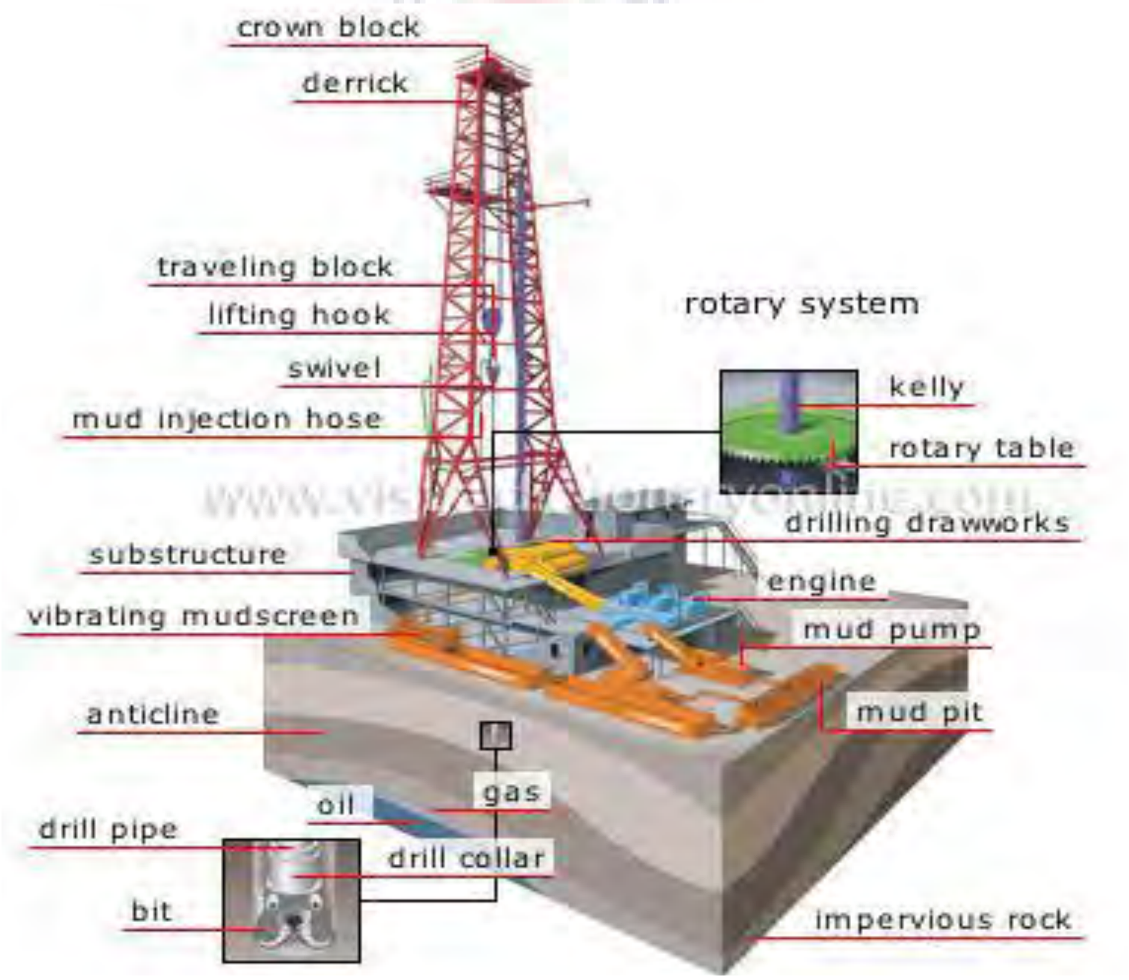


Figure 2: Drilling Rig setup

2.4 The main systems of a rotary drilling rig (Figure 1) are:

- The prime mover's system, consisting of one to four or more engines (commonly diesel engines) connected to the generators. Gas engines, as well as reciprocating turbines, are also used, depending on the site circumstances, to ensure the power for engines, compressors, pumps, site lighting, and water line requirements. The electrical power is then distributed around the rig site, to the rig components. Most rotating rigs nowadays need 1,000- 3,000 horsepower, while shallow drilling rigs may have need of as little as 500 horsepower. The power is primarily used to rotate the drill bit need 1,000- 3,000 horsepower, while shallow drilling rigs may have need of as little as 500 horsepower. The power is primarily used to rotate the drill bit.
- The hoisting tools consist of the tools used to raise and drop the equipment that may go into or come out of the well. The hoisting equipment includes the derrick (the tall tower-like structure made of steel 'I' beams that extend vertically from the well hole and that has a steel floor as substructure), the cables and pulleys, the draw works (the hoist mechanism which has a brake system), the crown block, the traveling block and the hook and wire rope. The derrick is erected on the substructure which supports the rig floor and rotary table and provides work space for the equipment on the rig floor. The drill line passes from the draw works to the top of the derrick. From there it is sheaved between the crown block and traveling block and then it is clamped to the rig floor by the deadline anchor. The whole string of pipe must be raised to the surface in furtherance of changing the bit. The draw works control the cable drums during the lifting of the elevators and swivel. The draw works gear (transmission) system gives the driller a wide choice of speeds for hoisting the drill string. The make-up cathead, placed on the driller's side, is used to spin up and tighten the drill pipe joints, while the

breakout cathead, located opposite the driller's position on the draw works is used to loosen the drill pipe when the drill pipe is withdrawn from the borehole.

- The rotating equipment consists of the swivel, Kelly, rotary table/top drive, drill string and bit. The swivel hangs from the drilling hook by means of large bail, or handle. The swivel continuously and freely rotates the drill string which has the bit, which cuts off the rocks, deepening the wellbore, at its end. The drilling fluid is introduced into the drill stem through a gooseneck connection on the swivel, which is connected to the rotary hose. The drill string is composed of pipe-long sections which are joined and unlinked during the drilling process according to the needs. The drill pipe and drill collars have threaded connection on each end. Whenever the drill stem is suspended by the traveling block and drill line, the entire load rests on the derrick. When a 'top-drive' system is used, the swivel is replaced by the power swivel. The Kelly is square or hexagonal and engages the Kelly bushing which fits into the master bushing from the rotary table.

The circulating equipment whose main objectives are the cooling and greasing of the drill bit while removing cuts and debris. The drilling fluid, which is circulated down through the well hole, is coating the walls of the well with a mud cake. On reaching the surface again, the drilling fluid is filtered to recover the reusable fluid. The mud exerts sufficient hydrostatic pressure on the formation preventing walls from caving, and reducing the friction between the hole and the drill string while delivering the hydraulic energy to the formation under the bit (International School of Well Drilling, 2008).

While drilling, the tubulars' handling is a repetitive process. The crew hoists the drill string with the draw works until the Kelly is out of the rotary table and then the driller shuts down the mud pumps. The floor hands position the slips around the pipe's joint, and then, above and below the connection, the tongs are latched onto the tool joints. The pipes are joined using the Kelly and the tongs to twist the joint. The draw works is elevating the Kelly to hitch up the joint. The joint of the suspended pipe is guided and lowered with the slips. The joints are fastened together using either the pipe spinner, spinning chain, or Kelly spinner's help. The lifting of the Kelly and string facilitates the removal of the slips.

The rotary table as well the drill string is stopped from rotating while the pipes are broken out with the help of the tongs, catheads, and the rotary table or kelly spinner which are gyrating the drill string. At the operation end the mud pumps are restarted, the slips are removed, and the drilling is resumed, the bit being slowly lowered back to bottom, to continue to deepen the hole. For each pipe connection the same steps are repeated. The process of removing and/or replacing the pipes from the well, whenever it is necessary to change the bit or the drill string pieces, or whenever certain tests in the wellbore are required, is called the tripping. The tripping out starts with the settings of the slips around the drill stem, followed by the breakout of the Kelly and its fixing into the rat hole. The elevators are attached by the crew to the elevator links and then are latched onto the pipe. The elevators are unlatched and the pipe's stands are guided into the fingerboard by the derrickman from the monkey board. The elevators are then slowly lowered and attached to the next pipe's stand. The crew breaks out the pipe and, after breaking the connection, the pipe is spun out using the rotary table. The stand is raised and pushed around to the pipe racking area. The tripping out process and tripping in process comprise essentially the same steps in reverse order. The tripping in starts with the elevators rising; and then its latching onto the pipe by the derrickman from the monkey board. The following steps are the pipe's moving to the rotary table: the joining of the pipes, the pulling and setting of the slip and the unlatching of the elevators. The process is repeated for all the stands.

The Kelly is picked up and attached to the drill string. The circulation is broken, and the drilling is resumed. The core samples are cut from the formation by means of a core barrel and are examined in specialized laboratories (Inglis, 1988). The drilling of a typical gas well consists of several cycles of drilling, running casing and cementing the casing in place to ensure isolation, the steel casing being installed in sequentially smaller sizes inside the previous installed casing string.

2.5 The Hole's Logging.

The hole logging produces information on all crossed formations, including the subsurface formations in the wellbore's actual depth and thickness, which allows the installation of the casing strings in the exactly right position to achieve the well's design objectives and the casing and cement isolation benefits. After the hole drilling is completed, and before the casing's installation and the beginning of the cementing operations, the operation called well logging takes place, by running in the drilled hole, on an electric cable, electrical sensors and other instruments (Devereux, 1997). The open-hole logging is carried out prior to setting casing and is used for locating and evaluating the hydrocarbon producing formations. The geologists select the types of logs that follows to be run in a well at the well's designing time. The well logs are used as critical data gathering tools, during the formation evaluation and the well design and construction optimization. In order to assess the well's integrity during its construction along with the well logs' various mechanical integrity and hydraulic pressure tests can be used. The common logging tools used for evaluation include the following log types:

- Gamma Ray—the device detects the naturally occurring gamma radiation.
- Resistivity— the device measures the electrical resistance between the probes placed on the logging tool in the wellbore. Usually three to ten resistivity logs are running,

depending on the distance between the probes. The investigation's radius is increased with the distance between these probes.

- Density—the device measures the formation's bulk density, and its porosity, by inference.
- Caliper—the wellbore's diameter physical measurement device. The caliper is used to calculate the actual hole size and wellbore's volume, necessary in the cement job's design. Other logging tool types are available and may be run according to each case specific basis.

2.6 The Running, Cementing, and Logging of the Casing.

The pipe's casing is usually larger in diameter and longer than the drill pipe. The casing is used to line the hole periodically throughout the drilling process. The casing running starts with the surface casing, continues with the intermediate casing, and ends with the production string, which is ran during well completion. These steel casing and cement multiple layers are required to be specifically designed and installed in order to protect the groundwater, including the fresh water aquifers, and to ensure the overlying formations' isolation from the producing zone. The fluids (water, mud, and gas) produced from the well must travel inside the well conduit directly from the producing zone to the surface, as the casing runs, and the cement placement provide barriers preventing the fluid's migration.

The drill string is used to drill the well. It consists of a drill bit, drill collars (the heavy weight pipe located just above the bit to puts weight on it), and the drill pipe (Azar & Robello, 2007). The drill string is assembled and ran into the hole, while suspended from the drilling derrick or mast, on the surface. The drill string is rotated using the turntable (the rotary table), top drive unit, or the down hole motor drive. In the first drilled hole, the conductor pipe is installed or driven into place, like a structural piling.

The following sequentially deeper drilled holes are used to install the surface casing, intermediate casing (when necessary), and the production casing, in this way the well's shallow portions have multiple concentric steel casing strings installed, as shown in Figure 2.

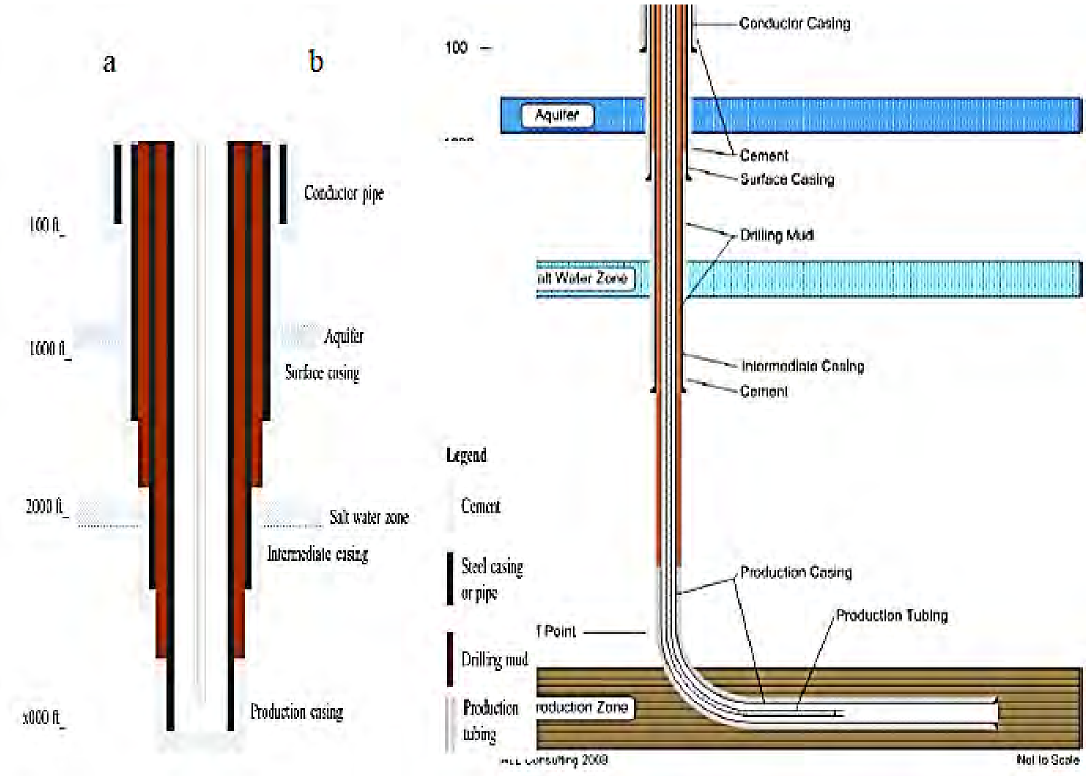


Figure 3: Production casing

Strings number and the appropriate drilling fluid selection are determined by each drilled well's geologic conditions likely to be encountered (Devereux, 1977). The various compressive, tensional, and bending forces, as well as the collapse and burst pressures are endured by the casing while running in the hole and during certain phases of the well's life. For example, the cement column exerts hydrostatic forces during cementing operations on the casing; after cementation certain subsurface formations exert collapsing pressures on the casing; and subsurface pressures on the casing exist regardless of the hydrocarbons' presence. The steel casing strings assure the zonal isolation and integrity of the wellbore, in this way requiring that the casing design and running to be carefully executed technical processes.

The casing is threaded on each end, and has a coupling installed to join it to the next pipe. The continuous casing "string" that isolates the hole is formed by screwing together several casing joints, while applying the proper amount of torque. Applying too much torque overstresses the connection determining its failure, while applying too little torque will lead to a leaky connection. The casing and coupling threads used in shale gas wells should meet the API standards that cover their design, manufacturing, testing, and transportation. The casing must meet strict requirements for tension, compression, burst resistance, collapse, quality, and consistency, as the casing should withstand the production pressures, hydraulic fracturing pressure, corrosive conditions, and other factors. The used or reconditioned casing should also be tested to ensure that it meets the same API performance requirements as the newly built casing. The threads from specialized suppliers must also pass rigorous testing and should adhere to API qualification tests applicable subsets.

In the borehole the conductor and the casing strings are cemented in place. The cementing is a fully designed and engineered process and oilfield cements. The goal of the cementing is the complete displacement of the drilling fluid by the cement realizing the cement interfaces' good bonding between the drill hole and casing immediately above the hydrocarbon formation, without any voids, thus preventing the migration paths. The casing's cementing provides zonal isolation between different formation, as well as the well's structural support. The cement maintains the well's integrity throughout its life and constitutes a part of the corrosion protection for casing. The cement must be placed around the casing in a complete annular filling, with tight cement interfaces between the casing and formation and at the proper height above the driller holes' bottom.

The casing hardware includes the float equipment (for example the scratcher, guide shoe, and float collar), centralizers, cement baskets, (top and bottom) wiper plugs, and stage tools (Azar, & Robello, 2007). The centralizers help to center the casing in the hole in this way providing for the good mud removal and cement placement. The casing centralizers are devices that are attached to the outside of the casing, allowing the cement to completely annularly fill the casing in a continuous sheath. The cementing critical areas are the casing shoes, production zones, and groundwater Aquifers. The standardized centralizers are classified according to their design in: the bow-spring design, the rigid blade design, and the solid design. The centralizers' selection, number and placement within vertical and deviated wellbores are determined according to API RP 10D-2 and API TR 10TR4 guidelines. To optimize the needed centralizers' number and their placement various computer programs can be used.

The service companies are carrying out the cement testing procedures. The cement slurry is designed in order to meet the following specific parameters that depend on the site-specific geologic conditions: slurry density, thickening time, free fluid; fluid loss control; compressive strength development; fluid compatibility (cement, mix fluid, mud, spacer), as well as sedimentation control; static gel strength development; expansion or shrinkage of set cement; and mechanical properties (Poisson's Ratio, Young's Modulus, and so forth). The cementing is accomplished by pumping the cement slurry down the casings' inside, and circulating it back up the casings' outside. To minimize the cement mixing with the drilling fluid during the pumping, the top and bottom rubber wiper plugs are used. Usually, the cement placement is a two-stage process. In the first stage a "lead" cement of lower density is used, and in the second stage a higher density and compressive strength "tail" cement is used to isolate the critical intervals in the well.

During the cementing process, the casings' rotation and reciprocation allow the scratchers to remove the excess wall cake in order to give the cement a better bond. An example of "a typical casing and cementing program for horizontal well" After the casing's cementing, the "cased-hole" logs are run inside the casing in order to determine the exact location of the casing, and casing collars, and to check the quality of the cement job. Its results show if the well drilling construction is adequate and achieves the desired design objectives, and serve as input data in well integrity and seals subsequent checks over the well productive life. The common logging tools used include the following log types:

- The gamma ray,
- The collar locator - the magnetic device which detects the casing collars.
- The cement bond log (CBL) - the acoustic device that measures the cement presence and its bond or seal quality between the casing and the formation by transmitting a sound or vibration signal, and recording the amplitude of the arrival signal. Large amplitude acoustic arrival signal shows that the cement does not surround the casing, as the energy remains in the pipe. A much smaller amplitude arrival signal shows that the casing has a good cement sheath filling the annular space between the casing and the formation. The acoustic energy was absorbed due to the "acoustical coupling" of the casing with the cement, which creates the desired isolation.
    - The variable density log (VDL) - is a device that displays the acoustic signal wave train commonly with the CBL. The display shows the cement operation key features, such as top of cement and the location of the casing collars. VDL is using the data derived from the previous run well logs. For example, during the well

perforation, the gamma-ray detector is running in the hole with the perforating guns, in order to have the exact location with regard to the formations of the perforating guns', location which is determined by comparison with the open hole gamma-ray response. The CBL-VDL is the most commonly used type of cement evaluation tool (Azar & Robello, 2007). Other cement evaluation tool types are available and can be used depending on each cementing program. Information regarding the current various cement evaluation tools types are available in API TR 10TR1.

The casing setting depths are determined in the drilling plan, each casing string depth being critical in assuring the isolation, as well as in meeting the regulatory requirements, while achieving the well system integrity needed to support the following drilling operation, and to contain the pressures that might occur inside the well. The actual casing strings length is adjusted during the drilling process, based on the actual measurements and data from the logs results, drill cuttings analysis and pressures and drilling loads analysis. The cement is required to be placed back on the surface on each casing string only in some cases specified in the well design and addressed by the regulations (Devereux, 1997).

The cement surrounding the casing shoe should have a compressive strength of over 500 psi, and should reach 1200 psi in 48 hours, at the bottom wellbore's conditions, after the cement is set and prior to commencing further operations of drilling or completion. However, for production casing, the cement should be adequate to withstand the anticipated hydraulic fracturing pressure, fact that is proven through the specific pressure tests. Except the conductor casing, all the other casing strings should be pressure tested prior to the "drill out" operation, depending on the casing string, depth, and other factors. The conductor casing is the first casing installed within the well, serving as the well's foundation, isolating the shallow groundwater and holding back the unconsolidated surface sediments, while protecting the subsequent casing strings from corrosion as well as structurally supporting some of the wellhead's load. Harder and more consolidated rocks are below the conductor casing.

The conductor steel casing is inserted into the drilled hole and cemented in place according to the well design and using the proper cementing practices. Another used method is to "hammer" the conductor casing into place, the casing being driven directly into the ground, similar to structural piling for buildings or bridges. The conductor hole is usually drilled using air, freshwater, or freshwater-based drilling fluid. The conductor casing's setting depth depend on the nearby water well's depth (Jackson, 2001).

During the conductor casing cementing, the cement is placed back on the surface by using ordinary pumping methods, or by running a small diameter pipe between the conductor casing and the hole and pumping the cement around the surface pipe outside. This cementing method is often called a "top job" or "horse collar." After the conductor pipe cementing, the surface hole is drilled using air, freshwater, or freshwater-based drilling fluid to a predetermined depth, and the surface casing is ran into the hole and cemented in place, to ensure the groundwater aquifers protection, through its isolation, and to contain the pressures which might arise during the subsequent drilling process. The surface wellbore depth is set from a few hundred feet up to 2000 feet deep or more, taking into consideration the deepest groundwater resources and the requirements of the subsequent drilling's pressure control. The surface casing should be set at least 100 feet below the deepest groundwater aquifer encountered while drilling the well.

The surface casing should be cemented from the bottom to the top, in order to completely isolate the groundwater aquifers. In the cases in which the cementation from bottom to top is not possible or required, the cementing across all groundwater aquifers (a "top job" that will provide the required isolation objectives) is recommended. Unique geologic conditions may not permit the surface casing to be run deep enough to completely isolate the groundwater aquifers or preclude from surface casing at all. In these cases, additional strings or a combination of surface, intermediate, and/or production casing are used and cemented, to achieve the needed isolation.

A casing pressure test is necessary after the surface casing cementing and prior to drilling out, to determine if the casing integrity is adequate, and a formation pressure integrity test (a "shoe test" or "leak-off test") is recommended right after the drilling out of the surface casing along with a few feet of the new formation below the surface casing shoe. These tests results may impose remedial measures to be undertaken. The intermediate hole's drilling and intermediate casing running serve to ensure the borehole stability and integrity by providing protection against abnormally pressured subsurface formations and by isolating the unstable subsurface formations. The intermediate casing string may be unnecessary in some cases, determined by the geological setting prior to drilling or by measurements and data collected during the drilling process. The intermediate casing is not required to be cemented back to the surface, in order to provide the adequate isolation, especially where the groundwater aquifers are fully protected by the surface casing string and cement, but the cement should be extended above all exposed underground sources of drinking water (USDWs) or all hydrocarbon bearing zones. Some attempts to cement the intermediate casing back to the surface resulted in lost circulation. CBL and/or other diagnostic tools are ran to determine the cement's integrity and a casing pressure test is usually conducted to verify if the casing integrity is also adequate to meet the well design and construction objectives.

A formation pressure integrity test (a "shoe test" or "leak-off test") is recommended right after the drilling out of the intermediate casing along with a few feet of the new formation below the surface casing shoe. If the test results of this test indicate a failure, remedial measures are required in order to maintaining the well's integrity.

The production casing hole is the final drilled hole. After the production hole drilling and logging, the production casing is run to the well's total depth and cemented in place, according to the casing and cementing program.

2.7 Loss of primary well control

Loss of primary well control is usually due to

2.7.1 Insufficient Mud Weight

The hydrostatic pressure exerted by the column of mud in the hole is the primary means of preventing kicks. Insufficient mud weight can result from penetration of an unexpected, abnormally high-pressure zone, or be due to deliberate under balance drilling methods in field development wells. Accidental dilution of the mud with water, in the surface tanks, is a relatively common occurrence, and must be guarded against. With water base mud and fast drilling, it is common to add considerable quantities of water.

If the drilling rate slows, and other problems distract attention from the routine checking of active mud weight, the slow reduction in mud weight may escape notice until it is too late. In some areas of the world, it is necessary to drill while taking a continuous small flow of water from aquifers. Great care must be taken here to ensure that excessive dilution does not occur.

2.7.2 Abnormal Formation Pressures

In an abnormal pressure, if a permeable zone containing fluids pressured above the normal gradient for the area is to be penetrated, then appropriate mud weights must be run. Where possible, prediction of likely abnormal pressures should be carried out, both during well planning and during drilling. A number of trends will signal changes in formation pressure. Sometimes low permeability formations known to be abnormally pressured, such as massive shale's, are deliberately drilled under balance to improve drilling rate. If the permeability is low, the formation fluid does not flow at a sufficient rate to be significant before the hole section is completed and cased off. Signs of high formation pressure may be seen in the form of 'sloughing' or 'heaving' shale's, excess hole fill, and elliptical hole sections or tight spots. Providing these effects can be kept under control, the hole may be more rapidly and economically completed using under balance drilling techniques.

It may be necessary in such cases to increase mud weight for trips, and care must be taken if permeable sand zones or lenses are encountered. These, being permeable, allow fluid to flow and, if sealed within abnormally pressured rocks, will have abnormal fluid pressure. Kicks can occur when total lost circulation occurs. If the loss of whole mud to natural or artificially induced fractures is sufficiently great, then all returns from the well will cease and the level of mud in the well annulus will drop.

2.7.3 Loss of Circulation

Loss of circulation can occur to cavernous formation; naturally fractured, pressure depleted or sub-normally pressured zones; fractures induced by excessive pipe running speeds, (surging); annulus plugging due to Bottom Hole Assembly (BHA). Packing-off or sloughing shale's; excessively high annular friction losses; or excessive circulation breaking pressures when mud gel strength is high. When this type of kick occurs, it may rapidly become very severe since a large influx can occur before a rising annulus mud level is seen, for this reason; it is recommended that the annulus should be filled with water to maintain the best possible hydrostatic head in the well.

2.7.4 Shallow Gas Sands

Drilling into shallow gas pockets is one, of the-most dangerous situations that can be encountered. In a shallow well, gas can travel to the surface very rapidly, giving little warning. While drilling surface hole, the short surface casing string is set in a relatively weak unconsolidated formation. It is normally necessary to divert the flow rather than shut the well in, risking fracture at the casing shoe and the possibility of gas coming up around the outside of the well. As the bottoms-up time involved is short, the drill crew should be alert for signs of a kick. The flow sensor may be the only item of equipment able to give an early enough warning of a shallow gas kick in progress, which allows the diverter to be put into use. This sensor should be kept working whenever possible. If in doubt shut off the pumps and carry out a flow check.

The pit level gains, although a valuable indication, are generally noticed too late. Most shallow gas pockets are found in exploration wildcat wells, though shallow gas-charged sands may be found in field development wells. In the latter case, the shallow formations have been charged with high-pressure gas from deeper zones in nearby wells, which has migrated due to a failure on the previous well. Poor cement jobs, casing failures, inadequate abandonment procedures, micro annulus, down hole blowouts and injection well operations are all possible causes.

2.7.5 Excessive Drilling rate in Gas Bearing Sands

When a formation containing gas is drilled, the mud becomes gas cut due to the breakout of gas from the cuttings as they are circulated to the surface. The gas in the hole is subjected to normal hydrostatic pressure. As it percolates or is circulated up the wellbore, the pressure decreases and the gas expand. Small quantities of gas can cause a large reduction in mud weight as measured in the flow-line at the surface. The reduction in total hydrostatic head in the well is quite small although the surface effect appears large.

If very fast penetration is made in a gas-bearing formation, the percentage of gas in the mud is likewise increased and problems may result. The rapid expansion of gas near the surface may cause 'belching' at the bell nipple with a loss of mud from the well and a consequent drop in the hydrostatic pressure. This may induce further belching' and lowering of the hydrostatic pressure to below that of the formation so that a kick may result. This sequence, once started, rapidly gets out of control.

2.7.6 Swabbing in a Kick

When the drill string is pulled up out of the hole during a trip, mud must flow down past it to fill the space left behind. The effect of the upward movement of the bit and bottom hole assembly can be compared with a loosely fitted plunger in a syringe.

Every time the drill string is moved, it follows there must be a pressure variation, however small, and this must be allowed for. The normal overbalance, or Trip Margin, is intended to overcome this potential problem. A swabbed kick is particularly hazardous since often a brief swabbing situation is followed by normal tripping conditions. If the small discrepancy in string displacement volume is not observed at once, it will probably be overlooked afterwards. No other warming sign of the presence of a kick in the well may be seen. An influx of gas, for instance, swabbed into an open annulus, may displace only a very short head of mud. The net decrease in bottom hole pressure is small and likely to be well below the normal range of the Trip Margin overbalance. No further swabbed influx will occur into the well and, if the well is shut in, no pressures will show on either drill pipe or casing pressure gauges since the well is still in balance.

If a gas influx has been swabbed in, it will slowly migrate up the well and expand. At first, this expansion is very slow, and it is unlikely that any significant flow will be seen at the surface unless the influx is very large, or very close to the surface. The greatest potential for swabbing generally occurs when tripping through a new hole section. This is because the initial mud filter cake deposited on a new section of hole is soft and thick. It has not been wiped by the bit. Particular care should be taken at the start of a trip to ensure that no swabbing occurs. As previously mentioned, bit and stabiliser balling are common causes of swabbing, especially in soft gumbo shale's and clays. The best protection here is to circulate until the hole is clean. The only reliable method of detecting a swabbed kick as it occurs is proper hole fi1l procedures, the trip volumes must be carefully monitored.

2.7.7. Human Error

Human error is the major cause of all kicks.

2.8 Signs of a Kick and Detection

When a kick occurs, the surface pressure required to contain it will depend mainly on the size of the influx taken into the wellbore. A small kick shut in early means lower pressures being involved during the well kill, it is easier to deal with a kick that is noticed early and shut in quickly. One of the most important duties of a Driller is to shut the well in quickly and properly with the least amount of gain. There are a number of warning signs and indications, which will alert the Driller to the presence of a kick, or an impending kick.

Not all the signs will necessarily be observed in any one instance, though some will be there to provide a warning to the Driller. Positive signs and indicators include;

2.8.1 Flow Rate Increase

When an influx is flowing into a well with normal circulation in progress, the total volume of drilling fluid returning from the well increases. A flow sensor, such as a flow paddle system, provides a means for measuring quite small variations in flow. If it can be detected, this change in flow rate is a definite sign of a kick in progress. There are few other possible causes for an increase in flow rate and for this reason it is said that a flow rate increase is the first reliable indicator of a kick in progress.

2.8.2 Pit Volume Increase

An influx of formation fluid must result in the expulsion of mud from the well, and this shows up as an increase in surface volume in what is, normally, a closed circulating system. As is the case with flow rate, a gain in pit level may be hard, or impossible, to detect when a slow bleed-in of fluid occurs. It is also very easy for other factors to mask a change in pit level. Surface additions to the mud system, or surface withdrawals and dumping, must be done with the Driller's knowledge. When a continuous addition is being made, the addition rate should be determined and monitored so that any further increase due to a kick can be detected.

2.8.3 Pump Pressure Decrease/Pump Stroke Increase

Invading formation fluid generally reduces the hydrostatic pressure in the annulus. The hydrostatic of mud in the drill pipe is unaffected, so that there is a tendency for fluid to 'U-tube'. This means that the pump does not have to provide so much energy and this may be seen as a pump pressure reduction. Depending on the rig installation, a small increase in pump rate may also be noted.

2.8.4 A Change in Penetration Rate

A sudden increase in rate of penetration is usually caused by a change in formation type. It may however signal an increase in permeability and a loss of pressure overbalance. Both these effects result in faster drilling. The drilling break may be spectacular, though most commonly a gradual change is seen. It is rare for the drilling break to indicate a kick is in progress, though it is often a sign that conditions are changing and formation pressure rising, which may lead to a kick.

It should be noted that, a Negative Drilling Break, a sudden decrease in penetration rate could also be a kick indicator.

2.8.5 Incorrect Hole Fill Volume

The importance of ensuring that the correct amount of mud is added to the hole to replace the drill string as it is removed has already been discussed. Equally, it is important to ensure that the correct amount of mud returns from the hole as the drill string is run into the hole. Careful monitoring of trip tank volumes, or hole fill up volumes, is essential. If serious doubt exists over a discrepancy, and recalculation and level checks still show that a discrepancy may exist, the safest response is to shut in and check the pressures. If none exist, then return to bottom and circulate bottoms up before tripping out again. When the possibility of swabbing is considered high, a short trip of a few stands, or possibly to the last casing shoe and back, may be made, with bottoms up then circulated to determine whether a full trip can be made safely.

2.8.6 Hole Keeps Flowing Between Stands while Running

While running the drill string into the hole, we expect the well to flow the amount of mud being displaced by the drill pipe metal volume. As a stand of pipe is run into the well, the flow of mud from the well commences. Once the stand is in and the slips set, the flow should subside over a few seconds as the system returns to balance. if the well has not stopped flowing by the time the next stand is ready for running in, it is probable that something is wrong. The well will be observed and shut-in if there is any doubt.

2.9 Well Control Methods in Conventional Drilling.

The objective of the various kill methods is to remove formation fluid from the wellbore and circulate a satisfactory weight of kill mud into the well without allowing a further influx into the hole. This must be accomplished with the minimum of damage to the well. If this can be accomplished, then when the kill mud has been fully circulated around the well, it is possible to open up the well and restart normal operations. Normally, a kill mud which provides a hydrostatic balance for formation pressure is circulated. This allows for an approximately constant bottom hole pressure that is slightly greater than the 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.

2.9.1 Driller's Method.

This is a two-circulation method (minimum). During the first circulation, the drill pipe pressure is maintained at a constant value until the influx is circulated from the wellbore. During the second circulation, kill mud weight is pumped to the bit while following a drill pipe pressure schedule. When the kill mud enters the annulus, finally.

Circulating Pressure is maintained constant until the kill mud reaches surface. Because very high annular pressure may arise when killing a gas kick with this method, care should be taken. Annular pressures will be at a maximum immediately before gas arrives at surface, and casing burst pressure limitations may be critical.

Advantages

1: Circulation can start immediately after surface pressures stabilise if hole conditions warrant.

2: This is a viable option if there is limited barite available.

3: Less chance of gas migration.

4: Simple and easy method with little or no calculations.

5: This is the preferred method in highly deviated or horizontal wells.

Disadvantages

1: Highest annulus pressures for the longest period of time.

2: In certain situations, the highest shoe pressures are generated.

3: Longest on choke time.

4: Greatest pressure applied to surface equipment.

2.9.2 Wait & Weight.

The Wait and Weight is sometimes referred to as the One Circulation Method, it does at least in theory, kill the well in one circulation. This is the preferred method used by most operators and recommended by many well killing experts. Its principal advantage is that it provides the lowest annular pressures during the circulation of the kill, making it the safest of the commonly used kill methods. Once the well is shut in and pressures stabilised, the shut-in drill pipe pressure (SIDPP) is used to calculate the kill mud weight. Mud of the required kill weight is mixed in the mud pits. When ready, the kill mud is pumped down the drill string. At the start of the kill operation, enough drill pipe pressure must be held to circulate the mud, plus a reserve equivalent to the original shut-in drill pipe pressure (SIDPP), this is the Initial Circulating Pressure, (ICP). This total steadily decreases as the kill mud is pumped to the bit, with kill mud at the bit Final Circulating pressure is achieved.

The choke is adjusted to reduce drill pipe pressure while kill mud is pumped down the string. With kill mud at the bit, the hydrostatic of the kill mud in the drill pipe balances formation pressure. For the remainder of the circulation, as the influx is circulated to the surface, followed by drill pipe contents and the kill mud, the drill pipe pressure is held at the Final Circulating Pressure value (FCP) by choke adjustment.

Advantages

1: Lowest wellbore pressures.

2: Lowest surface pressures therefore less equipment stress.

3: Minimum on choke circulating time.

4: In certain circumstances using the Wait and Weight Method give the lowest casing shoe pressures.

Disadvantages

1: Considerable waiting time (while weighting up).

2: Gas migration.

3: If large increases in mud weight required, this is difficult to do uniformly in one stage.

4: Cuttings settlement and the potential for annulus pack-off.

2.10. Well Control Considerations for horizontal and vertical wells.

Horizontal wells are widely drilled around the world because the production from the horizontal wells is outperform normal vertical or deviated wells at the same location. The productivity of the well increases because of longer penetration into a pay zone and/or more intersection of reservoir fractures (see Figure below).

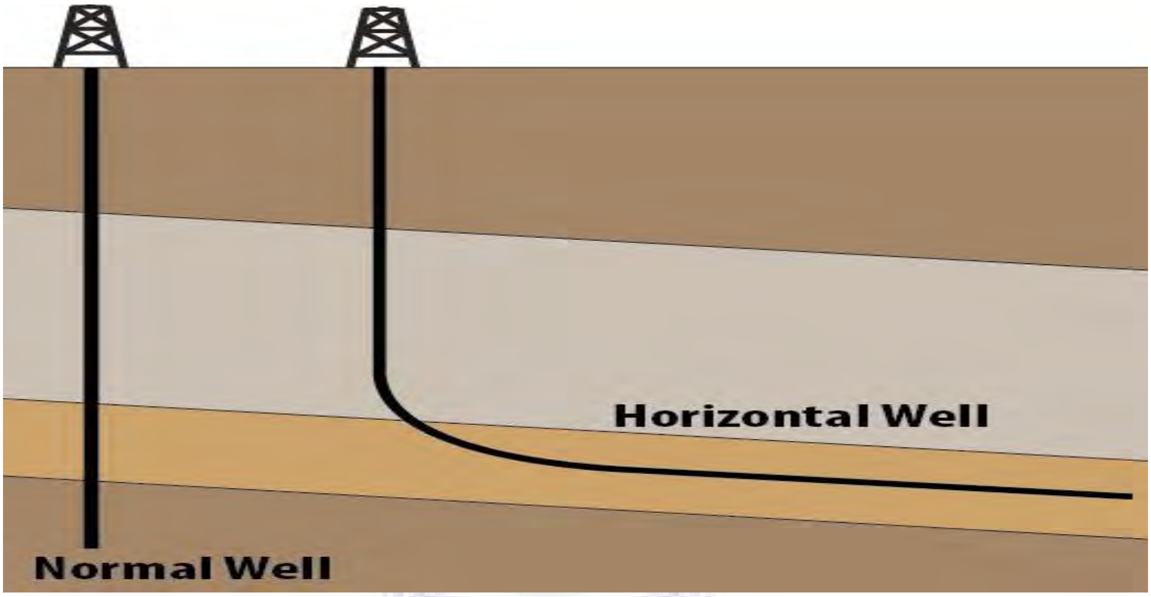


Figure 4: Typical Normal well and Horizontal well

Well control for the horizontal wells has the same fundamental principle during the circulation of influx from the well. There are some corrections which adjust for frictional pressure between true vertical depth and measure depth since the horizontal wells usually have very long depth in comparison to wellbore true vertical depth.

Driller's method is a preferred method for horizontal well control because it does not require drill pipe pressure schedule. Personnel can start circulate the first circulation to remove kick and displace the well with kill weight fluid using the second circulation method. However, if Wait and Weight method is planned to used, personnel should use a well control kill sheet with horizontal well feature to simulate the profile. It is very difficult to determine drill pipe schedule because there are several factors associated with calculations as well bore profile, size of pipe, hole size, etc. Performing the well control in the horizontal wells is similar to normal wells but you need to understand about the hydrostatic change when the gas kick moves from a horizontal section to a vertical section. This make casing pressure profile increase drastically when compared to vertical or deviated wells. Kick detection in horizontal wells is quite similar to the detection in vertical and deviated wells. Personnel need to use three positive kick indicators (pit gain, flow when pump off and flow show increase) to determine the influx. Typically, drilling horizontal well usually drills into one formation therefore without any change in drilling parameters you should not see any changes in ROP. Therefore, indications of change in formation as ROP, LWD, torque and drag are very helpful for early kick indication because the changes indicate that you are in new zone which may have difference in reservoir pressure.

In the horizontal hole section, it is very difficult to immediately detect the kick because the kick is at the same TVD level. You will notice the wellbore influx when it reaches the vertical part of the well. Additionally, if the kick is in the horizontal part, you will not see any change in casing pressure due to gas migration. You will see drastically increase in casing pressure when the kick goes into the vertical part. Hence it is very critical that reliable measurement equipment on the rig is very critical for the horizontal well drilling. What's more, personnel need to understand the physical changes of kick on each part on the well which we will be discuss further in next chapter

CHAPTER THREE

WELL DRILLING AND DRILLING TECHNOLOGY DEVELOPMENT

3.0 Introduction

This chapter discusses horizontal drilling, directional drilling, vertical drilling and provides the detail explanation to the various drilling technology development. In oil and gas drilling there is no such thing as a truly vertical borehole; however, wells which aim at a target directly below its surface location are considered to be vertical wells (Gatlin 1960; Chen 2011) as shown in the Figure 5.1.

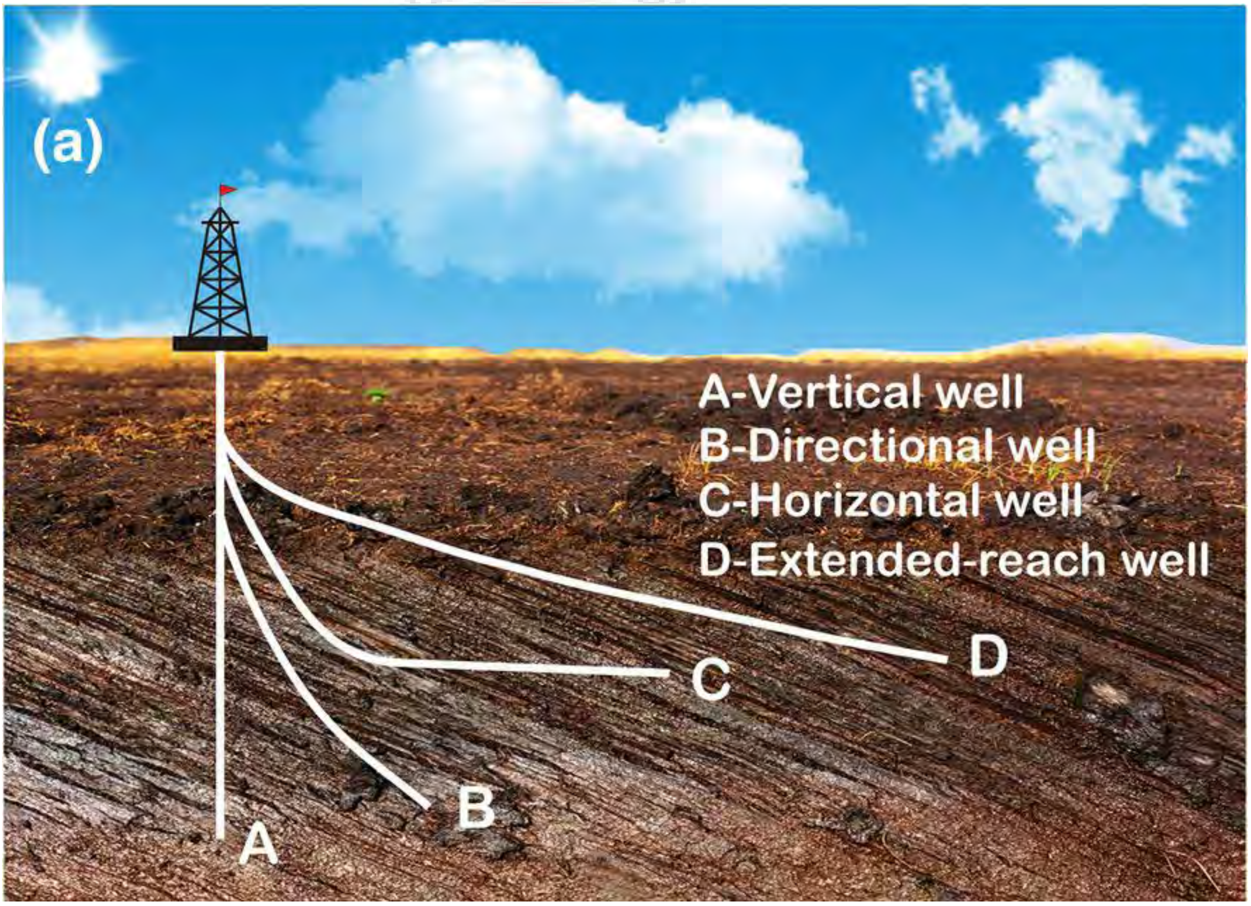


Figure 5: Types of well

The azimuth of deviation is usually secondary, but the deviation angle between the hole and the vertical is primary. Regarding the historical development of vertical drilling, the initial vertical wells were drilled by the percussion drilling method (also called as cable tool drilling method).

In 1895, the first commercial oil well was drilled to a depth of 65 ft using cable tools at Titusville in the United States, and it created with having started the American petroleum industry (Gatlin 1960). The percussion drilling method however, did not begin in the United States, but was employed first by the drilling of brine wells in China (Gatlin 1960; Chen 2011). In this method, the steel bit successive pounds the bottom hole by pulverizing the rock (Hyne 2001), people or animals are employed as power sources. Afterwards, the steam engines were employed as power sources to replace the people or animals.

Due to the limitations on drilling rate and depth, efforts were made to improve the operation efficiency. In 1863, Leschot, a French civil engineer, applied a rotary drilling method (Mitchell 1995). In the rotary drilling method, including the power, hoisting, rotating, and circulating systems. The drilling rig rotates a long length of steel pipe (called as drill-string) with a bit on the end of it to cut the borehole, and a downward force is applied on the bit. The cuttings are lifted from the down-hole by the drilling fluid which is continuously circulated down the inside of the drill-string through water courses or nozzles in the bit, and upward into the annular space between the drill-string and the borehole (Gatlin 1960). In other words, the conventional rotary drilling could meet the requirement of vertical drilling. Even to this day, the rotary drilling method still plays a very important role in the petroleum industry.

3.1 Directional Drilling

Directional drilling is the process of drilling a well which is to follow a prescribed traverse and intersect a specific objective. The objective is called a target and is usually an enclosed area in a horizontal plane, the target also could be a circular area at the top of a producing zone (Mitchell 1995; Chen 2011), as shown in figure above. Both the azimuth and deviation angle are primarily for directional drilling. Regarding the historical development of directional drilling, the first directional drilling was due to a ‘‘fish’’, unrecoverable drilling tools lost in the borehole. As early as 1895 special tools and techniques were being utilized to handle the ‘‘fish’’ (Short 1993).

In the early 1930s, the first records of directional well were drilled deliberately to reach its target and to produce oil from beneath shallow coastal waters by setting up a drilling rig on a jetty that ran out at right angles to the shore at Huntington Beach, California (Short 1993). Thus, the offshore oil fields in California could be regarded as the spawning ground for directional drilling practices and equipment (Inglis 1987). This was the beginning of directional drilling as it is known today. In 1934, the directional drilling was used to drill a deviated well to kill a blowout in the Conroe Field, Texas. The blowout was killed by pumping heavy mud down the deviated relief well, and it first gained prominence for further applications (Short 1993). From then on, the directional drilling has been widely applied to exploit oil and gas from beneath shallow coastal waters in the United States.

In 1941, the turbo-drill was invented by the Soviet Union, and the directional wells were drilled using the turbo-drill. In 1944, the first recorded true horizontal oil well was drilled in the Franklin Heavy Oil Field, Pennsylvania, at a depth of 500 ft. In the 1950s, the cluster wells (also called as multiple wells) began to be utilized.

In the 1960s, the directional drilling was utilized in the offshore oil field, such as the Gulf of Mexico and North Sea. In the 1970s, the positive displacement motor (PDM) was produced by various companies, such as Dyna drill, Navi drill, Baker drill, Christensen and Smith. In the 1980s, to improve the control precision and adaptability for directional drilling, measurement while drilling (MWD) was invented and widely applied, and the computer aids' drilling was also involved due to the application of computer technique. Directional drilling has now become an essential element in oil field development, both onshore and offshore. It is widely used and is gaining acceptance in the petroleum industry. The applications of directional drilling can be summarized as follows (Inglis 1987; Short 1993; Chen 2011): sidetracking, controlling vertical wells, drilling beneath inaccessible locations, cluster drilling, offshore development drilling, salt dome drilling, fault control, relief well, horizontal wells, extended reach wells, multilateral drilling, and non-petroleum uses.

3.2 Horizontal Drilling

Although horizontal well and extended reach well is only a special case in directional drilling, however, due to more features and difficulties, we also discuss these two methods. Horizontal and high-angle drilling operations generally are similar to the directional drilling but more complex because of higher build rates and drift angles, longer tangent and horizontal sections. The discussion referring to horizontal drilling generally applies to high-angle extended reach patterns unless otherwise noted. Horizontal drilling, high-angle deviation drilling and extended reach drilling (ERD) described here includes angles greater than about 60 degrees, more commonly about 70–90 degrees.

Horizontal drilling is the process of drilling a well from the surface to a subsurface location just above the target oil or gas reservoir called the ''kickoff point'', then deviating the well bore from the vertical plane around a curve to intersect the reservoir at the ''entry point'' with a near-horizontal inclination, and remaining within the reservoir until the desired bottom hole location is reached. Conventional directional wells may be drilled to an inclination of around 60 degrees. Inclinations beyond 60 degrees give rise to many drilling problems that substantially increase the cost of the well drilling. However, there are certain advantages in drilling highly deviated wells and horizontal wells (Inglis 1987; Short 1993; Helms 2008; Chen 2011):

- increasing the drainage area of the platform;
- prevention of gas coning or water coning problems;
- increasing the penetration of the producing formation;
- increasing the efficiency of enhanced oil recovery (EOR) techniques;
- improving productivity in fractured reservoirs by intersecting a number of vertical fractures.

The classification of horizontal wells can be distinguished using the angle-build rates. The angle build rates are in degrees per 100 ft of measured depth. Table 1 contains a summarized average of classifications used by various operators and service companies. These are guidelines within a wide variation of angle build rates. There are gaps between the pattern ranges in. It is more difficult to drill in the gap areas because of equipment limitations, and it is naturally easier to drill within the pattern ranges (Short 1993). A few wells are drilled outside of the pattern ranges, but most are drilled within the range. In addition, there is a type of horizontal drilling technique with a higher angle-build rate, called as Ultrashort-Radius Radial System (URRS), it's a special drilling system to build such higher turn rates.

3.3 Directional Technique Development

3.3.1 The first generation of directional technique

The first generation of directional technique is a result of initial directional drilling. There are two kinds of directional method (Inglis 1987; Short 1993; Chen 2011; Han 2011):

1. Passive directional drilling: the well trajectory lies in the natural deflection law of formations, the drill-string buckling and drill bit also can affect the well trajectory, but the well trajectory cannot be controlled accurately.

Active directional drilling: some special devices, tools and technological measures are utilized to actively control the well trajectory along the expected path, the substance of active directional drilling is changing the tool axis deviates from the borehole axis using an artificial method. During this period, the conventional bottom hole assembly (BHA) and whip stock were utilized to drill directional wells.

(i) The conventional BHA: the conventional BHA with multi-stabilizer just can be used to control the hole deviation angle based on the lever principle or pendulum effect, it's the initial and active directional method. According to the function, the BHA can be classified as angle build, angle drop, angle hold or stiff BHA. This method is benefit for cleaning hole, reducing drill-string drag, reducing dogleg angle, and saving drilling costs. But there is a lack of controllable ability for well azimuth.

(ii) The whip stock/deflecting wedge: the initial down-hole deflecting tool should be the deflector, also called as the whip stock, is a specialized tool which is used to lead drill bit to deviate from the borehole axis and direct the required direction. Thus, the directional process is performed before run in the hole. The whip stock can be used to control azimuth, it overcomes the defect of the conventional BHA.

However, this method has so much disadvantages, multiple and repetitive trip, failure to deviate, a waste of time and cost, complex operations, and poor control accuracy. When changing the well azimuth, the tool face is fixed, also called as a fixed tool face mode. To continue changing the well azimuth, the tool face must be adjusted discontinuously, that means the new hole and original hole exist in a tapered plane, so this can be called as the azimuth adjusting mode on a tapered plane. In some specialized situation, this method still works effectively, such as sidetracking, sidetracking is the procedure method still works effectively, such as sidetracking, sidetracking is the procedure for deviating in an original hole at a point above the bottom and drilling a new hole in a different direction, it can be done in either open or cased hole, common uses are for bypassing a fish or drilling to another objective located away from the original wellbore. In addition, when drilling in an ultra-deep well with high temperature, which makes PDM failure and doesn't work this method may be an effective replace method.

3.3.2 The second generation of directional technique

The second generation of directional technique is a result of tool invention and development. During this period, the typical feature is the invention of downhole motor and monitoring method.

1. The down-hole motor usually includes positive displacement motor (PDM), turbo-drill and electric drill (Short 1993; Chen 2011; Han 2011). PDM and turbo-drill uses the pressure and volume of the circulating mud to rotate the bit, but electric drill uses the electric energy to rotate the bit. This, in conjunction with other tools (bending rod, bending joint, eccentric joint or similar tools), provides an efficient method to change the borehole direction.

2. The monitoring method includes hydrofluoric acid inclinometer and photographic inclinometer (Short 1993; Chen 2011). To achieve the purpose of adjusting azimuth, the key is fixing the whole drill-string and let the down-hole motor to rotate the bit, that means the tool face is fixed during the adjustment process, it can be called as the fixed drill-string mode. The tool face can be adjusted continuously, that means the new hole and original hole exist in a tapered plane, so this mode also can be called as the azimuth adjusting mode on a tapered plane. However, compared with the first generation, the trajectory becomes smoother and more accurate. Meanwhile, the PDM and turbo-drill tools also can be used in either sliding and rotary drilling, the rotary drilling with PDM also called as composite drilling, it has been wide used to improve the rate of penetration (ROP) either in directional and vertical wells.

In addition, another kind of directional method also appears in this period, which is called as jetting or nudging. It is a procedure for deviating the hole without using conventional directional assemblies. It is most effective in softer formations and for building angles at low build rates. It is a moderately efficient method of directional drilling under favorable conditions but does not have widespread application. The maximum angle buildup is about 0.5–1.5/100 ft in holes with low angles of drift. This gives a long, smooth, curved section with semi normal drilling. The procedure is used to gradually separate a group of wells from each other. It is also used for moving the kickoff location in the direction of the target and reducing the angle required in later directional drilling.

3.3.3 The third generation of Directional Technique

The third generation of directional technique is a result of advanced monitoring method or tools. During this period, the typical feature is the appearance of measurement while drilling (MWD), which improved the measured and controlled accuracy, the directional operation can be done while drilling (Chen 2011; Han 2011). In addition, due to the initial PDM tool is straight, to improve the efficient of directional drilling, the PDM tools have been designed with a bending housing, such as the straight PDM, single bent PDM, double bent PDM, and etc. One popular motor variation is the single bent PDM, which has a bend constructed near the lower end. This method belongs a fixed tool face mode, the tool face can be adjusted continuously, that means the new hole and original hole exist in a tapered plane, so this mode also can be called as the azimuth adjusting mode on a cylinder surface. Due to the advancements in monitoring method and tools, the directional operation has been greatly simplified. Until now, the third generation is still the major method for directional and horizontal drilling.

3.3.4 The fourth generation of directional technique

The fourth generation of directional technique is a result of drilling automation; the typical feature is the invention of the rotary steerable drilling system (RSDS) (Chen 2011; Han 2011). Due to the tool face must be adjusted artificially, so the drill-string must be fixed while directional drilling, that's so-called slide drilling. Because the drill-string drag is always opposite to the direction of motion, which makes drill-string drag increases and has a poor influence on drilling efficiency, hole cleaning, hole quality, and etc. Therefore, in order to improve the drilling efficiency and controlled accuracy, and decrease the drill-string drag, RSDS was firstly developed by Schlumberger in 1999. RSDS allows us to plan complex wellbore geometries, including directional, horizontal and extended-reach wells. It allows continuous rotation of the drill-string while steering the well and eliminate the troublesome sliding mode of conventional steerable motors. Currently, the industry classifies RSDSs into two groups, the more prevalent ''dogleg control'' systems and the less mature ''deviation control'' systems (Downton et al. 2000).

1. The ‘‘deviation control’’ systems are developed from the conventional BHA, the diameter variable stabilizer (DVS) is utilized to control the well deviation.
2. The ‘‘dogleg control’’ systems are also the conventional RSDS, the industry classifies ‘‘dogleg control’’ systems into two types, the more prevalent ‘‘push-the-bit’’ systems, including the PowerDrive system and Auto Trak system, and the less mature ‘‘point-the-bit’’ systems, including the Geo-Pilot system and CDAL system. It’s clearly found that the directional accuracy and borehole quality are improved with the development of directional techniques.

3.4 Directional Tools

Most of down-hole equipment for directional and horizontal drilling are usually same with vertical drilling, such as the drill pipe, heavy weight pipe, compressive pipe, drill collar, fluted spiral drill collar, substitute sub, short pony drill collar, stabilizers, and so on. Clearly, without advanced directional tools, it might not be physically possible to drill a given well, the well might be drilled in a suboptimal location or it might be more expensive or risky. The directional technique development is driven by advanced directional tools. According the development history of directional techniques, the main directional tools can be summarized as follows: deflector, down-hole motor, RSDS, and vertical drilling system.

CHAPTER FOUR

SIMULATION FOR VERTICAL AND HORIZONTAL DRILLING OPERATION

4.0 Introduction

This chapter discusses simulation exercise performed on model DS-20FS/W for a horizontal and vertical drilling operation. The following were connected to the consoles Surface/Subsea BOP, work over well control: production tree-in- place, choke manifold and stand pipes.

Figure 6: Well control Simulator Setup

Table 1: Vertical Well Data Sheet

Length of well	3750m
Length of casing	2890m
Length of drill collars	220m
Length Heavy walled drill pipe	180m
Densities	
Density of mud	1.35SG
Density at Leak-ff Test	1.44 SG
Shut in casing Pressure	49 bar
Shut-in drill pipe pressure	40 bar
Slow circulating pump rates	Pressure at 30 SPM 38 bar
	Pressure at 40 SPM 47 bar
Pressure at Leak-off-Test	65 bar
Bit size	$8^1/_2$
Pump Displacement	16.85 litres/Stroke
Capacities	
Drill Pipe (DP)	4.01 l/m
Heavy Weight Drill Pipe (HWDP)	3.80 l/m
Drill Collars (DC)	2.95 l/m
Heavy Weight Drill Pipe (HWDP) in open Hole Capacity	34.5 l/m
Drill Collars (DC) in open Hole Capacity	25.0 l/m
Drill Pipe in Casing	41.0 l/m
Pit gain	$8m^3$

The well was killed using 30SPM

FORMATION STRENGTH TEST DATA

SURFACE LEAK-OFF PRESSURE FROM FORMATION STRENGTH TEST: (A) 65 bar

DRILLING FLUID DENSITY AT TEST: (B) 1.44 kg/l

MAX. ALLOWABLE DRILLING FLUID DENSITY =

$$(1.44) + \frac{(65)}{2890 \times 0.0981} = (C)\ 1.66\ \text{kg/l}$$

INITIAL MAASP =

((C) - CURRENT DENSITY) X SHOE T.V. DEPTH X 0.0981: (C) 87

(1.66-1.35) x 2890 x 0.0981

= bar

PUMP NO. 1 DISPL.	PUMP NO. 2 DISPL.
16.85 stks/l	stks/l

SLOW PUMP RATE DATA	(PL) DYNAMIC PREESURE LOSS (bar) PUMP NO. 1	PUMP NO 2
32 SPM	38	
40 SPM	47	

CURRENT WELL DATA

CURRENT DRILLING FLUID:

DENSITY: 1.35 kg/l

CASING SHOE DATA:

SIZE: 9⅝" in

M. DEPTH: 2890 m

TVD: 2890 m

HOLE DATA

SIZE: 8½" in

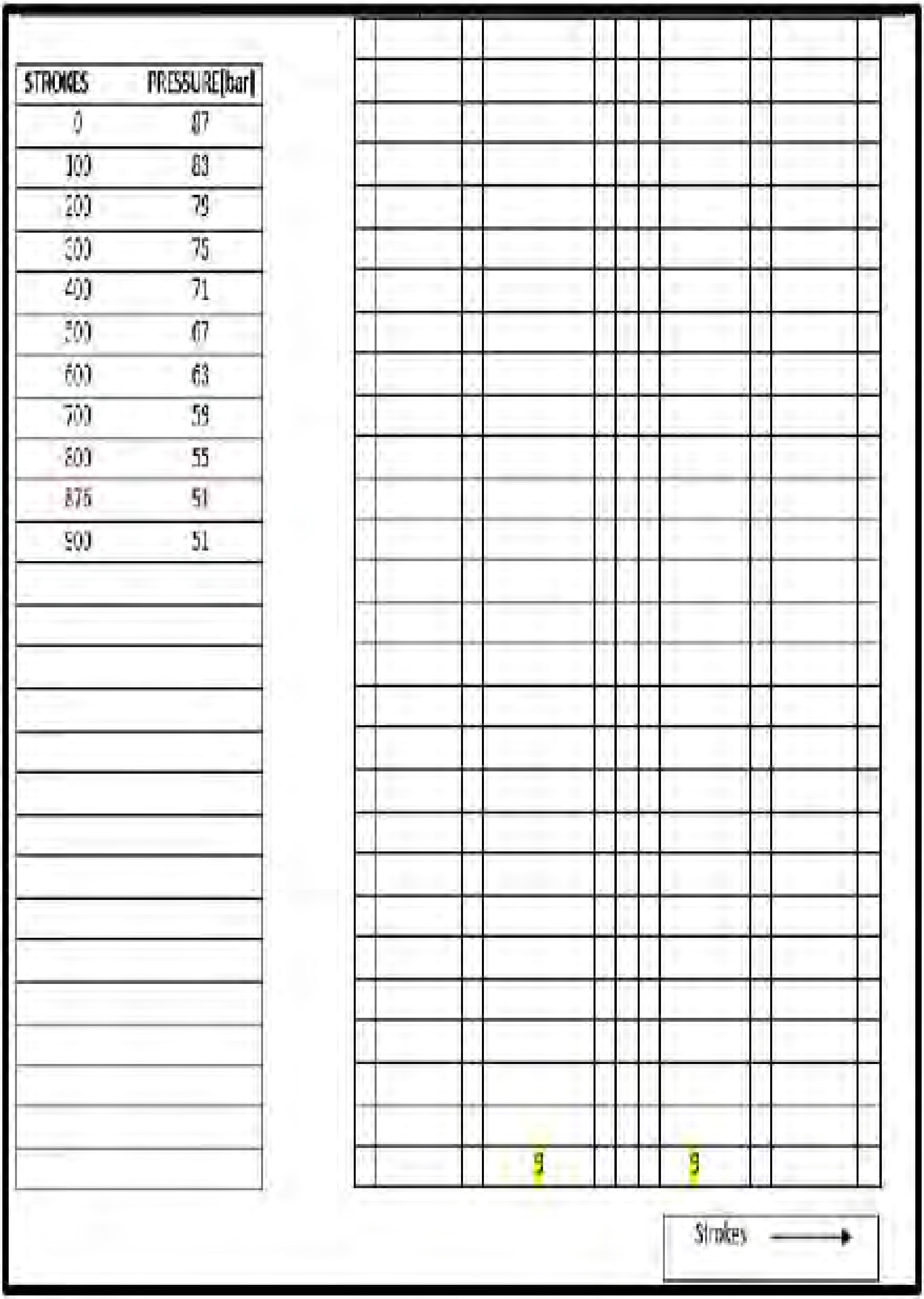
M.DEPTH: 3750 m

T.V.DEPTH: 3750 m

Figure 7: Formation Data Sheet

PRE-RECORDED VOLUME DATA	LENGTH m	CAPACITY l/m	VOLUME Litres	PUMP STROKES stks	TIME minutes
DRILL PIPE	3350	X 4.01	= 13434	VOLUME / PUMP DISPLACEMENT	PUMP STROKES / SLOW PUMP RATE
HEAVY WALLED DRILL PIPE	180	X 3.80	= 684 +		
DRILL COLLARS	220	X 2.95	= 649 +		
DRILL STRING VOLUME			(D) 14767	(E) 876 stks	22 min
DCX OPEN HOLE	220	X 25	= 5500		
DP/HWDPX OPEN HOLE	540	X 34.5	= 22080		
OPEN HOLE VOLUME			(F) 27580	1637 stks	41 min
DPX CASING	2890	X 41.0	=(G) 118490	7032 stks	176 min
TOTAL ANNULUS VOLUME		(F+G)=(H)	146070	8669 Stks	217 min
TOTAL WELL SYSTEM VOLUME		(D+H)=(I)	160837	9545 Stks	239 min
ACTIVE SURFACE VOLUME		(J)	15000	Stks	
TOTAL ACTIVE FLUID SYSTEM		(I+J)	175837	stks	

Figure 8: Volumetric Data Sheet



STROKES	PRESSURE[bar]
0	87
100	83
200	79
300	75
400	71
500	67
600	63
700	59
800	55
876	51
900	51

Figure 9: Kill sheet

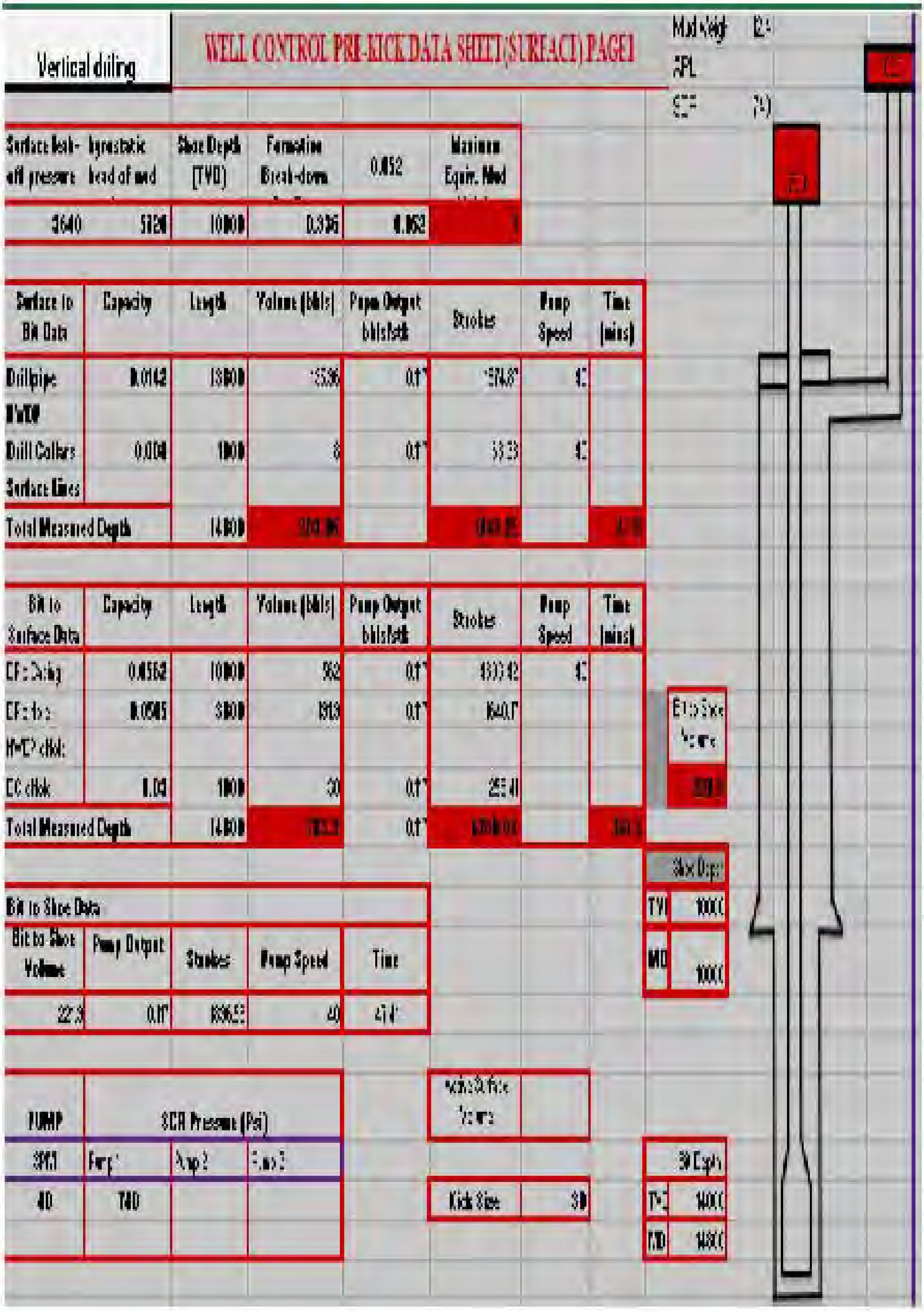


Figure 10: Vertical Drilling Data Sheet

WELL CONTROL KICK SHEET (SURFACE) PAGE 2

Total Well System Volume, bbls

Surface to Bit Volume (bbls)	Bit to Surface Volume(bbs)	T.W.S Volume(bbls)	Pump Output bbls/stks	Strokes to Dispalce TWSV
203.96	783.9	987.86	0.117	8443.25

Total Active Fluid System Volume, bbls

Total well System Volume (bbls)	Active Surface Volume (bbls)	T.A.F.S Volume (bbls)	Pump Output (bbls)	Strokes to Displace T.A.F.S (bbls)
987.86	0	987.86	0.117	8443.25

Bottom Hole Circulating Pressure(BHCP)

Hydrostatic (Ph) of Mud	Annular Pressure Loss APL	Bottom Hole Circulating Pressure
9027.2	0	9027.2

Equivalent Circulaitng Density(ECD)

Annular Pressure Loss APL	0.052	Bit Depth (TVD	Current Mud Weight	Equivalent Circulating Density
0	0.052	14000	12.4	12.4

Figure 11: Well control kick sheet

Equivalent Circulaitng Density(ECD)				
Annular Pressure Loss APL	0.052	Bit Depth (TVD)	Current Mud Weight	Equivalent Circulating Density
0	0.052	14000	12.4	12.4

New MAASP with Kill Mud Weight, psi				
Annular Pressure(APL)	Kill Mud Weight	0.052	Casing TVD	New MAASP with Kill Mud Weight
18	13.36153846	0.052	10000	2412

Safety Margin between initial Dynamic MAASP and initial Dynamic Casing Pressure		
MAASP	SICP	Safety Margin
2912	1050	1862

Figure 12: Circulating Density sheet and Kill mud weight

WELL CONTROL KILL SHEET (SURFACE) 3

Kill Mud Weight

SIDPP	Bit Depth (TVD)	0.052	Present Mud Weight	Kill Mud Weight
700	14000	0.052	12.4	13.36

MAASP

Max. Equiv. Mud	Present Mud Weight	0.052	Shoe Depth (TVD)	MAASP
18	12.4	0.052	10000	2912

Initial Circulating Pressure

Slow Circulating rate Presure @	SIDPP	Initial Circulating
740	700	1440

Final Circulating Pressure

Slow Circulating Rate Pressure	Kill Mud Wt	Present Mud Weight	Final Circulating pressure
740	13.36	12.4	797

Figure 13: Well control kill sheet

Pressur Drop from ICP to FCP per 100 strokes			
ICP	FCP	Surfcae to bit stks	Pressure Drop per Stroke
1440	797	1743	0.37

Pressure Reduction per stroke	Stroke /100	Pressure Drop psi/100
0.37	100	37

Figure 14: Pressure drop from FCP per 100 strokes

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.0 Introduction

This chapter highlights the major findings of the study in relation to the analysis performed in the previous chapters. It consists of summary, conclusion and recommendation.

5.1 Summary

This sections presents summary of the simulation for horizontal and vertical drilling control methods, where the kick is experienced at a depth at or above the end of the drill string in the hole. There are instances where kicks cannot be circulated out of the hole using these conventional methods, and some of the alternative methods of killing a well have to be applied. The focus of the study was to compare the horizontal and vertical drill techniques, its effects on the exploration of oil and gas using a well control simulator. Horizontal drilling is a routine operation in many areas today, and great advances have been made since its massive growth in the mid-80s.

Horizontal drilling is the process of drilling a well from the surface to a subsurface location just above the target oil or gas reservoir called the "kick off point", then deviating the well bore from the vertical plane around a curve to intersect the reservoir at the "entry point" with a near-horizontal inclination, and remaining within the reservoir until the desired bottom hole location is reached (Lynn Helms, *Horizontal Drilling*) .Most oil and gas reservoirs are much more extensive in their horizontal dimensions than in their vertical (thickness) dimension. By drilling a well which intersects such a reservoir parallel to its plane of more extensive dimension, horizontal drilling exposes significantly more reservoir rock to the well bore than would be the case with a conventional vertical well penetrating the reservoir perpendicular to its plane of more extensive dimension. (Lynn Helms, *Horizontal Drilling*)

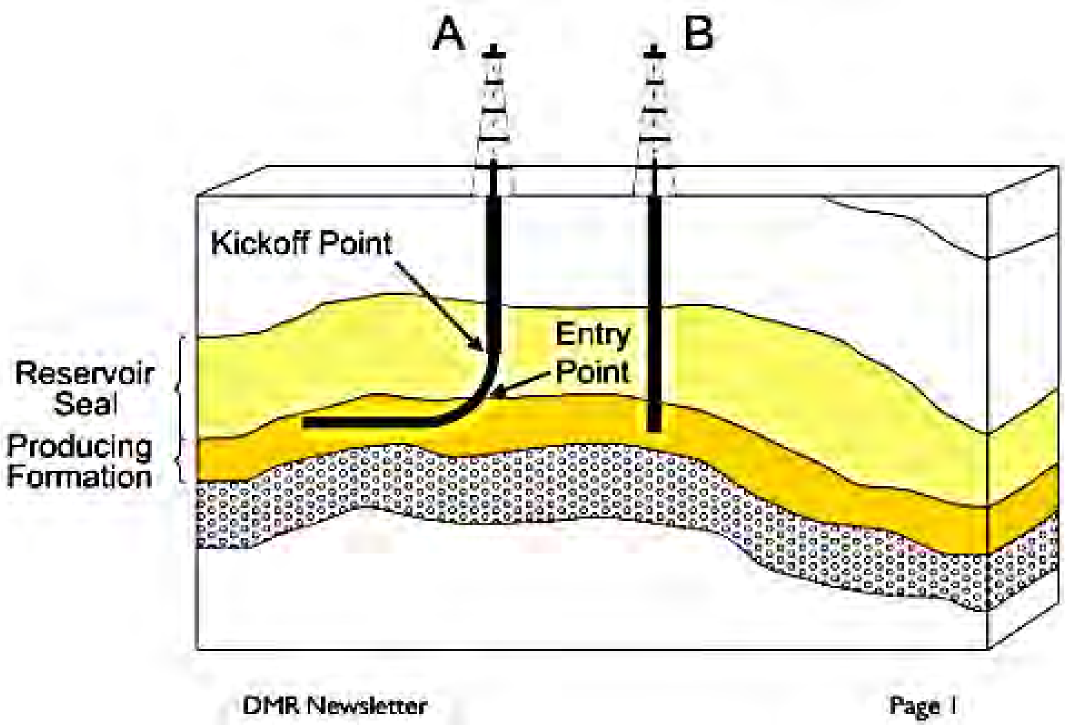


Figure 15: Formation Figure

The achievement of desired technical objectives via horizontal drilling comes at a price. A horizontal well can cost up to 300 percent more to drill and complete for production than a vertical well directed to the same target horizon. Due to its higher cost, horizontal drilling is currently restricted to situations where vertical wells would not be as financially successful. In an oil reservoir which has good matrix permeability in all directions, no gas cap and no water drive, drilling of horizontal wells would likely be financial folly, since a vertical well program could achieve a similar recovery of oil at lower cost.

But when low matrix permeability exists in the reservoir rock (especially in the horizontal plane), or when coning of gas or water can be expected to interfere with full recovery, horizontal drilling becomes a financially viable or even preferred option producing 2.5 to 7 times the rate and reserves of vertical wells. The higher producing rate translates financially to a higher rate of return on investment for the horizontal project than would be achieved by a vertical project.

By drilling a well vertically, and then kicking off to build angle in a curved section, one can arrive at an angle of 90º. This horizontal section often intersects the reservoir of interest parallel, which enables production from a much longer interval than that of a vertical well. This has improved "production rates and recoveries."

Along with these obvious advantages follow some well control considerations.

5.1.1 Application of Horizontal Drilling

- Horizontal drilling is highly applicable to existing cased vertical and directional wells with larger diameter casing and under favorable conditions.
- Horizontal drilling increases injectivity, improve sweep efficiencies, and reduce the number of wells needed for waterflooding and steam injection for recovering heavy oils.
- Horizontal drilling places pipelines underneath areas where conventional methods cannot be used. These locations include roads, rivers, ship channels, and industrial areas.
- Horizontal wells are efficient at producing methane gas from shallow coal beds in the western United States.

5.1.2 Advantages of Horizontal Drilling

- Intersect many fractures in a hydrocarbon containing formation. Very popular in limestone and some shale formations.

- Avoid drilling into water below (or gas above) hydrocarbon or perforating adjacent to water or gas. Either are thought to promote gas and water coning. Popular in formations containing relatively thin oil zones as compared with the underlying water zone.
- Increase both the drainage area of the well in the reservoir and the lateral surface area of the wellbore. The first is thought to increase the cumulative hydrocarbon production, while the second enhances the hydrocarbon production rate. Popular in formations containing heavy oil. These holes may be thought of as drain holes in some cases.
- Intersect layered reservoirs at high dip angles.
- Improved coal gas production (degasification)
- Improve injection of water, gas, steam, chemical, and polymer into formations

5.1.3 Disadvantages of horizontal drilling

1. **Hole cleaning.** As the drill string lies on the low side of the hole, beds of cuttings build up around the bottom of edge of the drill string. These can be very hard to shift.

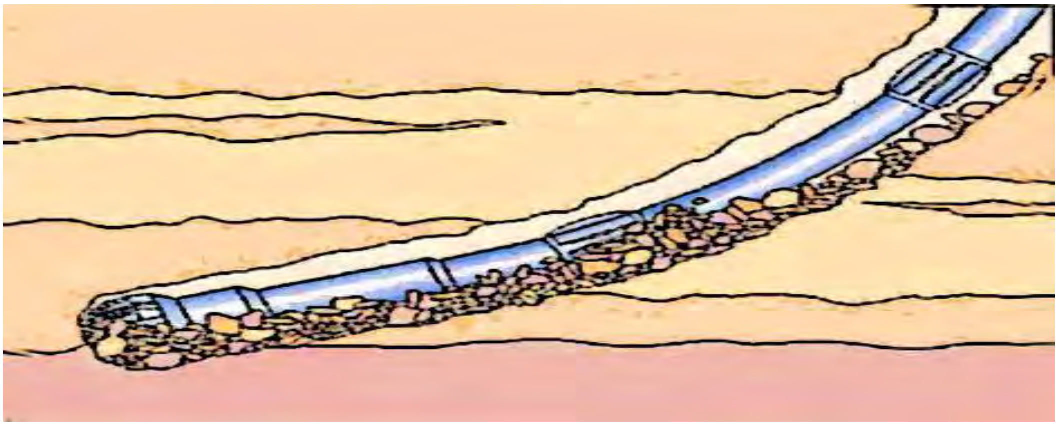


Figure 16: Poor hole cleaning

3. **Frictional forces.** The power needed to turn the drill string or to pull it out of the hole are higher on horizontal well than on a normally deviated or vertical well.

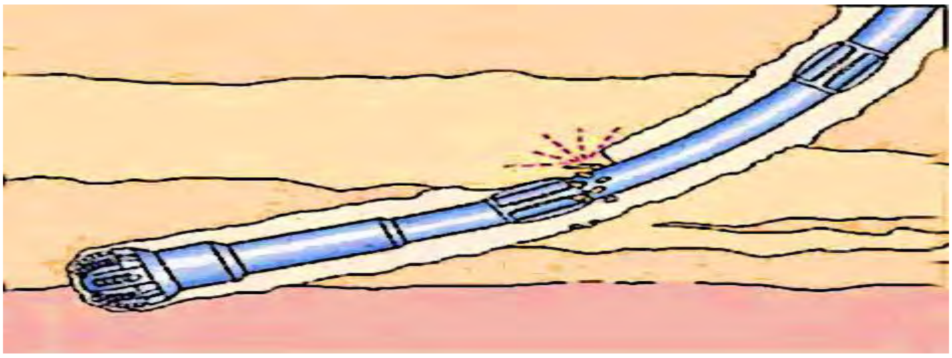


Figure 17: Friction force

3. **Accurate navigation in the reservoir**. Navigation within the reservoir is relative the reservoir characteristics and not computed according to inclination and azimuth only.

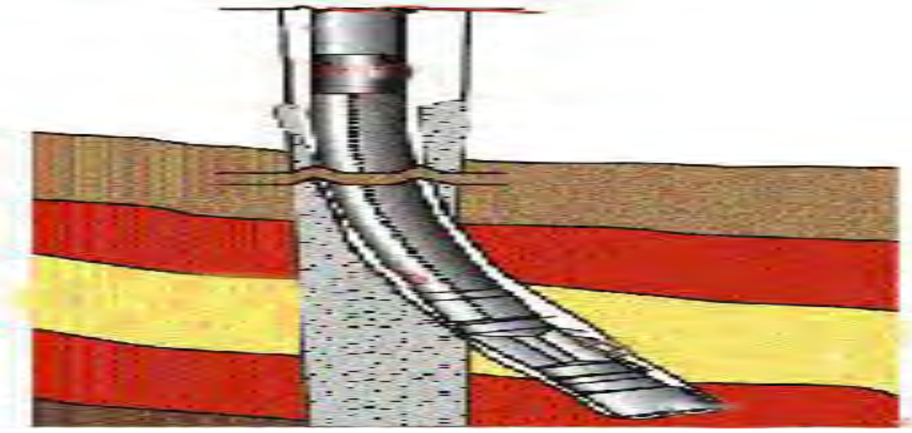


Figure 18: Navigation in the reservoir

5.2 Conclusion

The research was focused on the simulation for vertical and horizontal well control techniques in oil and gas exploration; and to evaluate the problem associated with the two drilling methods in well control. The present overview of 125 years of development since the pioneering method of the 1890s is aimed to present the state of the art in the vertical and horizontal drilling technologies and their recent developments. It appears that integral understanding of the vertical and horizontal drilling technologies.

The developments of the directional techniques, the main directional tools (deflection tools, down hole motor, rotary steerable drilling system and vertical drilling system), the directional survey techniques (measuring and transmission techniques), the main drill bits (roller cone bits, fixed cutter bits and hybrid bits), and the main drilling fluids (gas-base drilling fluid, water-based drilling fluid and oil-based drilling fluid) are summarized and analyzed.

This part presents concluding remarks and some potential applications for the vertical and directional drilling technologies.

1. In the last hundred years, the drilling technology has advanced from cable tool drilling to the use of advanced and automated rotary drilling. The advanced techniques and tools are the motive force of the development.

2. Most of the current oil and gas wells have been drilled more than 6000 m in depth and 2000 -4000 m in horizontal displacement. The ultimate extended ability has reached 10,000 m not only in horizontal displacement, but also in vertical depth. Therefore, the main technologies will revolve around how to drill deeper or longer wells. For deep or ultra-deep wells, the key is to solve the problem that induced by high-pressure and high-temperature. For directional wells, the key is to solve the advanced automatic control techniques.

3. The vertical and directional drilling has advanced from real-atomized to digitized, visual, automated, integrated and intelligent zed. However, the degree of automation is still not enough for real industry. Thus, the advanced automated vertical and directional drilling is still the promising field.

4. The applications of vertical and directional drilling is very successful in petroleum extraction, such as oil and gas exploration, oil and gas production. Meanwhile, the vertical and directional drilling also can be extended to scientific drilling, geothermal drilling and the other related aspects.

A major discrepancy was found when calculating the influx density and the influx mass from the shut-in pressures and the pit gain for the vertical well. Both of the calculated values were around twice the magnitude of the values obtained directly from the simulation. The cause of this is not known.

Simulations on well control scenarios indicated that the conventional gas filled well scenario induces less pressure at the weak point than a gas bubble migrating in a shut-in annulus. It is therefore important to ensure that the weak point of a wellbore is located in the open hole section, even if the well is said to have full well integrity.

5.3 Recommendation

If simulations similar to the ones presented in this thesis are to be conducted, it is recommended to model the drill string in a better manner. By also using the AUSMV scheme within the drill string, one could obtain more accurate simulation results. Particularly compressibility is important for trustworthy readings of drill pipe pressure.

Further, it is suggested to implement an ability to shut-in the well at seabed, and to take returns through the choke line or riser as desired. This would add flexibility to the simulations and open new possibilities for modeling for instance hard and soft shut-in. Another recommendation is to make better use of the implemented choke model.

Two issues should be resolved. The underestimation of fluid velocities at low flow rates causes inaccuracy, primarily with respect to friction loss. It has been shown that the error is reduced at finer discretization. However, it should be investigated if this malfunction could be resolved completely.

The second issue is the PI-regulator. The tuning of the regulator is quite cumbersome and time consuming. A better way to maintain constant bottom hole pressure should be established. If this cannot be achieved, perhaps the biggest potential in the current scheme is as a training simulator, where the bottom hole pressure does not need to be automatically regulated.

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