FINAL YEAR PROJECT PROPOSAL (MAY 2013)

Cementing Design For the HPHT Well By Using Land Mark Software

AUTHOR: Malik Muhammad Humza (15205)

SUPERVISED BY

Dr. MUHANNAD TALIB SHUKER

& Mr. MUHAMMAD ALI BURIRO.

TABLE OF CONTENTS

Abstract.

This study is aimed that how to reduce the results of failed cement job which involved time and high cost, remedial work and causes kick and well control problem. It needs an extra care from time to time and soft wares used in order to monitor all characteristic of the cement during the cementing job.

The objective of this work is to design the proper cement program which is compatibale with the formation , that which would be the case study.

The methodolgy is based on the finding of the class of cement , to know the zone and interval and on the rheology of the cement. We will then be using the opticem soft ware to proceed with the results.

This research and studies, has helped us to solve the problem by designing the suitable cement program. Over all data was used in Opticem module to stimulate and observe casing cementing procedures.

-

CHAPTER 1

INTRODUCTION

An Introductory chapter in this paper will describe brief information of the Project in terms of the background of this study, Problem statement, objectives and project scope.

1.1 Background of the study

Cementing is an integral and necessary aspect for drilling oil and gas wells. Cement is used to protect casing string and zonal isolations for production purpose as well as to solve various hole problems. In order to perform the cementing process, cement slurry must be carefully designed to full fill the requirement of the reservoir condition.

The designing process of cement will need some mixture of additives to make the cement slurry performed better under the downhole condition. Additives can be included as accelerators and retarders , which are related to time of the cement. Inorder to make cement light weighted . As additives are added to transform the compressive strength of the cement, as well as flow properties and dehydration rates. Extenders can also be used to expand the cement, and antifoam additives can be added to prevent foaming with in the well.

However ,all the additives and cement cannot be simply mixed to form good a slurry. A lot of factors must be considered, the design of the cementing job must be done properly to prevent big lost including life. This paper will be focusing specially on high pressure and high temperature reservoir. A software called OPTICEM which is land mark software will be used in order to perform the simulation.

Opticem software calculates real time equivalent circulation densities (ECDs) with the help of using actual job volumes , rates and fluid densities. By using this software, more realistic simulators and rheology models can be obtained. OptiCem software compares planned data with actual job data , giving operators the information they needed to adjust the original displacement schedules. It also monitors the location of the fluids during the job, and generate a detailed schedule with monitoring of the location of the fluids during the job ,with generation of detailed post job report. Using the optional Opticem module, operators can simulate jobs while they are being completed – with adjusted displacement rates and pump speeds for optima results.

Overall this project will discuss in details on how to perform cementing design and evaluation of additives controlled by using the land mark software at HPHT condition.

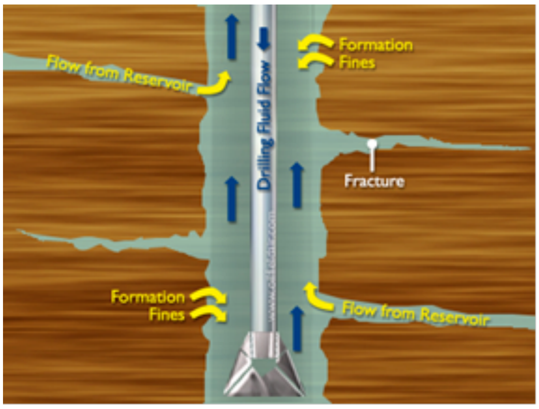
1.2 Problem Statement

While perfomring the cementing job how to avoid the kick of the well is one of the important issue in the Oil industry. More over how to save the time and cost is also important factor. Last but not the least to monitor a well from time to time is also considerable.

In order to design a cement slurry , a lot of factors are needed to be taken into account. These are some of the list of properties that will be needed to be discovered in performing the cementing design process

1) Pumpability of the cement
2) Mixing condition including additives
3) Slurry design
4) Displacement of fluid from top to bottom

All of these properties must be looked with extra care , when it comes to a High pressure and High temperature condition. Cost is also important thing that is needed to be looked in any operations of well. Cementing jobs are the one of the expensive jobs during all design. Poor setting job or damage to the casing (if cementing job is not done properly) can cost a lot of money. While the circulation of cement in production casing prevents the ultimate recovery and potential reuse of the casing when the well is plugged and to prevent the replacement of the casing during the life of well.



1.3 Objective

The objectives of this research is to optimize the slurry design by doing a cementing simulation using landmark software or to be specific, Opticem module of land mark.

Scope of Study

This study is limited to the dsigning of HPHT wells using the Land Mark Soft ware.

CHAPTER : 2

LITERATURE REVIEW

2.1 Cementing design

The first use of cement in the oil industry was recorded as a water shut off attempted in 1903 in California . At first, cement was hand mixed and then runned in a dump bailer to spot plug. Pumping the cement down a well was soon recognized as a beneficiary with forerunner of the modern two plug method was first use in 1910. The plugs were seen as way to minimize mud contact with cement. Although both mechanical and chemical improvements have been made in the cementing process, as the original plug concept is still valid. Cement design includes the selection of additives and equipment to remove mud and properly placed to evaluate the cement. The cement designed depends upon the purpose of cementing operation. The initial cement is usually to fill the annular space between the casing and the hole from the casing shoe to the surface or to point several hundred feet above the zone that must be isolated. The first cementing job is called primary cement and its success is absolutely critical to the successor with the subsequent well control plus completion operation. When a primary cement job fails completely to isolate the section of interest, then repair of the cement job must be done before drilling so it can proceed.

As these repair steps are covered by the collective label of squeeze cementing. In a squeezing job, cement is forced into the zone through perforations, ports in tools , holes produced by corrosion or through the clearance between casing overlap liners / strings. Although squeezed cementing has become common place, it is expensive and it can be used by curtailed through improved primary cementing procedure. As it should be done properly and accurately in order to save from big lost.

2.2 Equivalent circulating density (ECD)

ECD is the effective density exerted by a circulating fluid against the formation that takes pressure drop, gravitational force and true vertical depth into the ECD calculation. The ECD is important in avoiding kicks and losses, particularly in wells that have a narrow window between the fracture gradient and pore pressure gradient.

2.3 Rheological Properties

Reliable prediction of ECD in HPHT wells requires the use of temperature and pressure which is dependent on rheology and density. The pressure and temperature dependence of rheology can be obtained from laboratory measurement at HPHT conditions of the actual mud system or from a model that is developed, based on data from similar mud systems.An article regarding rheological properties, says it is important to keep the mud and cement fluids separated when cementing the wells in NZ field since mixtures may result in extremely high viscosity fluids. Rheologies of most of the mixed ratios of mud and cement tested were not measurable in standard rheometers found in field laboratory. High friction pressures that occurred will contribute in the factor of abnormal cementing job pressures

A measurements of the time during which a cement slurry remains in a fluid state and is capable of being pumped. Thickening time is assessed under simulated downhole conditions using a consistometer that plots the consistency of a slurry over time at the anticipated temperature and pressure conditions. The end of the thickening time is considered to be 50 to 70 Bc for most applications. Thickening time is really an important factor for cement. Adequate thickening times are required for a good cement job. Excessive waiting time are required for a good cement job. Excessive waiting will provide a weak support which can risk the well structured and severely damage the subsea head equipment.

2.4 Thickening time

A measurement of the time during which cement slurry remains in a fluid state and is capable of being pumped. As the thickening time is assessed under simulated down hole conations using a consist meter that plots the consistency of slurry over time at the anticipated temperature and pressure conditions, the end of the thickening time is considered to be 50 or 70 BC for most applications. Thickening time is really important factor for cement and adequate thickening times are required for a good cement job. Excessive waiting will provide a weak support which can risk the well structure and severely damage the subsea head equipment.

2.5 Circulation Rate

Circulation rate of cement to displace all mud in the well bore give quite a big impact on the process. The high yield point cement is required for a flow rate when exceeds more than 22,8 dm3/a (8.5 Bbl/min). While the low yield point cement is required for a flow rate around 13.0 dm3/s (5 Bbl/min).

2.6 Geothermal gradient

Geothermal gradient is the rate of increasing temperature with respect to increasing depth in the Earth's interior. Away from tectonic plate boundaries, it is 22.1 degree Celsius per Km of depth (1 degree Faren height of depth) in most of the world. as we go deeper to the ground , the temperature will be increased. At HPHT, the temperature that will be studied will be around 200 F and above. Temperature is one of the factors in designing a cement.

2.7 Pore and Fracture pressure

It is well known that in the HPHT condition case of wells the pore and fracture windows are narrow. Managing the equivalent circulating density (ECD) becomes extremely important as well as challenging. In the pressure of these narrow windows, precise management of the ECD is the difference between not fracturing the formation and not allowing in flux from the well.

In high temperature and high pressure wells (HPHT) , it often becomes very difficult to predict the ECD based on some assumed mud properties which ends up either over or under predicting the actual values. Unfortunately , in wells with narrow margins both situations ends up in being potentially disastrous causing either a lost of circulating scenario or a well control situation.

2.8 Density of Drilling fluid used during drilling or any well completion

Density mud density or also called as mud weight is measured by the means of a mud balance with the weight of 8.33 ppg. As the mud weight can be increased by adding barite (barium sulphate). Barite has a specific gravity which is between 4.2 - 4.3. Mud, weight is really important to know so we can prevent Kick or Losses.

2.9 Flow regimes of drilling fluid

Flow regimes are ranged of stream flows having similar bed forms, flow resistance and means of transporting sediments. The process of mud removal for primary cementing process can be achieved in these two flow regimes. Most of research paper claims that in order to overcome the mud channelling in the lower side of the inclined annulus. Turbulent flow has to be created in that section while pumping the cement. Turbulent flow has the chaotic motion of the fluid particles which eventually can reach the narrow side of the casing or casing open hole annulus and make the mud that settled down in that side to move, breaking the gel of the mud. In order to have turbulent flow in the annulus side we have to create a high velocity profile in that region. As turbulent of the flow regimes is highly affected by the flow rate used, with the geometry of the hole and rheological properties of the cement

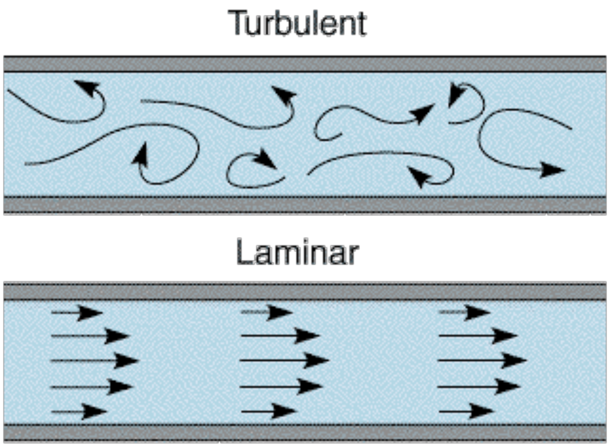


Figure 1 Turbulent And Laminar Flow

2.10 Drilling mud composition (Emmanuel Awona ,November 2011)

Composition of a typically betonies gel water based mud, density 1300 kg / m3. While this composition is added to 1 barrel of water : (bbl = barrel , pps = pounds per barrel) ; CMC : (Carboxy methyl cellulose). So the composition is of typical oil based mud density 1318 kg / m3 , salinity 22.5% , oil to water ratio 65 : 35.and combines to give a total volume of one barrel. (bbl : barrels ; ppb : pounds per barrel ; gpb : gallons per barrel) . Mud in this paper is used to kill the well to prepare for the cementing operations. In modern days drilling mud is typically a water based mixture of heavy clay minerals and synthetic additives. As these minerals provide the weight, which can range from 9 pounds per gallon, to as much as 12 or 14 pounds (water weighs about 8 pounds per gallon). The additives allow the mud to maintain a plat form, filling an exposed well head at pressure of 2500 psi and temperature of 30 F or squeezing into the narrowness of the well, where conditions could be closed to 9000 psi and 200 F.

2.11 Physical properties of drilling fluids at HPHT (Fisk , J.V., Jamison , D.E , Baroid Drilling Fluids , December 1989)

At high temperature and high pressures, rheological and dynamic filtration properties are presented for water and oils based drilling fluids. The physical properties were obtained at temperature of 4000 degree F and pressure of 15000 psi as it effects on the viscosity of oil muds. The dynamic filtration rates of drilling fluids are greatly affected by the solid plugging of the pore in the formation. As temperature and pressure affects dynamic filtration by changing the dispersion of the solid in the solid.

2.12 Ensure long term Zonal isolation in harsh environments (Schlumberger)

As cementing is permanently exposed to a down hole conditions. about 110 degC [230 deg F]. The commonly used Portland cement may shrink, lose strength and gain permeability. This deterioration can be minimized or even prevented by adding at least 35% silica by utilizing cements engineered for the HPHT environment. Even of the zonal isolation is initially adequate, changes in down hole temperature and pressure can crack or even shatter the cement sheath ; radial pressure / temperature fluctuations can create a micro annulus. These concerns are particularly significant in deep, hot wells and thermal recovery wells.

2.13 The Main functions of drilling fluids (Erik Sofge, May 2010)

Main Function of drilling fluids is to provide hydrostatic pressure to prevent formation fluids from entering into the well bore, as it keeps the drill bit cool and clean during drilling. Drilling fluid helps in carrying out drill cutting and suspending the drill cuttings while drilling is in progress and when the drilling assembly is bought in and out of the hole. However it is also been used as a medium to kill well. In many cases, when drilling mud is waded up to offset a sudden increase in pressure coming from the subterranean formation. The mud is released in deep well, through holes in the drill but it self. When the well is being sealed completely, as opposed to using the mud to make slight pressure adjustment during drilling or pumping it is called Killing the well. The top kill is generally a less desirable version, where the kill happens from top down , with mud forced into the kill lines built into the blowout preventers . However the mud is applied, from above or below, it is done slowly and carefully.

2.14 Investigation of Drilling Fluid To Maximize Cement Displacement Efficiency (T.R Smith ,Shell Canada Ltd. October 1991)

One of the most important function of a primary cement job is to provide a hydraulic seal in the casing /bore hole annuls to accomplish this .As this necessary to remove or displace the drilling fluid with a cement slurry. There are many factors which have been least investigated either in laboratory or during field operations in drilling fluid properties.The drilling fluid must be mobile and circulated before the cement is pumped into place.The drilling fluid used to drill a well is usually selected on its rheology , filtration control or formation inhibition properties.Prior to cementing the wellbore , minor adjustments are often made to the properties of drilling fluid such as thinning or dispersing to lower the viscosity. The investigation is concentrated on how the drilling fluid properties affect the displacement efficiency.

2.15 High Density Elastic Cements Applied to solve HPHT challenges in South Texas (Barry Wary , Cimarex Energy ; David Bedford , Lennox Leotaud and Bill Hunter , Halliburton , November 2009)

Well cementing operations in South Texas tend to present a number of challenges to those responsible for constructing oil and gas wells. For instance, the temperatures and pressures at which the cement needed to be placed can be extremed, routinely exceeding bottom hole static temperature of 300 degree F and pore pressure requiring fluid densities of 17 Ibm /gal or greater to maintain well control. These extreme conditions can present challenges not only during placements of the cement slurry in the well bore but also later to the set cement sheath during the life of well. To effectively meet these challenges , well operations in South Texass have been using high density cements that have been mechanically modified so the set cement will be more elastic and resilient. Advanced diagnostic software is used to predict well situation where these cements are required.

Currently , high density elastic cements (HDEC) have been placed in more than 40 wells of Southern Taxes and the use of these sealants are combined with the diagnostic software which has become routine.

As this article not only focuses on the Cementing of High Pressure and High temperature well but also on the best solutions that are being applied.

Challenges Faced during the operations in HPHT wells from this paper :

1) Insufficient bore hole pressure integrity , especially during cutting through depleted zone intermingled with high pressure intervals.Shales and / or sands weakened by depletion , leaking faults or unfavorable rock properties results in lost returns when mud weights are close to pore and fracture pressures. In one field , for example, often times the target sand is normally pressured with over pressured shales above and below the sand , with some faulting present. Setting a casing string to isolate normal pressure zones from high pressure zones can be problematic if the faults exit at the casing shoe and the cement sheath does not provide a good hydraulic seal. Additional casing strings are often set to allow drilling to continue with narrow margins can create potential well control issue while construction of the well is in progress.

2) Difficult to select for the drilling fluids to use in these wells. Oil based mud (OBM) systems provide definite advantages , generally delivering improved shale stability and clay control, reduced pore-pressure transmission, less differential - sticking tendencies , higher rates of penetration and better lubricity to minimize torque and drag.

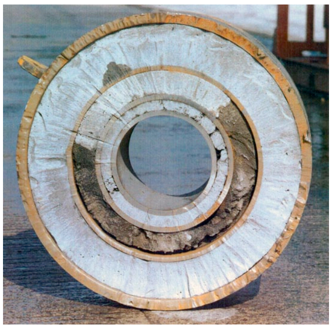


Figure 2 : Micro Annulus Inside Casing

3) These fluids are often costly due to the disposal , lost circulation issues and regulatory / environmental considerations. There fore , when there are small differentials between pore pressure and fracture-initiation pressure. Operators in the South Texas prefer to use conventional water -based mud (WBM) below the intermediate casing string to better losses combat losses and hole ballooning, even through larger washouts are possible with WBM. Hole ballooning is defined by the walls expanding outward because of the increased pressure during pumping. When pumping stops, the well contracts and return to normal size , forcing excess mud out of the well bore.

4) The largest specific challenges these conditions create for those tasked with placing an effective cement seal in HPHT wells are High equivalent-circulating densities (ECDs) are created when the defined fluids required for the well control purpose are pumped into the well, often leading to formation break down , followed by annular fluids loss in the fractures created that can potentially lead to well control issues and after high pressure well stimulation and production ,casing failure can occur if the cement sheath that has been placed is incomplete or does not process the requisite mechanical properties to the with stand the high differential pressure to the which it is subjected.

2.16 Cement Fatigue and HPHT Well Integrity with Application to the Life of Well Prediction

Conditions in HPHT wells are particularly challenging , and little is known about the fatigue of cement and the performance of the casing - cement interface in HPHT wells. Drill string-induced vibrations and changing pressures and temperatures causes damage at the casing-cement interface by forming micro annuli and the accumulation of that damage can lead to a loss of well integrity and well failure. Tubulars used in HPHT wells are tested under simulated bore hole conditions prior to field applications. Cement slurries and properties are also measured, but none of the known methods are able to evaluate the life of the well based on actual well bore parameters. Even less information is known on the fatigue of cement under cyclic loading under HPHT conditions.

2.17 Role of cementing in Oil and Gas Operation.

Cementing is one of the most critical steps in well completion. It will be used at the end of drilling and in the haste to put a well on production. Rarely in the time and commitment take to get a good job done. How ever , usually the cementing contractors spend significantly more time correcting it or battling the effects of a bad cement job. Cement fills and seals the annulus between the casing string and the drilled hole. Three general purpose can be extracted

1) Zonal isolation and segregation

2) Corrosion Control

3)Formation stability and pipe strength improvement.

Cement can forms a nearly complete impermeable seal from the slurry. Which is It dependent on some components and additives that are used to make the cement slurry. This will determine the properties and behavior of the slurry.

Cement particles has a direct relation ship with water is requirement to make a slurry with out producing an excess of water at the top of the cement includes : C3S-tricalcium silicate , C2S- dicalcium silicate , C4AF - tetracalcium aluminoferrite, C3A-tricalcium alminate, MgO-periclase or magnesium oxide and CaO-free line.

Not all cements, even those made from the same components, will react in the same manner when mixed with water. Basically , the differences are in the fineness of the grind of the cement, impurities in the water and in some minor additives added during the cement manufacturing process.

Figure below gives the API designated classes for cements. These classifications of cement were in response to HPHT down hole conditions. Note that the useful depths given in the data are derived from average pumping times of neat (no additives) cement for average temperature involved at these depths. Actual well environment controls the limit of the cement. Also, additives such as accelerators and retarders can be used to modify the behavior os the cement. In this manner , a class H cement , for example can be used to much greater depths than the 8000 ft limit seen in the table

API Cement Class (API RP 10-B)

Class	Depth	Conditions
A	Surface-6000ft	Special properties are not required
B	Surface-6000ft	Require Properties for high sulfate resistance
C	Surface-6000ft	Require high early strength
D	6000ft-10000ft	High temperature and pressure
E	10000ft-14000ft	High temperature and pressure
F	10000ft-16000ft	Extremely High temperature and pressure
G	Surface-8000ft	Can be used with accelerators and retarders to cover wide range of well depths and temperatures
H	Surface-8000ft	Can be used with accelerators and retarders to cover wide range of well depths and temperatures
J	12000ft -16000ft	Extremely high temperatures and pressures. It can be used along with accelerators and retarders to cover wide range of well depths and temperatures

75% Cement, 25% Mud

50% Cement, 50% Mud

25% Cement, 75% Mud

5% Cement, 95% Mud

2.18 Properties of Cement (Servicio De Pozos, November 2010)

2.2.1 Time Pump Ability (think)

The time pump ability of grout is the time for the cement slurry can be pumped and displaced with in the annular space (the slurry is pumped during this time). The grout must have sufficient time to be

- Mixed
- Pumped into the pipe
- Scroll through the drilling fluid until it is located where required

Usually 2-3 hours of pump ability time is sufficient to allow operations to be completed. This time is enough to cover up any delays or interruptions in cementing operations. Pump ability time is required for a particular operation should be carefully selected in order to complete the following operational activities

- The grout should not be set as you start pumping

- The grout should not stay smooth for long , because it could be contaminated with the formation fluids or other contaminants

- Cementing operations should not take too long in a drilling operations.

Conditions at the bottom of the well have a significant effect on pump ability time. It might been increased in temperature, pressure or reduce in fluid loss could have reduced the pump ability time. As these conditions should be simulated on the stage of design and testing of grout in the lab before they develop any operations in the well.

This project will use Opticem cementing software in performing the cementing design.

2.2.2 Slurry Densities

The standard density of the slurry can be altered to meet specific operational requirements (a formation that has a low fractures gradients may not with stand a hydro static pressure of grout whose density is around 15 Ib / gal). The density can be altered by changing the amount of water or using aditivospara mixing the grout. The density of many cement slurries range from 11 to 18.5 Ib / gal (ppg). Its should be stressed that this aspect of cement slurries are hving relatively heavy grout (high density) , if there requirment is to harden the cement to its highest resistance to compression

2.2.3 Loss of Water (Water - Free)

The hardening of the grout is the result of the cement begins to hydrate with water mixture. If water is lost from rout before it has been positioned in the annular space, it would decrease pump ability time and water sensitive formations may be adversely affected. The amount of water lossed that can be tolerated depends on the cementing operations and the development of the grout.

Forced cementing requires low valves of water loss , because the cement should be injected under pressure that is generated by a plaster and it blocks the perforations. The primary cementing does not depends critically on the loss of water. The amount of fluid lost from a slurry in particular thorough a laboratory test. Under standard laboratory conditions (1000 psi of pressure in the filtering test, with a mesh size of 325 mesh).

2.2.4 Permeability

After the cement has hardened , the permeability is very low.

2.2.5 Slurry Design

The first concern in designing cement systems for oil and gas wells is to ensure that the slurries are suitable for the field applications. This means that they can easily be mixed and pumped with conventional surface equipment, and placed at the required depth with proper thickening time. The slurry must remain stable during the whole process. For this purpose , an optimization is carried out for each system. So there fore proper slurry design is key for the success full cementing job.Some deficiencies may be tolerable in vertical wells, while in horizontal wells its not acceptable and highest quality of slurry must be used.

2.19 Cement Additives (Servicio De Pozos, November 2010)

Many cement grout containing additives , to modify the properties of the slurry and optimize cementing operations. Although a lot of additives are known by its trade name used by the cementing services companies . Cement additives may be used to :

- Vary the density of the grout
- Change the compressive strength.
- Accelerating or delaying the time sets
- Control of filtering and fluid loss.
- Reduces the viscosity of slurry.

Additives (Extender or Retarders) can be delivered to the drilling location in granular or liquid state can be mixed with cement powder or added to water before mixing the cement slurry is mixed. The amount of additives used is commonly expressed in terms of percentage by weight of cement powder (based on each sack of cement weighs 94 Ibs). Many additives affect more than one property and there for should be carefully used

2.20 OPTICEM Soft ware

It is one of the land mark software used by the Halliburton. Moreover it is cement modelling software which is really best method as compare to the other available software present in the market. As one of the plus point is that it helps in reducing the cost. The article which supports the previous point is that it is rewired during the cementing job at PERMIAN BASIN.

As the customer was going thought the drilling process at 13000 ft at the slim hole gas well. As under balance will reduce the rig time and overall well cost during drilling.There was demand by the customer to make such software of the cementing that would provide the good zonal isolation while eliminating the need for 16.0 ppg and a heavy weighted spacer.So the Halliburton company ultimately designed the software for the cementing program called as OPTICEM. The testing started on the cement slurry which incorporated Halliburton's the Super CBL for gas migration control, but the condition was that the slurry properties and well conditions data was required in order to run the software. A pumping schedule with rates, surface pressure, equivalent circulating densities (ECD) and back up pressure necessary to maintain the required ECD was generated. The Opticem RTT ™ software could then be used to monitor the job in real time and make adjustment if necessary.

The cementing design and procedure were reviewed with the customer and operations continued as per planned. The well as cemented using a pumping schedule designed with opticem software and the customer did not have to use 16.0 ppt mud and heavy weight spacers to achieve good zonal isolation. This allowed the customers to reduce rig time by 1/2 days and resulted in a mud cost saving of 60,000 $, so the estimated economic value to the customer was 90,000 $.

Conclusion is that this software is really reliable in reducing the cost. Opticem provides a good suggestion and method in order to work safely in danger and risky area. This is one example from BP cement case which has caused 11 oil rigs workers and millions of barrels of oil spill into the Gulf of Mexico. It was BPs deep water horizon oil well.

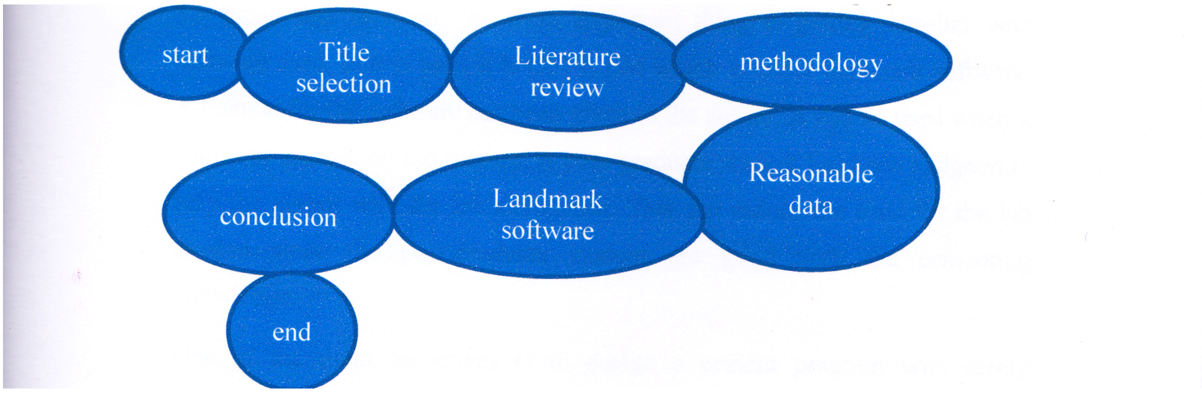
An opticem test has been done 5 days before the incident. From the case, Halliburton's point of view based on the opticem cementing simulation suggested BP to use 21 Centralisers. some of technical problems occurred , still BP proceeded with the drilling , with only 6 centralisers , deciding another known technique of injecting cement in other places would work. (Leo King , November 2010). From this article, it shows that Opticem is a reliable cement simulator and its proven that has suggested the right thing and the incident would not have happened.

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

This is overall Research methodology that are used for the project



3.1.1 Sources Gathering

For doing research we get help from the books journal and technical papers for better understanding. Most of the references are taken from the Society Of Petroleum Engineering (SPE) technical papers which were presented on their website. Oil and gas news are also being used more over books related to cementing in oil and gas operations are used which are available at the IRC of University Technology Petronas as above all has contributed a lot in coin this research.

3.1.2 Analysis

The existing cementing design will be studied in order to find the weakness or certain features that they are lacking off so that it can be improved. All information will be compared and analysed in details. After wards, this paper we would be able to reveal a better solution for current problem such as safety and cost.

3.2 Project Activities

In order to proceed we must be familiar with software which we are going to use. A manual for the software has been given to the author. As it will be used when it comes to the Lab simulation session. For helping in this research the Post - graduate student has been assigned to help the author with the lab stimulation. This can reduce the time for the lab session since the assigned person is well aware of the software.

One main objective is to design a cement program with safety optimization in order to prevent form kick. A control of ECD must be done accurately by using opitcem. In order to perform casing design using the software, data is needed

1) Class of Cement

First step is to determine that what class of cement is suitable for the HPHT well condition. As this can be referred to the literature review which is mentioned before.

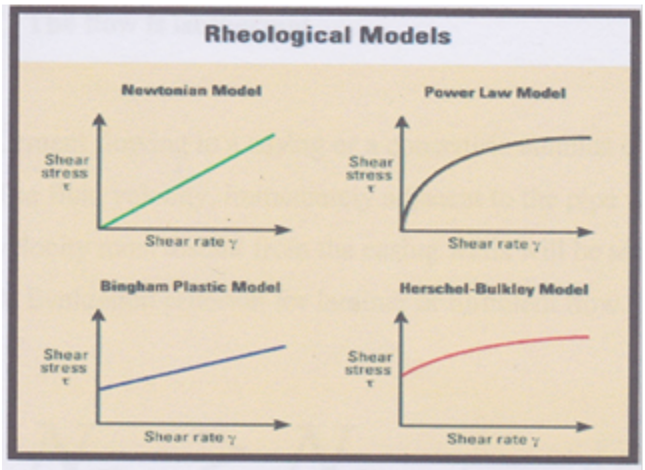
2) Rheology of The Cement

The next step is to determine the rheology of the cement, because the calculations of determining the flow regime and friction caused by the fluid vary depending on the rheology type of the fluid in, our case cement.

The Fann viscometer is a concentric cylinder viscometer was designed specifically for use with drilling fluids and various constants into the rheological models that can be measured easily.

The Rheological models intended to provide assistance in characterizing fluid flow. No single, commonly - used model completely describes rheological characteristics of drilling fluids over their entire shear rate range. Knowledge of rheological models along with practical experience is necessary to fully understand fluid performance. A plot of share stress versus share rate is often used for the graphically depict a rheological model.

While from lower graph of the share stress vs share rate can determined the rheology of the cement that will be used in our project. While oil industry uses the Bignham and Ostwald De Waele (Power Law) models to represent drilling fluid as well as cement slurry behavior. As standard API method for drilling hydraulics assume either a Power Law or Rheological models of fluid Bingham Plastic model. This distinction is particularly important for the annular geometries typical of normal drilling conditions where shear rates are usually low. In these situations Power law model underestimates while Bingham Plastic model over comes the estimation frictional pressure drops. Several complex relationships for Herschel - Buckley rheological model presents more adequate rheological parameters but the formulation and solution to it holds very sophisticated detailed approach. That is why my calculations will be based on the Bingham Plastic Rheology model for the cement, same as the drilling mud rheology



.

Figure 3 : Rheological Models

The drilling engineering deals primarily with the flow of drilling fluids and cements down the circular bore of the drill string and up the circular annular space between the drill string and well bore. In order to develop the mathematical relationship between flow rate and flow regime of the cement the following assumptions must be made.

1. Casing to be cemented place concentrically in the casing or the hole.
2. The sections of open hole are circular shape and of known diameter.
3. Cement is incompressible.
4. The flow is isothermal cement.

Cement flowing in a casing or a concentric annulus does not have a uniform velocity. The fluid velocity, immediately adjacent to the pipe walls will be zero and fluid velocity most distant from the casing walls will be at maximum level.

3) Equivalent Circulating Densities

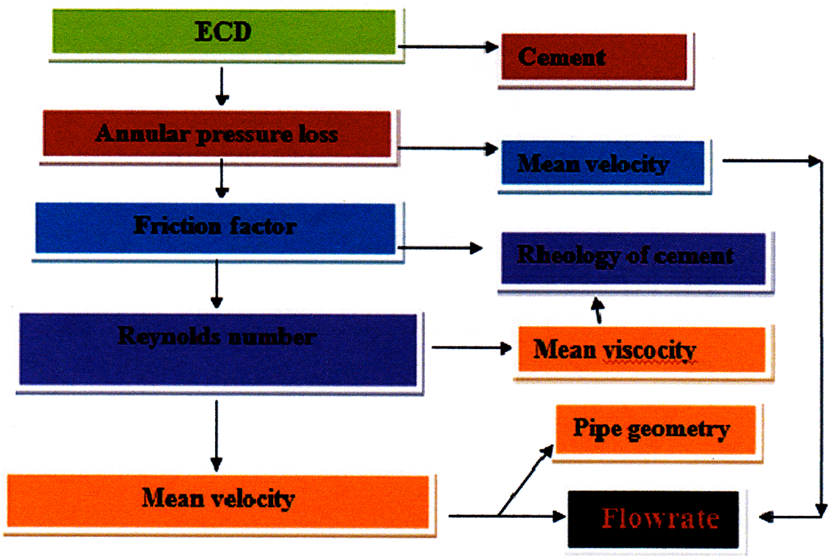
Pump Pressure and its hydraulic power are not the only parameters for determining the maximum flow rate for the system. As it is bounded by the fracture gradient of the formation being cemented. The Equivalent Circulating Density (ECD) of the following cement should not exceed the fracture gradients in order to prevent the fracturing the formation which can eventually lead to a loss of the cement and mud , especially in the low pressured zones.

ECD = CW + Pt.ann / 0.052 * TVD

where,

CW = weight of the cement , ppg ; Pt.ann = total annular pressure losses , psi

TVD = true weight depth of the cemented depth , ft



As we can see from the chart ECD eventually ends up depending on the flow rate as well as on Reynolds Number which determines the flow regime of the cement slurry pumped. Thus to meet the objectives of my project i will mainly focus on choosing the right Flow rate of the system while cement slurry is pumped and manipulating it as to get the proper results. It is more challenging to change the rheology of the cement as well as almost impossible to change the geometry of the well bore and casing used as the Reynolds number and friction factors depending on rheology indeed.

4) Land Mark Soft Ware

In the landmark soft ware , lots of data will be inputted. The data used is not from a real field data but its a reasonable data that was found from internet. The data has been changed to make it parallel with the topic which are for HPHT well. The depth was set to be at 20000ft which shows that it is a high pressure well and the temperature was set to be at more than 400 degree Fahrenheit., which indicates that well is having high temperature. The landmark software will shows the plot of downhole pressure.

The cementing procedure than will be simulated by inserting the obtained value into the Landmark software. The results will be recorded ; analyzed and appropriate conclusion will be made.

The correction will be made for the circulations and / or by the procedures if the outcome expected will fail or will not meet the objectives of the project. The new results and criteria will be checked through the Landmark software of Halliburton again.

5) The Effect of Silica Fume

It is found that silica fume , also known as micro silica or silica dust, has been world widely used for many years in the area where high strength and durable concrete were required. Silica fume improves the properties of both fresh and harden concrete. Since there are many advantages that can be found from the addition of silica fume in a cement mixture , landmark software will help to enhanced the reason that silica fume must be used world widely. The result will be studied and analyzed further.

Summary

- Silica fume reduced the permeability of the concrete. Water and chemicals ingress are thus reduced.

- The ability of high C3A cement to complex with chlorides results in the formation of insoluble compounds , able to reduce the mobility of free chloride ion to the reinforcement - concrete surface.

3.3 Key Mile Stone & Gantt Chart

No	Details / Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15	16
1	Project Work Continues	■	■	■	■	■	■	■	M	■								
2	Submission of Report								I	■								
3	Pre - Sedex								D				■					
4	Sedex													■				
5	Final Draft Submission								S					■				
6	Final Oral Presentation								E							■		
7	Hard Copy Submission								M									■

3.4 Equipment / Tools Required for the Project

- The tools that are needed in this project are
- Training manual for OPTICEM software
- PC Installed with the OPTICEM software
- OPTICEM software expertise

This software requires a licensed key to run the system which is quite expensive. As our university has 15 PCs which are equipped with the relevant software provided by Halliburton Malaysia. Acquiring the manual for running this software is other most important thing in order to make this research success full.

CHAPTER 4

Result And Discussion

4.1 Land Mark Software start up

The course of landmark software of Halliburton has been taken in this university for two weeks that was organized by the Drilling Engineering Lecturer Dr Reza Ettehadi Osgouei and again for three days training organized by the Advance Drilling Engineering Lecturer Dr Sony Arwan.

The parts that were included in the training were consisted mainly of following suites:

- Compass
- Casing Seats
- Well Plan
- Well Cat

The topic of this project is " Designing a cement program for HPHT well using Landmark software" and the most suitable Landmark software for me was WELL PLAN Suite which includes Opticem, that is used to simulated the cementing jobs using various techniques and by manipulating various data such as :

- Sequence and rates fluids to be pumped
- Shoe tracks
- Automatic Rate Adjustments and Safety Factors
- Job Stages
- Cement materials requirements (sacks)
- Displacement Volumes
- Fluid Animation when reviewing many job parameters
- Hole cleaning during cement job, etc

4.1.1 Initial / Essential Data Input into the Software

My first step started by inputting the data is essential for the work of the module which is importing the well path data from the actual field sheet to the program. Three values are only needed for the software to find out and come up with other required data to build the right well trajectory. The data are

1. Measured Depth
2. Azimuth
3. Inclination

TVD (ft)	DLS (°/100ft)	AbsTort (°/100ft)	RelTort (°/100ft)	VSect (ft)	North (ft)	East (ft)	Build (°/100ft)	Walk (°/100ft)

All those three data needed has been inputted manually in a section called WELLPATH EDITOR in a software. The TVD was set to be at 20000ft to indicate that this is a high pressure well. The maximum inclination used is 60 degree and the dog leg is maintained to be 3.05. from study, the dog leg must not be more than 3.05.

Wellpath Editor

Identification

Name: Wellpath Options...

Description:

Well Depth (MD): 20000.0 ft Generate with Actual Stations

VSection Definition

Origin N: ft

Origin E: ft

Azimuth: 224.84 °

	MD (ft)	INC (°)	AZ (°)	TVD (ft)	DLS (°/100ft)	AbsTort (°/100ft)	RelTort (°/100ft)	VSect (ft)	North (ft)	East (ft)	Build (°/100ft)	Walk (°/100ft)
1	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00
2	600.0	0.00	224.84	600.0	0.00	0.00	0.00	0.0	0.0	0.0	0.00	0.00
3	5200.0	0.53	224.84	5199.9	0.01	0.01	0.00	21.3	-15.1	-15.0	0.01	0.00
4	5315.0	3.53	224.84	5314.8	2.61	0.07	0.00	25.3	-18.0	-17.9	2.61	0.00
5	5413.4	6.53	224.84	5412.9	3.05	0.12	0.00	34.0	-24.1	-24.0	3.05	0.00
6	5511.8	9.53	224.84	5510.3	3.05	0.17	0.00	47.7	-33.8	-33.6	3.05	0.00
7	5610.2	12.53	224.84	5606.9	3.05	0.22	0.00	66.5	-47.2	-46.9	3.05	0.00
8	5708.7	15.53	224.84	5702.4	3.05	0.27	0.00	90.4	-64.1	-63.8	3.05	0.00
9	5807.1	18.53	224.84	5796.5	3.05	0.32	0.00	119.2	-84.5	-84.1	3.05	0.00
10	5905.5	21.53	224.84	5888.9	3.05	0.36	0.00	152.9	-108.4	-107.8	3.05	0.00
11	6003.9	24.53	224.84	5979.5	3.05	0.41	0.00	191.4	-135.7	-135.0	3.05	0.00
12	6102.4	27.53	224.84	6068.0	3.05	0.45	0.00	234.6	-166.4	-165.5	3.05	0.00
13	6200.8	30.53	224.84	6154.0	3.05	0.49	0.00	282.4	-200.2	-199.1	3.05	0.00
14	6299.2	33.53	224.84	6237.4	3.05	0.53	0.00	334.6	-237.2	-235.9	3.05	0.00
15	6397.6	36.53	224.84	6318.0	3.05	0.57	0.00	391.0	-277.3	-275.7	3.05	0.00
16	6496.1	39.53	224.84	6395.5	3.05	0.61	0.00	451.7	-320.3	-318.5	3.05	0.00
17	6594.5	42.53	224.84	6469.8	3.05	0.64	0.00	516.3	-366.1	-364.1	3.05	0.00
18	6692.9	45.53	224.84	6540.5	3.05	0.68	0.00	584.7	-414.6	-412.3	3.05	0.00
19	6791.3	48.53	224.84	6607.6	3.05	0.71	0.00	656.7	-465.6	-463.1	3.05	0.00
20	6889.8	51.53	224.84	6670.8	3.05	0.75	0.00	732.2	-519.2	-516.3	3.05	0.00
21	6988.2	54.53	224.84	6730.0	3.05	0.78	0.00	810.8	-574.9	-571.7	3.05	0.00
22	7086.6	57.53	224.84	6785.0	3.05	0.81	0.00	892.4	-632.8	-629.2	3.05	0.00
23	7200.0	60.00	224.84	6843.8	2.18	0.83	0.00	989.3	-701.5	-697.6	2.18	0.00

Figure 5 : Well path editor

Next main data to be inputted was pore pressure profile of the drilled section

Pore Pressure

	Vertical Depth (ft)	Pore Pressure (psi)	EMW (ppg)
1	600.0	223.38	7.17
2	1476.0	580.50	7.57
3	1804.0	732.70	7.82
4	1969.0	810.10	7.92
5	2297.0	962.40	8.07
6	3181.0	1403.00	8.49
7	3279.0	1449.80	8.51
8	3344.0	1479.60	8.52
9	3764.0	1681.50	8.60
10	4505.0	2034.30	8.69
11	4624.0	2176.10	9.06
12	4712.0	2285.50	9.34
13	5108.0	2513.50	9.47
14	5344.0	2762.60	9.95
15	5480.0	2965.50	10.42
16	5680.0	3211.90	10.89
17	5801.0	2738.00	9.09
18	6475.0	3069.40	9.13
19	7355.0	3610.70	9.45
20	7798.0	4071.10	10.05
21	8281.0	4577.00	10.64
22	8767.0	4939.60	10.85
23	9259.0	5363.00	11.15
24	9493.8	5499.00	11.15
25	9600.0	6109.10	12.25
26	10254.0	6791.60	12.75
27	10504.0	6957.20	12.75
28	10743.0	7394.50	13.25
29	11253.0	7774.80	13.30
30	11753.0	8144.70	13.34
31	12253.0	8516.60	13.38
32	12503.0	8716.40	13.42
33	12753.0	8917.20	13.46
34	13253.0	9294.30	13.50

Tab1 Tab2 Wallplot

Figure 6 : Pore pressure profile

And then fracture pressure profile

Fracture Gradient

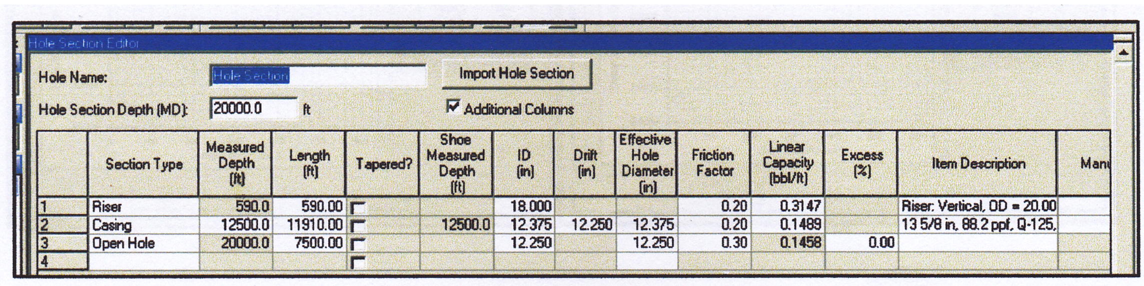
	Vertical Depth (ft)	Fracture Pressure (psi)	EMW (ppg)
1	600.0	280.52	9.00
2	1476.0	861.80	11.24
3	1804.0	1068.30	11.40
4	1969.0	1182.40	11.56
5	2297.0	1420.00	11.90
6	3181.0	2032.50	12.30
7	3279.0	2120.70	12.45
8	3344.0	2188.80	12.60
9	3764.0	2493.00	12.75
10	4505.0	3030.60	12.95
11	4624.0	3182.80	13.25
12	4712.0	3284.90	13.42
13	5108.0	3584.90	13.51
14	5344.0	3844.90	13.85
15	5480.0	4039.50	14.19
16	5680.0	4287.30	14.53
17	5801.0	3983.90	13.22
18	6475.0	4453.50	13.24
19	7355.0	5146.60	13.47
20	7798.0	5630.80	13.90
21	8281.0	6198.90	14.41
22	8767.0	6585.50	14.46
23	9493.8	7274.50	14.75
24	10254.0	7920.90	14.87
25	10504.0	8114.00	14.87
26	10753.0	8311.90	14.88
27	11253.0	8710.10	14.90
28	11753.0	9109.30	14.92
29	12253.0	9509.60	14.94
30	12503.0	9716.60	14.96
31	12753.0	9924.10	14.98
32	13243.7	10319.80	15.00

Figure 7 : Fracture pressure profile

Both of them are inserted in **PORE and FRACTURE PRESSURE** sections of the WELLPLAN suite.

4.1.2 Cementing 9 5/8" casing

Starting from this point we can start cementing our well with 9 5/8" casing running, as the previous casing 13 5/8" production casing is driven into the earth to the vertical depth of 12500ft.
First step is to edit the hole section where the casing will be run and cemented:
In **HOLE SECTION EDITOR,** section type will be defined together with their required specification. The data inputted is not based on real field but a realistic data.

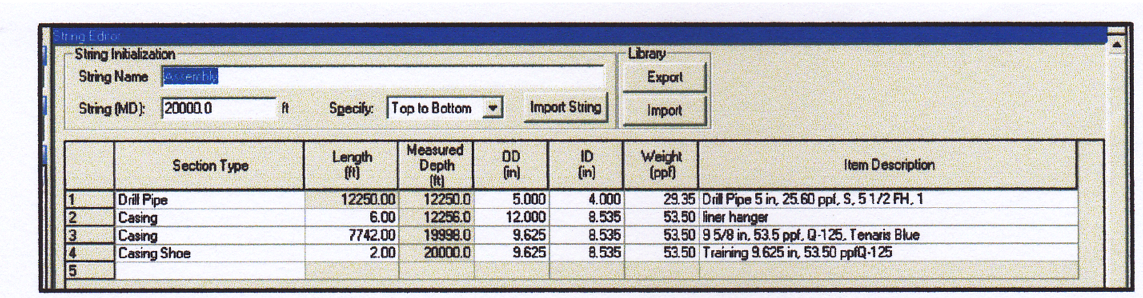

Hole Section Editor
Hole Name: Hole Section   Import Hole Section
Hole Section Depth (MD): 20000.0 ft   Additional Columns

	Section Type	Measured Depth (ft)	Length (ft)	Tapered?	Shoe Measured Depth (ft)	ID (in)	Drift (in)	Effective Hole Diameter (in)	Friction Factor	Linear Capacity (bbl/ft)	Excess (%)	Item Description	Manu
1	Riser	590.0	590.00			18.000			0.20	0.3147		Riser: Vertical, OD = 20.00	
2	Casing	12500.0	11910.00		12500.0	12.375	12.250	12.375	0.20	0.1489		13 5/8 in, 88.2 ppf, Q-125,	
3	Open Hole	20000.0	7500.00			12.250		12.250	0.30	0.1458	0.00		
4													

Figure 8 : Hole section editor

from this section, it shows that 13 5/8" casing was set at 12500 ft and 12 1/4" hole is was drilled until the MD of 7500 ft.
The next step is to edit the string that will be inserted into the new drilled section:

In **STRING EDITOR,** the data are filled as the picture below.


String Editor
String Initialization
String Name: Assembly
String (MD): 20000.0 ft   Specify: Top to Bottom   Import String
Library: Export   Import

	Section Type	Length (ft)	Measured Depth (ft)	OD (in)	ID (in)	Weight (ppf)	Item Description
1	Drill Pipe	12250.00	12250.0	5.000	4.000	29.35	Drill Pipe 5 in, 25.60 ppf, S, 5 1/2 FH, 1
2	Casing	6.00	12256.0	12.000	8.535	53.50	liner hanger
3	Casing	7742.00	19998.0	9.625	8.535	53.50	9 5/8 in, 53.5 ppf, Q-125, Tenaris Blue
4	Casing Shoe	2.00	20000.0	9.625	8.535	53.50	Training 9.625 in, 53.50 ppfQ-125
5							

Figure 9 : String editor

This section represents that only string that will be inserted into the 12 1/4" hole is 12" liner hanger, 9 5/8" casing with 53.5 poundage with its casing shoe at 20000 ft. Other than that, the drill pipe data will also be key in as it is one of the component need for circulating all fluids.
At this point,the schematic diagram from surface until depth 20000ft can be viewed as follow.

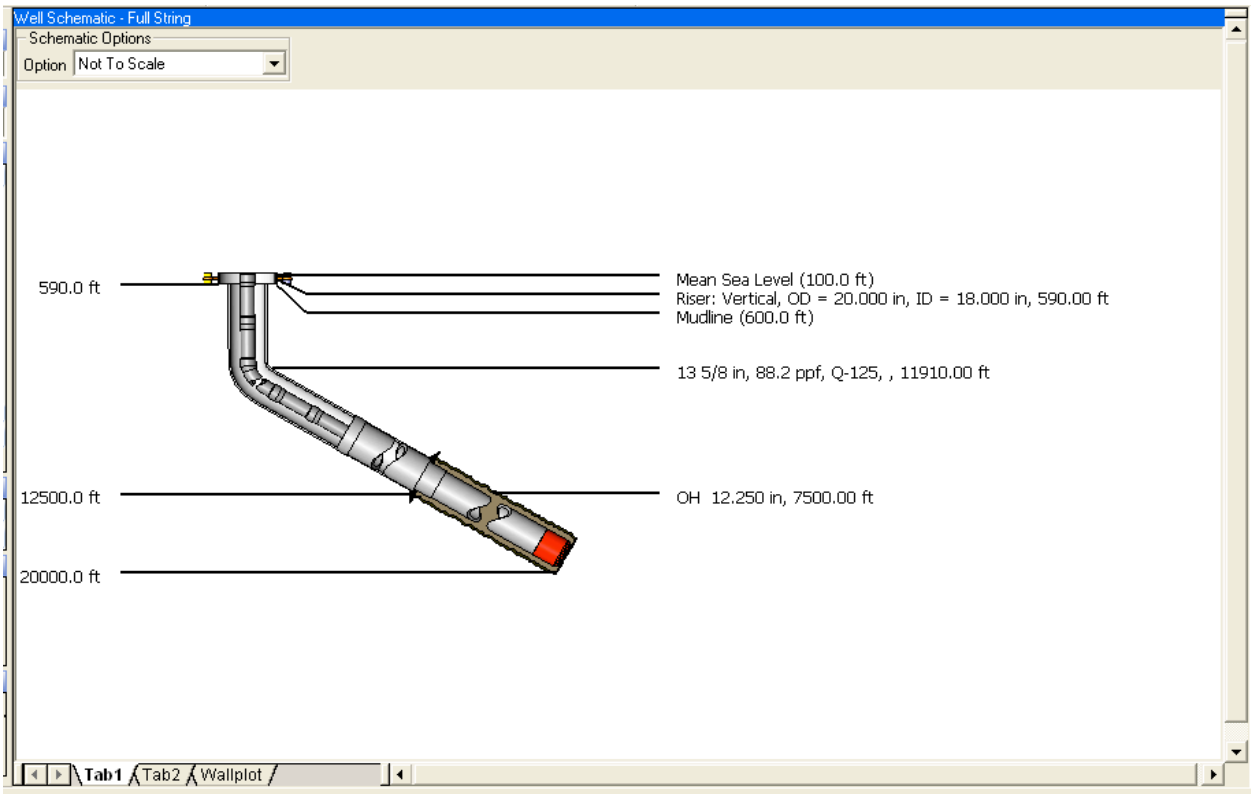


Figure 10 : Well schematic-full string

This is considered as a simple operation,using only riser and liner, since the main point of this project is on the cementing part only. The riser shown has a length of 590ft,casing has 11910 ft and the rest was occupied by open hole.

All the fluids – cement slurries, drilling fluids, and spacer's data were placed into the section named **FLUID EDITOR** as following:

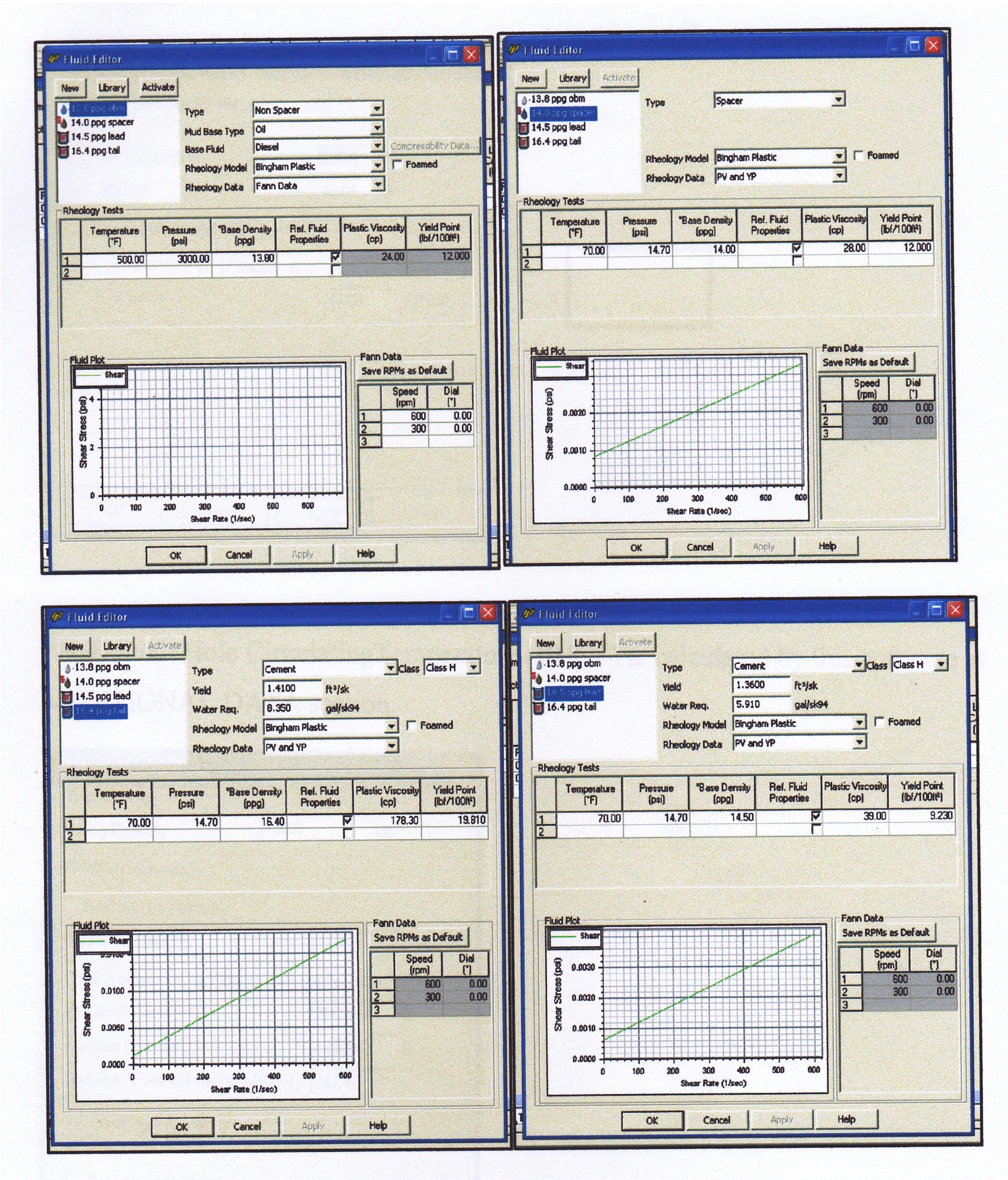


Figure 11: Fluid editor for normal practice cement

Only four types of fluid that were needed to be defined which are mud,spacer,cementing tail,and lead. Next part is focusing on the Temperature. The Bottom Hole StaticTemperature (BHST) is set to be at 547.75 degree Fahrenheit with geothermal gradient of 4.00 degree Fahrenheit/100ft.

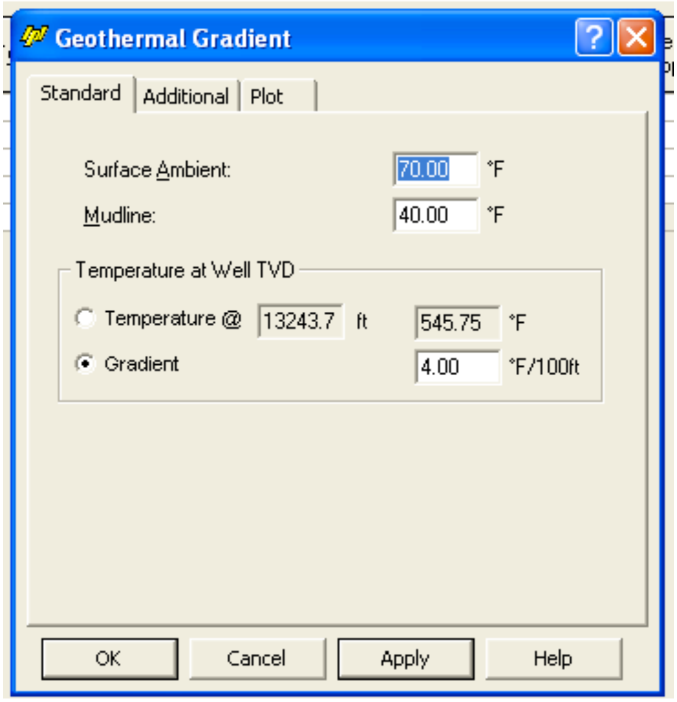


Figure 12 : Geothermal gradient

The Bottom Hole CirculatingTemperature (BHCT) is calculated by this software at ADDITIONAL DATA section.

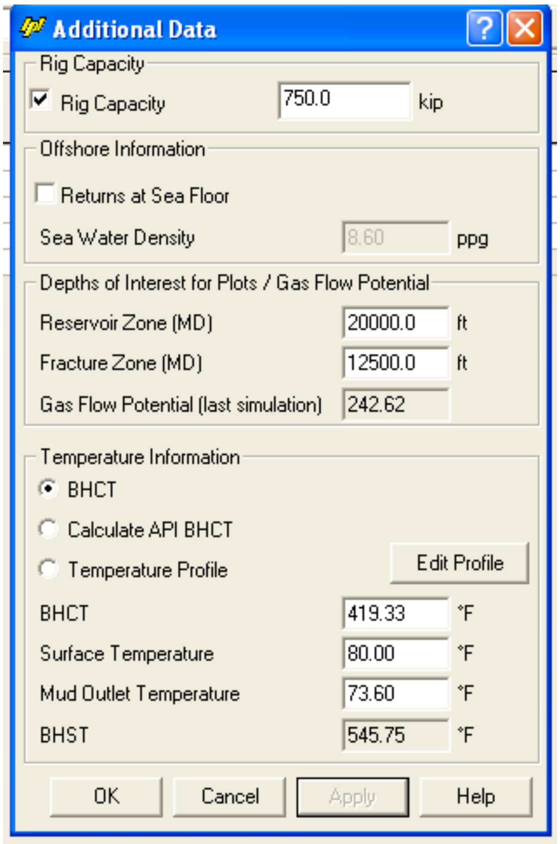


Figure 13: Additional data

The next step is one of most important which is called Job Data. In which we indicate the sequence of the fluids to be pumped during cementing , together with their respective flow rate , volumes , fluid lengths and tops. The following figures represents the casing Job Data for 13 5/ 8 " casing cementing

Job Data

☐ Automatic Rate Adjustment Safety Factor 0.00 psi Fluid Editor

☐ Use Foam Schedule ☐ Disable Auto-Displacement Calculation ☐ Annulus Injection

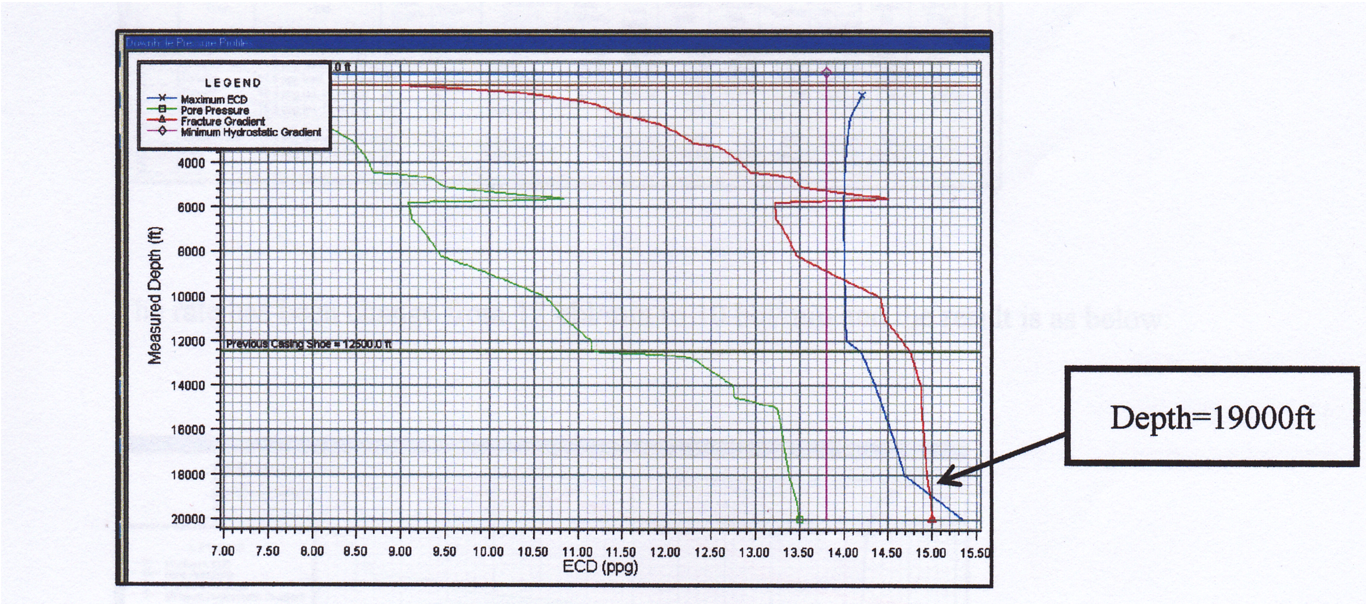
Inner String ☐ Used Edit

	Type	Fluid	New Stage?	Stage No	Placement Method	Rate (bbl/min)	**Stroke Rate (spm)	Duration (min)	Volume (bbl)	**Strokes	Top of Fluid (Measured Depth) (ft)	Length (ft)	Bulk Cement (94lb sacks)
1	Drilling Fld (Muc	13.8 ppg obm, 13.80 ppg	☑	1	Volume	17.00	340.00	0.00	0.00	0.0	0.0	11848.3	
2	Spacer/Flush	14.0 ppg spacer, 14.00 pp	☑	2	Volume	17.00	340.00	2.94	50.00	1000.0	11848.3	401.7	
3	Cement	14.5 ppg lead, 14.50 ppg	☑	3	Top of Fluid	17.00	340.00	18.89	321.19	6423.8	12250.0	5750.0	1325.99
4	Cement	16.4 ppg tail, 16.40 ppg	☑	4	Top of Fluid	17.00	340.00	6.90	117.22	2344.5	18000.0	2000.0	466.78
5	Cement	16.4 ppg tail, 16.40 ppg	☑	5	Shutdown			5.00					
6	Top Plug*		☑										
7	Spacer/Flush	14.0 ppg spacer, 14.00 pp	☑	6	Volume	17.00	340.00	0.59	10.00	200.0	19778.7	141.3	
8	Mud	13.8 ppg obm, 13.80 ppg	☑	7	Volume	17.00	340.00	42.54	723.17	14463.3	0.0	19778.7	
9			☐										

Stroke rate

Figure 14 : Job data for normal practice cement 1st trial

From the table we can see the sequence of pumped fluids, with their respective properties. The flowrate is constant for all the fluids which is 17 bbl/min (714 gpm). 13.8 ppg drilling mud reaches surface from MD of 11848.3. After that, 401.7 ft of 14 ppg spacer is pumped followed by 5750 ft (length) of 14.5 ppg cement lead. The TOC of cement lead showed by this section is 12250 ft indicating 250 ft above previous casing shoe (13 5/8" at depth 12500 ft) from the depth of 18000 ft. The 16.4 ppg cement tail is pumped after cement lead. The TOC is found to be at 18000 ft which means 5500 ft below previous casing shoe.
Other information provided by this section is the amount of lead and tail cement required. As shown by the last column, 1326 sacks of lead cement and 467 sacks of tail cement are predicted.
After we set all the data in Job Data, we are ready to see the plot of pressure profile, where we can see the ECD interference with the fracture gradient. The following pressure profile was obtained from the OptiCem software using the combination of all previous input data:



Depth=19000ft

Figure 15 : Downhole pressure profile 1st trial

From the plot we can see clearly that the blue line which presents ECD is exceeding the fracture gradient on the bottom of the hole at depth 19000ft. Thus during pumping the cement indication could lead to a fracture of formation and further drilling problems like loss of circulation.

Now we can simulate the data to fulfill the ECD requirements, such as:

- **Decreasing flowrate**
- **Decreasing the lead cement height**
- **Decrease the lead cement weight to suitable levels**
- **Decrease the spacer weight to suitable levels**

We can highly play around with one or two data and reach the desired results, but in this case, only flowrate will be the manipulating data. The decrease of the flowrate will leads to an ECD getting smaller and that is the outcome we would like to see.

The following is the modified Job Data:

Job Data

☐ Automatic Rate Adjustment   Safety Factor 0.00 psi   Fluid Editor   Inner String ☐ Used   Edit

☐ Use Foam Schedule   ☐ Disable Auto-Displacement Calculation   ☐ Annulus Injection

	Type	Fluid	New Stage?	Stage No	Placement Method	Rate (bbl/min)	**Stroke Rate (spm)	Duration (min)	Volume (bbl)	**Strokes	Top of Fluid (Measured Depth) (ft)	Length (ft)	Bulk Cement (94lb sacks)
1	Drilling Fld (Muc	13.8 ppg obm, 13.80 ppg	☑	1	Volume	10.00	200.00	0.00	0.00	0.0	0.0	11848.3	
2	Spacer/Flush	14.0 ppg spacer, 14.00 pp	☑	2	Volume	10.00	200.00	5.00	50.00	1000.0	11848.3	401.7	
3	Cement	14.5 ppg lead, 14.50 ppg	☑	3	Top of Fluid	10.00	200.00	32.12	321.19	6423.8	12250.0	5750.0	1325.99
4	Cement	16.4 ppg tail, 16.40 ppg	☑	4	Top of Fluid	10.00	200.00	11.72	117.22	2344.5	18000.0	2000.0	466.78
5	Cement	16.4 ppg tail, 16.40 ppg	☑	5	Shutdown			5.00					
6	Top Plug*		☑										
7	Spacer/Flush	14.0 ppg spacer, 14.00 pp	☑	6	Volume	10.00	200.00	1.00	10.00	200.0	19778.7	141.3	
8	Mud	13.8 ppg obm, 13.80 ppg	☑	7	Volume	10	160.00	90.40	723.17	14463.3	0.0	19778.7	
9			☐										

Figure 16 : Job data for normal practice cement 2nd trial

The rate has been change from 17 bbl/min to 10 bbl/min and the result is as below:
Figure

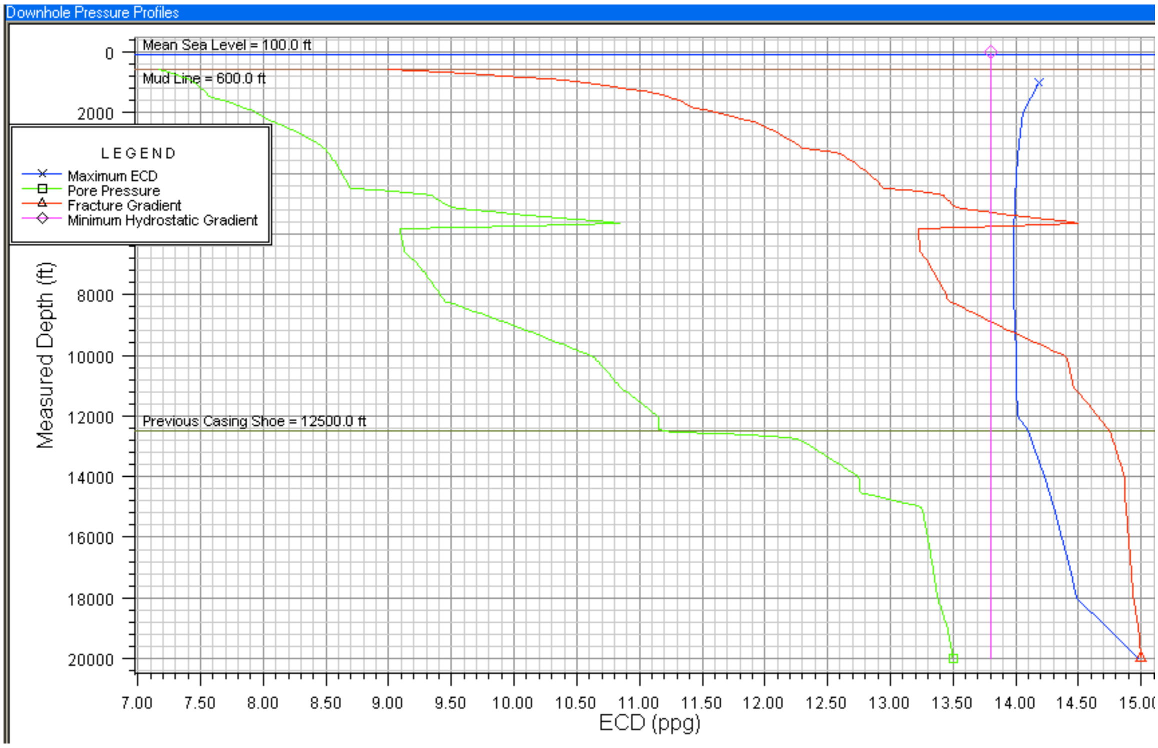


Figure 17 : Downhole pressure profile 2nd trial

This time we can see that ECD is not exceeding the fracture gradient and we can perform the cementing job with the latest data and procedures with no taking a risk to fracture the formation that can lead to well problems.

HOWEVER, since the ECD line at depth 20000ft is right on top of the fracture line, a little bit more decrease in pumping rate will give a better result and smaller ECD.

The rate is then changed from 10bbl/min to 8bbl/min and the result is as below:

Job Data

Automatic Rate Adjustment Safety Factor 0.00 psi Fluid Editor Inner String Used Edit

Use Foam Schedule Disable Auto-Displacement Calculation Annulus Injection

	Type	Fluid	New Stage?	Stage No	Placement Method	Rate (bbl/min)	**Stroke Rate (spm)	Duration (min)	Volume (bbl)	**Strokes	Top of Fluid (Measured Depth) (ft)	Length (ft)	Bulk Cement (94lb sacks)
1	Drilling Fld (Muc	13.8 ppg obm, 13.80 ppg	☑	1	Volume	8.00	160.00	0.00	0.00	0.0	0.0	11848.3	
2	Spacer/Flush	14.0 ppg spacer, 14.00 pp	☑	2	Volume	8.00	160.00	6.25	50.00	1000.0	11848.3	401.7	
3	Cement	14.5 ppg lead, 14.50 ppg	☑	3	Top of Fluid	8.00	160.00	40.15	321.19	6423.8	12250.0	5750.0	1325.99
4	Cement	16.4 ppg tail, 16.40 ppg	☑	4	Top of Fluid	8.00	160.00	14.65	117.22	2344.5	18000.0	2000.0	466.78
5	Cement	16.4 ppg tail, 16.40 ppg	☑	5	Shutdown			5.00					
6	Top Plug*		☑										
7	Spacer/Flush	14.0 ppg spacer, 14.00 pp	☑	6	Volume	8.00	160.00	1.25	10.00	200.0	19778.7	141.3	
8	Mud	13.8 ppg obm, 13.80 ppg	☑	7	Volume	8.00	160.00	90.40	723.17	14463.3	0.0	19778.7	
9			☐										

Figure 18 : Job data for normal practice cement 3rd trial

And the ECD result is as below:

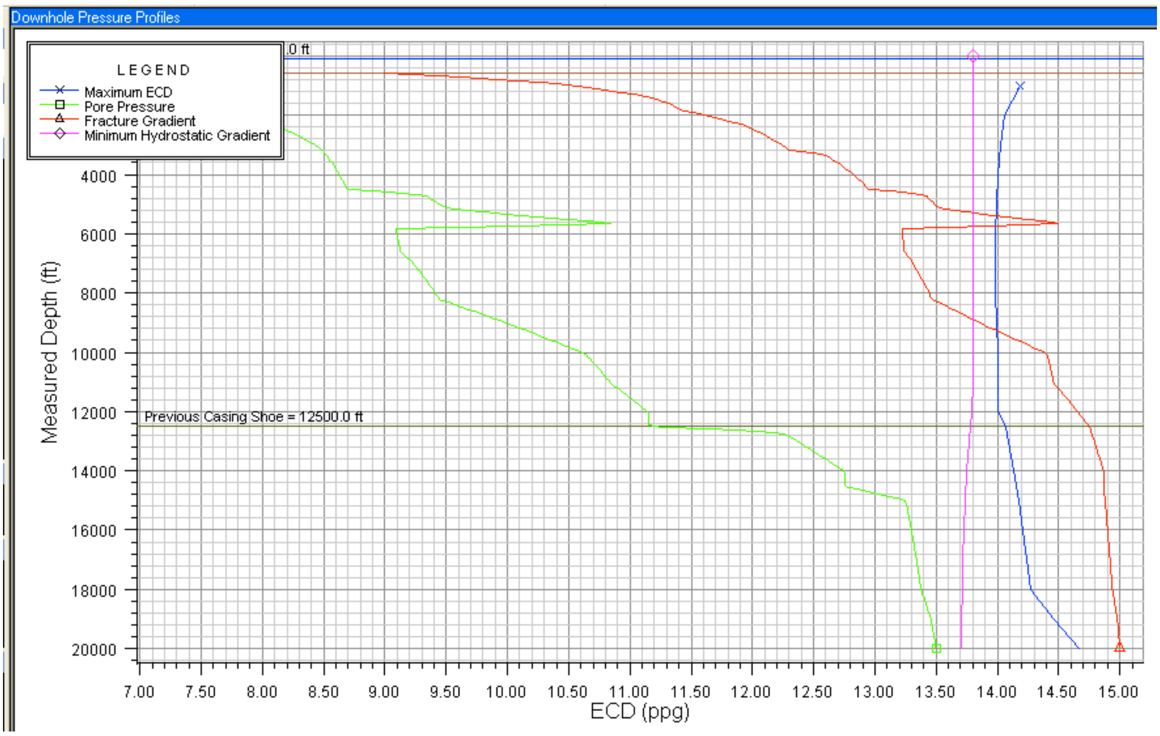


Figure 19 : Down hole pressure profile 3rd trial

From the picture above,the ECD is decreasing and its moving away from fractured line. This result shows a better ECD line if compare to the other two results

Therefore,the best pump rate can be used for the cementing operation for this kind of well is 8bbl/min. As it also shows that the cement data used is the best and optimum.
The next figure represents the fluid positions frame after the animation of how the fluid moves inside casing and out to annulus and their final respective positions after the cement reaches to its designated positions:

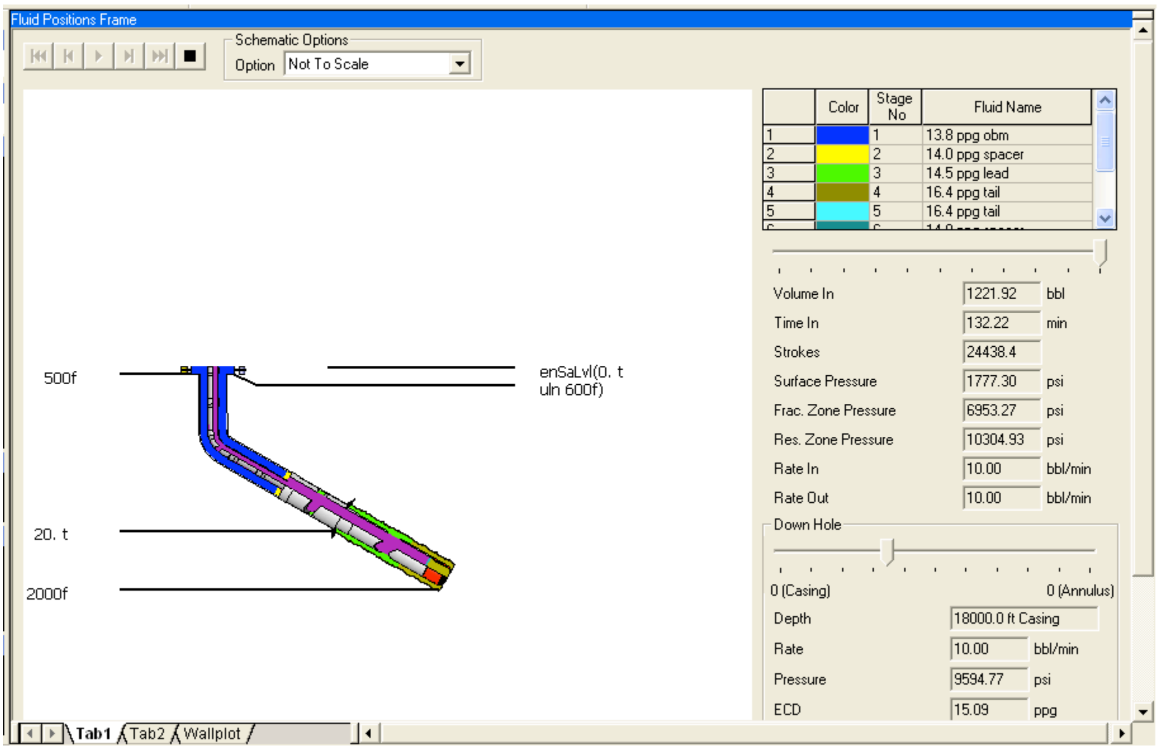


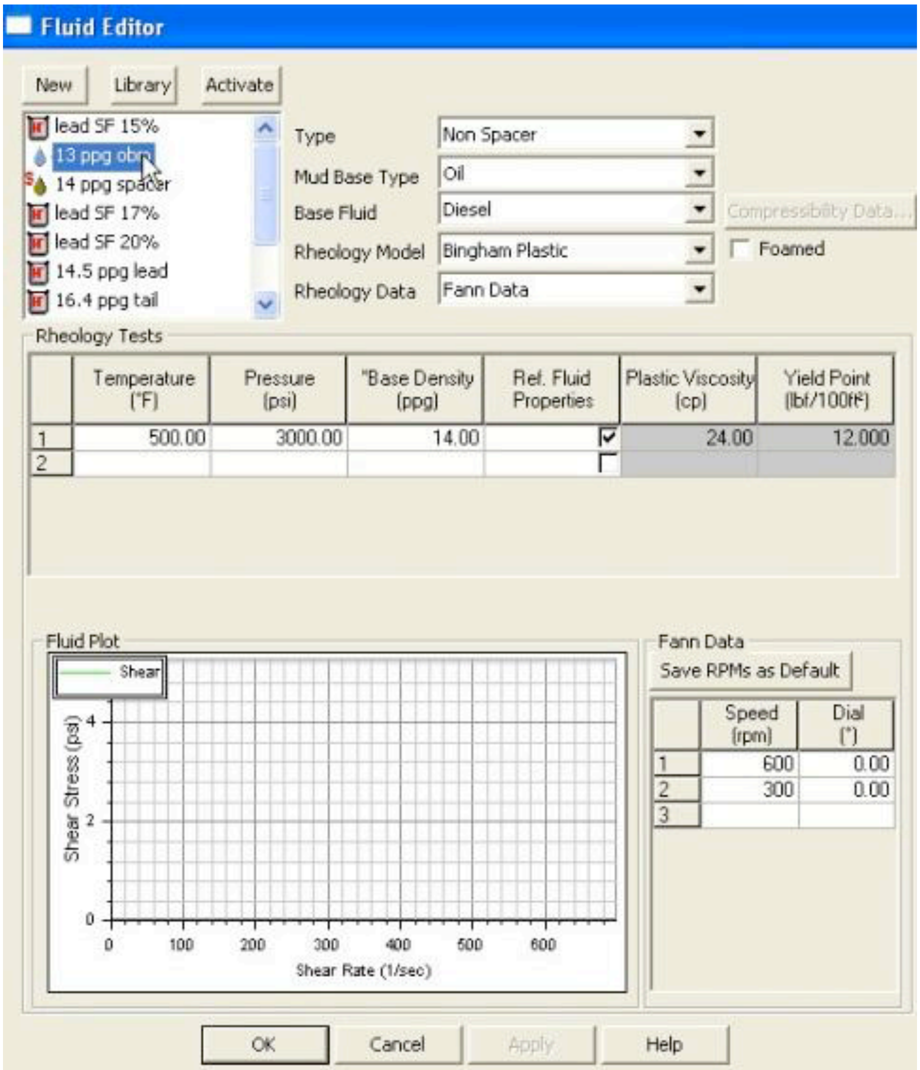
Figure 20 : Fluid animation for 3rd trial of normal practice cement

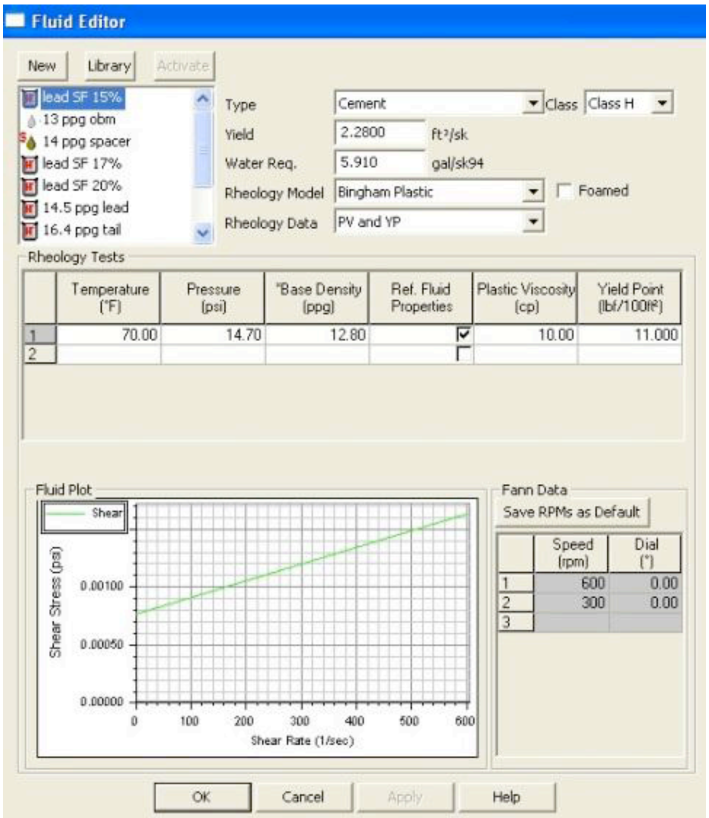
This animation shows the whole condition of the hole after the cement be set at the target area. The blue line indicating the drilling fluid used,followed by spacer,lead and tail.

The effect of Silica fume in cementing design.

In this part, 15 % of silica fume is used in the cement. Several data has been found from experiment that are being used in the analysis.

The main data that needed is to be changed in the software is at JOB DATA section. The fluid used this time has different rheology properties





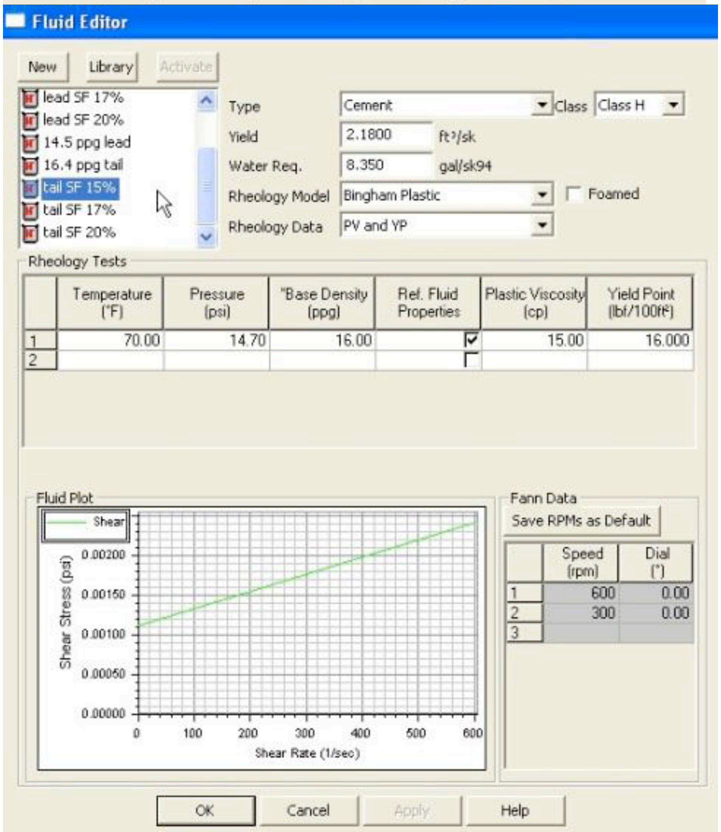
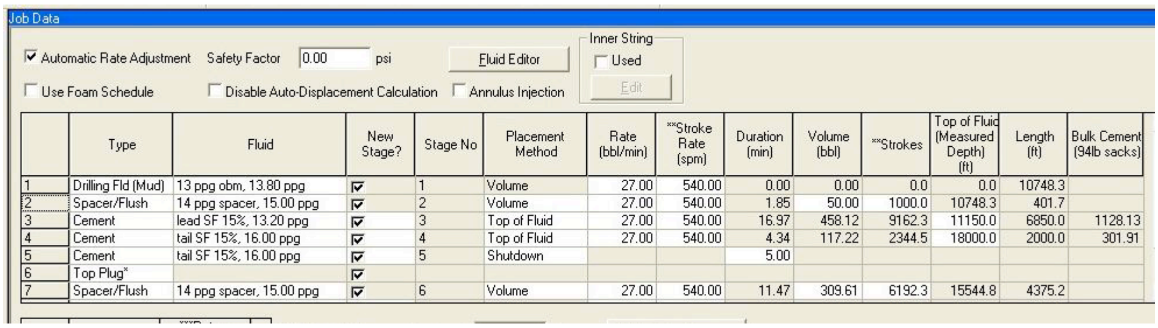


Figure 21 : Fluid data for cement with 15% SF

As all the data is defined in this fluid editor, we can proceed with the job data section.


Job Data

☑ Automatic Rate Adjustment   Safety Factor 0.00 psi   Fluid Editor   Inner String ☐ Used   Edit

☐ Use Foam Schedule   ☐ Disable Auto-Displacement Calculation   ☐ Annulus Injection

	Type	Fluid	New Stage?	Stage No	Placement Method	Rate (bbl/min)	**Stroke Rate (spm)	Duration (min)	Volume (bbl)	**Strokes	Top of Fluid (Measured Depth) (ft)	Length (ft)	Bulk Cement (94lb sacks)
1	Drilling Fld (Mud)	13 ppg obm, 13.80 ppg	☑	1	Volume	27.00	540.00	0.00	0.00	0.0	0.0	10748.3	
2	Spacer/Flush	14 ppg spacer, 15.00 ppg	☑	2	Volume	27.00	540.00	1.85	50.00	1000.0	10748.3	401.7	
3	Cement	lead SF 15%, 13.20 ppg	☑	3	Top of Fluid	27.00	540.00	16.97	458.12	9162.3	11150.0	6850.0	1128.13
4	Cement	tail SF 15%, 16.00 ppg	☑	4	Top of Fluid	27.00	540.00	4.34	117.22	2344.5	18000.0	2000.0	301.91
5	Cement	tail SF 15%, 16.00 ppg	☑	5	Shutdown			5.00					
6	Top Plug*		☑										
7	Spacer/Flush	14 ppg spacer, 15.00 ppg	☑	6	Volume	27.00	540.00	11.47	309.61	6192.3	15544.8	4375.2	

Figure 22 : Job data for cement with 15% SF 1st trial

The flowrate for all the fluids is initially set to be at 27 bbl/min.13.8 ppg drilling mud reaches surface from MD of 10748.3 ft. After that, 401.7 ft of 15 ppg spacer is pumped followed by 6850 ft (length) of 13.2 ppg cement lead. The TOC of cement lead showed by this section is 11150 ft indicating 1350 ft above previous casing shoe (13 5/8" at depth 12500 ft) from the depth of 18000 ft. The 16 ppg cement tail is pumped after cement lead. The TOC is found to be at 18000 ft which means 5500 ft below previous casing shoe.
Other information provided by this section is the amount of lead and tail cement required. As shown by the last column, 1129 sacks of lead cement and 302 sacks of tail cement are predicted.
After we set all the data in Job Data, we are ready to see the plot of pressure profile, where we can see the ECD interference with the fracture gradient. The following pressure profile was obtained from the OptiCem software using the combination of all previous input data: Figure 23

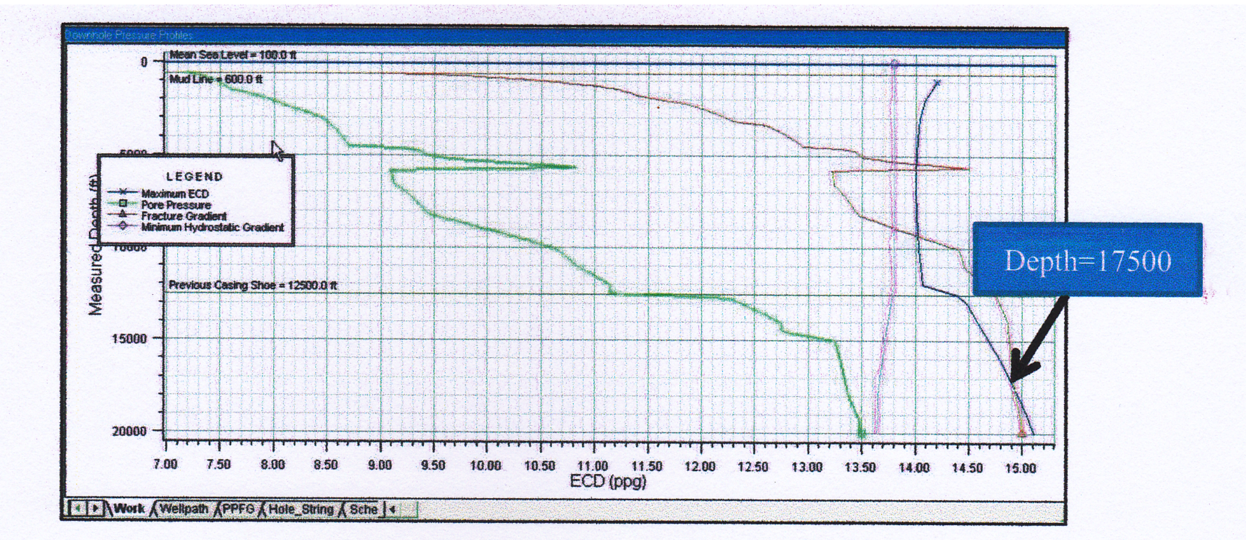


Figure 23 : Down hole pressure profile for !5% SF 1st trial

The blue line representing maximum ECD is founded to exceed the fracture gradient on that bottom of the hole at depth 17500 ft. This will lead to formation damage and next will lead to loss of circulation.
Therefore, some modifications need to be implemented in order to make the ECD line to be within the range. This time, several parameters has been changed in order to see the effect of them.
The modifications to the data made:

- **The spacer weight was decreased from 15 ppg to 14 ppg**
- **The Lead Cement height was decreased from 6850 ft to 5750 ft**
- **Lead Cement weight was decreased from 13.2 ppg to 12.8 ppg**
- **The flowrate was decreased from 27 bbl/min to 10 bbl/min**

Job Data

☑ Automatic Rate Adjustment   Safety Factor 0.00 psi   Fluid Editor   Inner String ☐ Used   Edit

☐ Use Foam Schedule   ☐ Disable Auto-Displacement Calculation   ☐ Annulus Injection

	Type	Fluid	New Stage?	Stage No	Placement Method	Rate (bbl/min)	**Stroke Rate (spm)	Duration (min)	Volume (bbl)	**Strokes	Top of Fluid (Measured Depth) (ft)	Length (ft)	Bulk Cement (94lb sacks)
1	Drilling Fld (Mud)	13 ppg obm, 13.80 ppg	☑	1	Volume	10.00	200.00	0.00	0.00	0.0	0.0	11848.3	
2	Spacer/Flush	14 ppg spacer, 14.00 ppg	☑	2	Volume	10.00	200.00	5.00	50.00	1000.0	11848.3	401.7	
3	Cement	lead SF 15%, 12.80 ppg	☑	3	Top of Fluid	10.00	200.00	32.12	321.19	6423.8	12250.0	5750.0	790.94
4	Cement	tail SF 15%, 16.00 ppg	☑	4	Top of Fluid	10.00	200.00	11.72	117.22	2344.5	18000.0	2000.0	301.91
5	Cement	tail SF 15%, 16.00 ppg	☑	5	Shutdown			5.00					
6	Top Plug*		☑										
7	Spacer/Flush	14 ppg spacer, 14.00 ppg	☑	6	Volume	10.00	200.00	30.96	309.61	6192.3	15544.8	4375.2	

Figure 24 : job data for cement with 15% SF 2nd trial

As shown,the number of cements required also changed. It requires 791 sacks of lead cement and 302 sacks of tail cement which are lesser amount than the one without silica fume.
The downhole pressure profile is viewed again as below:

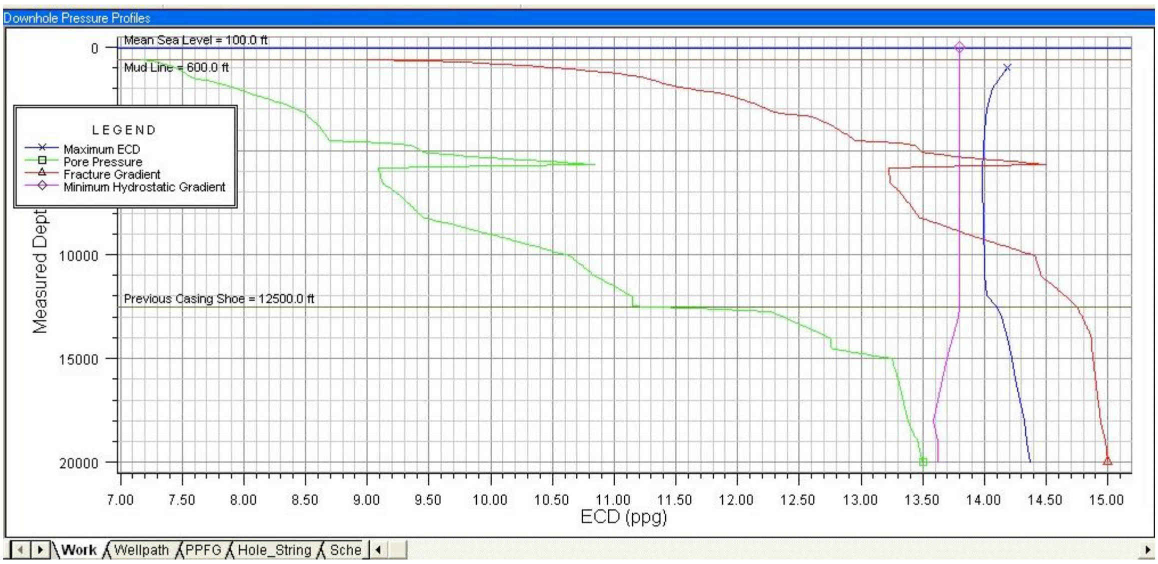


Figure 25 : Down hole pressure profile for 15% SF 2nd trial

The result shown is positive and all the designed parameters are the best and optimum. Here are the summary of the cement design data which is the best and optimum for both cement type,with silica fume and without silica fume.

Analyzed Data For SF 0%

Cement	Plastic Viscosity ,CP	Yield Point,Lb f/100 ft 2	Yield ft 3 / sk	Water Req. gal / sk94	Based Density , PPG	Flow rate ,gpm
Tail	178.3	19.810	1.41	8.35	16.4	8
Lead	39	9.23	1.38	5.91	14.5	8

Table 2 : Analysed data for cement without silica fume

Analyzed Data for SF 15%

Cement	Plastic Viscosity ,CP	Yield Point,Lb f/100 ft 2	Yield ft 3 / sk	Water Req. gal / sk94	Based Density , PPG	Flow rate ,gpm
Tail	15	16	2.18	8.35	16	10
Lead	10	7	2.28	5.91	12.8	10

Table 3 : Analysed data for cement with 15% silica fume

This is the best data for the cementing design for both cement with SF and without SF. Clearly, the cement with silica fume plastic viscosity is way lesser than the one without silica fume. It is good to have lesser viscosity to make things easy in pumping the cement. The flowrate of cement with silica fume shows 10 gpm which is faster than without silica fume. It can help us to reduce the time and cost.

From this simulation also has shown the best data to perform cement with silica fume safely. In fact,all the benefit from using Silica fume can now be achieved.

Chapter 5

Conclusion

Cementing of a HPHT well is an essential part of completion and it influences the future production of the well. Designing proper cement program which is compatible with formation conditions are the key to a successful cementing job. Throughout the research papers that have been discussed, it shows HPHT well condition is really complex and a lot of factors are needed to be considered especially the ECD. However, all of the complexities must be put aside. Number of HPHT wells are now increasing in many areas of the world. Acceptable production from HPHT well needs successful drilling and completion operation. As cementing is one of the drilling and completion activities. It is really important to have a perfect design which is optimum and efficient.

From the first step in preparing this paper which is reviewing literature review as much as possible. It was found really helpful to get better understanding on the condition in HPHT well. HPHT well is really complex to be cemented. It needs a suitable drilling program in order to be safe in term of cost and life. Through this paper / research , it has been successfully proven that landmark software is a very reliable software to be used in order to resolved all this complexities found in HPHT well condition.

This paper / research is focusing on some parameters that can be tuned to have a safe cementing job. HPHT wells has a very narrow and small pore-frac window which makes us difficult to pump any fluid in the hole. The term ECD or Equivalent circulating density is the density that must be looked carefully, and controlled to be in between this pore-frac window when fluid pumping operation is done. Once cement is pumped in the hole, the ECD must not exceed the fracture gradient line and must not be below than pore pressure gradient line. If it exceeds the fracture line ,it means the formation underground will be fractured and this will definitely lead to a loss of circulation. On the other side,if it is below pore pressure, kick might happen. This will then lead to a blowout which can cause damage to all facilities and the biggest loss is the loss of human's life.

The initial results from the OptiCem module of the Landmark software shows us that the higher flowrates lead to a big value of ECD which can eventually break the formation by exceeding the fracture gradients. The following modifications could be made in order to decrease the ECD of the pumped cement during circulation:

a) **Decreasing flow rate (ensure there will be no free fall)**
b) **Decreasing the lead cement height (suitable levels)**
c) **Decrease the lead cement weight to suitable levels**
d) **Decrease tail cement height and weight (if suitable)**
e) **Decrease the spacer weight to suitable levels**

In this project, flowrate is the easiest parameters to be played around. As it can be seen from the result of cement without any Silifa Fume added, the flowrate was changed from 17 bbl/min to 10 bbl/min and lastly it is found that 8 bbl/min is the best flowrate which give a safe circulation condition. However in second case,which silica fume is added, as this paper proved the effect of tuning more parameters such as cement tail and lead density and height as well.

This paper has come out with two sets of data which are for cement without silica fume 0% and cement with 15% silica fume. These data are the optimized data that can be used safely in cementing operation.

Since there is a set of optimized data for silica fume, this paper also suggested that silica fume should be practiced in cementing operation nowadays. It has a lot of advantages as been mention in the discussion part and all of these advantages can be achieved by the assistance of Landmark software.

This paper has met its objectives which is to optimize the slurry design by controlling their respective ECD.

Chapter 6

REFERENCES

1 Ted Littlechild, “Enhanced kick detection, management systems and crew training may be required to maximize safety” [online] Available at http://www.drillingcontractor.org/well-contorl-risks-on-hpht-wells-may-call-for-system-upgrades-11623.

2 Roberto Maglione, SpA, Agip , Giovanni Robotti, Natl, Raffaele Romagnoli, “In-Situ Rheological Characterization of Drilling Mud “ [online] Available at http://www.onepetro.org/mslib/servlet/onepetropreview?id=00066285.

3 Norton J. Lapeyrouse, “ Formulas and Calculation for the Drilling, Production and Workover”.Second Edition ,Nov 27th , 2002.

4 Fisk, J.V., Jamison, D.E., “Physical Properties of Drilling Fluids at High Temperatures and Pressures” [online] Available at http://www.onepetro.org/mslib/servlet/onepetropreview?id=00017200.

5 A. Brandl, E.R. Acorda, D.R. Doherty, V. Rajaneekornkrilas,” Lightweight Cementing Design Improves Zonal Isolation on Challenging High Temperature Offshore Thailand Wells” [online] Available at http://www.onepetro.org/mslib/app/Preview.do?paperNumber=SPE-147012-MS&societyCode=SPE.