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Study on Effectiveness of P4 Propellant in Gravel Pack Clean-out

By

MUHAMMAD NOR HANIF BIN KASAH
10338

Dissertation Submission in
Partial Fulfillment of the Requirements of the
Bachelor of Engineering (Hons)
Petroleum Engineering

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Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan.

CERTIFICATION OF ORIGINALITY

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

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MUHAMMAD NOR HANIF BIN KASAH
10338
PETROLEUM ENGINEERING

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A Project Dissertation Submitted to the
Geoscience & Petroleum Programme
Universiti Teknologi PETRONAS
In Partial Fulfillment of the Requirements of the
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Approved by,

....
(Mr Elias B Abllah)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
APRIL 2011

EXECUTIVE SUMMARY

This report provides an analysis and findings throughout the entire progress towards the completion of the project: **Study on Effectiveness of P4 Propellant in Gravel Pack Clean-out**. It consists of introduction of P4 propellant, case study on conventional gravel pack clean out methods, P4 propellant job design and the case study on well candidate #1. The report finds that the P4 propellant application as gravel pack clean-out method can deliver a promising result and good substitutes for conventional methods since it is much cheaper, safe and simpler operation. Several recommendations were also written in this report;

- Further test should be done to prove the effectiveness of this method.
- For the information regarding the job simulation to be available for further study on the designing the specific job.

ACKNOWLEDGEMENT

I would like to express the deepest appreciation to Universiti Teknologi PETRONAS (UTP), specific to Geosciences & Petroleum Engineering Department. Therefore, thanks to Assoc. Prof. Ir. Abdul Aziz Omar, the Head of Department of Geosciences & Petroleum Engineering, Ms Mazuin Bt Jasamai, Final Year Project II coordinator, for their hard work to ensure the thriving of this subject.

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It is a pleasure to thank those who contribute towards the completion of my case study on P4 Propellant. Especially Mr Ibrahim B. Subari, Baronia field production technologist, Mr Victor Hugo Hamdan, Northern senior reservoir engineers, and Mr Muhammad B. Samsu, Schlumberger engineer for providing the materials needed for the study. I appreciate their support.

A token of appreciation also goes to my parents, family and colleagues for their support and kindness in making this project a success.

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Project Background:

Gravel Pack completion is a verified solution to sand production wells for years but consequently it is also known that by time, sand and fine debris from the formation could stuck inside the completion, resulting loss in production.[7] A conventional method of cleaning the gravel pack are by using treatment fluid such as acid; injected into the wellbore via bullheading or coiled tubing or by pull the completion. These methods can be really expensive and incompatible with well on smaller platform (need working barge to support treatment fluid injection operation).

Post Perforation Propellant Pulse (P4) by Schlumberger is use as substitute to clean out the sand and other solid in gravel pack. When the propellant ignites, it will produce hot gas; a low frequency pulse is generated and vibrates the gravel pack. It is believe that the vibration will caused fine to dislodge. P4 is also conveyable on wireline, thus eliminating the cost of using work barge.[2]

1.2 Problem Statement:

P4 propellant stimulation have been used before in formation fracturing of consolidated formation but never been used as gravel pack clean-out. Consequently, there is no case study/journal to refer to since none has been published. In view of the fact that it is the first application as gravel pack clean-out, it is important to understand the principle of gravel pack design in order to make sure the propellant pressure is not damaging the screens but still sufficient enough to dislodge the sand or debris inside the gravel pack.

Gravel Pack

Gravel packing is a commonly applied technique to control formation sand production from open-hole oil and gas wells.[10] In a gravel pack completion, a screen is placed in the well across the productive interval and specially sized, high permeability gravel pack sand is mixed in a carrier fluid and circulated into the well to fill the annular space between the screen and formation. [8]A carefully design gravel pack will help to enhance wells efficiency and will control the migration of fine formation sand into the wellbore.[9]

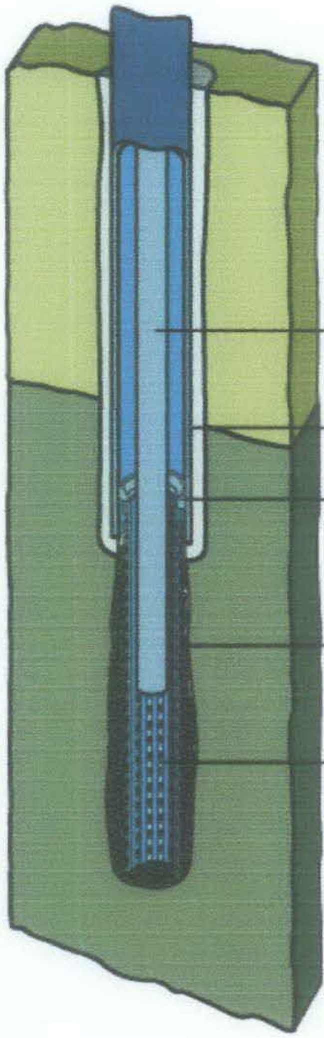


Figure 1: Gravel pack completion in the wellbore.

P4 Propellant Stimulation Description

Propellant is an energetic material that generates a large amount of gas while burning. Post-Perforation Propellant Pulse (P4) use Arcite® 386M as the propellant because of its good safety record and material stability.[2] [1]

Well stimulation using P4 system is much safer because the propellant deflagrates instead of detonating like an explosive (it generate a low frequency pressure pulse that can be sufficient enough to break the formation without damaging the casing).[2]

1.3 Objective and Scope of study:

Objective

To study the effectiveness of P4 propellant job in gravel pack clean-out by come out with a complete case study on three well candidates for the stimulation job.

Scope of study

To have a fully understanding of the idea of using P4 propellant as gravel pack clean-out, a research on the principle of gravel pack design must be done in conjunction to the case study of production loss due to unconsolidated sand formation from the existing journals.

To study on other variation methods of gravel pack clean-out, in order to find out the advantages of using P4 propellant stimulation. The study will be done on the basis of the operation cost, result deliverability and safety value. As of now, three methods have been considered for the study;

i. Using injection of treatment fluid (e.g.: acid)
ii. Re-completion (pull out and replace the gravel pack completion)
iii. Rotary Jetting Head

Analyses of the post job treatment consist of well test data will be collected from two well candidates for the stimulation job. The data will be used to prove the effectiveness of P4 propellant stimulation in gravel pack cleaning. (From the pressure survey data gathered after the jobs done, the latest skin value can be determine). A written report of this project will be produced after all activities have been successfully conducted.

1.4. Relevancy of Study:

Unconsolidated formation had required engineers to put up gravel packing completion in the well's design in order to enhance the well performance. As a result of the fines sand and formation debris migration into the wellbore, the gravel pack will be plugged, resulting poor production performance. For example, in PETRONAS Sarawak operation, a conventional method to clean-out the sand is by injecting a treatment fluid via bullheading. This method required extra cost of renting work barge since most of the platform has a very limited space to accommodate pumps, power pack and other surface equipments required for the operation. In conjunction with the objective, this project will help to identify the effectiveness of P4 propellant stimulation usage with the aim to reduce the operation cost of cleaning the gravel pack as the substitute of the traditional methods

CHAPTER 2

LITERATURE REVIEW

2.1. What is P4 Propellant stimulation?

Post-Perforation Propellant Pulse (P4) system by Schlumberger provides the maximum energy produced to the formation to enhance near-wellbore treatments. It has been widely use in;[2] [1]

- Perforation
  - Clean perforation tunnel from any debris prior to shooting.
- Workover operation
  - Removes fines due to migration.
  - Breakdown and remove up scales.

It is newly applied as a cleaning method for gravel pack completion

2.2. Advantages of P4 Propellant stimulation

Propellant stimulation has been known successful in heavy oil wells, through several well tests. [11] The principle was based on these three main reasons;

1. **Specific Pressure Loading Rate**
   As the propellant burns, it released a pressure which eventually spread into the perforation tunnel, thus clearing the path to a better flow. The pressure released is above the tensile strength of any plugging material in the perforations.[2]

2. **Oil Re-energization**
   Oil in the immediate wellbore area, which may have been degasified due to a pressure drop at the perforations resulting in a higher viscosity oil or 'visco-skin effect', is re-energized by the rapid injection of carbon dioxide and carbon monoxide generated by the propellant.[11] [2]

3. **Low Frequency Pulse**
   Propellant burns generate a low frequency pulse, which is lower than the conventional explosive (lower frequencies travel greater distance before attenuating). The pressure pulse that travels through the formation will concern and breaking down sand arches. The same effect has been observed through the result of an earthquake which shown stimulating effect on well production.[13]

To recognize the advantage of P4 propellant stimulation usage in cleaning out the gravel pack; a study on other cleaning out methods such as fluid treatment and re-completion is needed.

Fluid treatment

Gravel pack will get plug by fines damage composed of either quartz particles (silica), silicates and alumino-silicates (clays and feldspars) or, more commonly, a combination of these. Thus engineers preferred to use a method of cleaning using acid, (e.g.: Hydrogen Fluoride) to overcome this problem. The treatment fluid is also known as "mud acid". The use of such acid systems is to dissolve silica, silicates and alumino-silicates. There are some concerns regarding the gravel pack cleaning out method using fluid treatment; [7]

i. During a Hydrogen Fluoride treatment, the particles that need to be removed can release significant amount of precipitates and cause more damage than is removed by the treatment.
ii. The result of the application in the unconsolidated formation may weaken the zone, thus making the fines problem much worse.

There are two ways on how to inject the treatment fluid inside the wellbore; by using bullheading methods or coiled tubing.

1. **Bullheading**

   Treatment fluid is pump directly down the production tubing. It is the easiest method to inject fluid into the wellbore but there is a risk it will be ineffective because of poor placement of treatment fluid and the corrosion dangers associated with pumping corrosive fluids down the production tubular. To overcome this inefficient bullhead placement issue, high fluid treatment volumes are often used, creating a costly design and the risk of over treating one section of the gravel pack while possibly under treating other sections. [7]

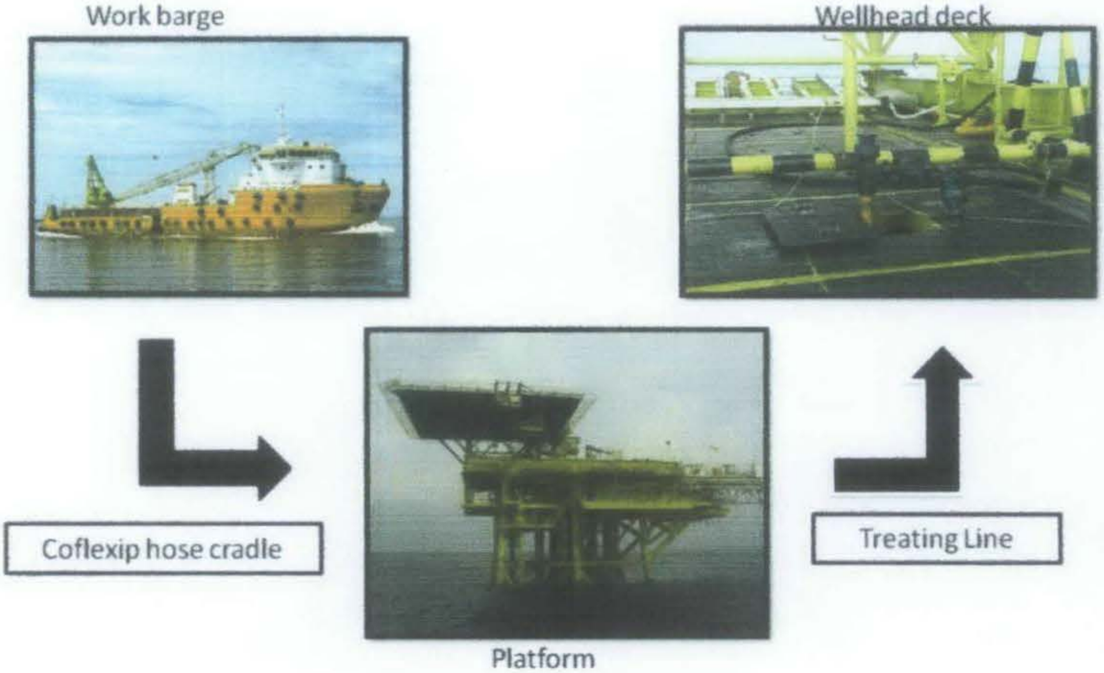


Figure 2: Example on the standard fluid injection operation flow via bullheading. (The treatment fluid will be pump from the work barge through the coflexip hose cradle and onto the platform before it enters the treating line on the wellhead.

2. Coiled Tubing

Treatment fluid is pump through the coiled tubing to selectively place. The placement efficiencies with coil tubing often allow reduced treatment fluid volumes, which can reduce the job cost and because of the fluid will be contained inside the coiled tubing that is initially put inside the production tubing, the risk of damaging the tubular is greatly reduced. Coiled tubing can be moved to different depth during the treatment so that the treatment fluids can be placed where they are needed. [7]However coiled tubing method is more expensive than bullheading because of extra equipment required.

Figure 3: The coiled tubing unit (The treatment fluid are pumped through the coiled tubing to exit open-ended, a wash nozzle or a rotating jetting head)

Workover

Another method to clean the gravel pack is to replace it with the new one by pulling the completion. It is necessary to first kill the well with salt water, drilling mud, oil or special workover fluid, which has sufficient hydrostatic pressure to counteract the formation pressure when the hole is filled with the fluid. Because of this method involves killing the well thus, it is very risky and only to be considered by engineers as the last option.

Figure 4: Offshore Workover rig.

By comparing P4 propellant stimulation with these two gravel pack cleaning out methods, such as fluid treatment and re-completion, this stimulation offers many advantages;

- **Safer operation**
  Propellant is considered as non-explosive material. [2][15]Whilst, in the method of using a fluid treatment is very dangerous as it involve the usage of highly concentrated acid in a large volume.

- **Wireline conveyable**
  Contrast with the other methods, by using P4 propellant stimulation method, the need to hire the work barge to support the operation is eliminated, thus will greatly reduce the overall operation cost.[2]

- **Shorter operation time duration per well**

  Due to the simplicity and straight-forward operation procedures, the time duration needed to complete the whole operation will be shorter than other methods.

2.3. P4 Propellant Downhole Tool Configuration

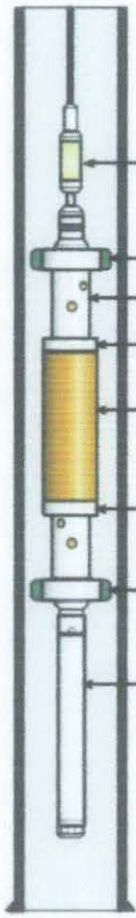
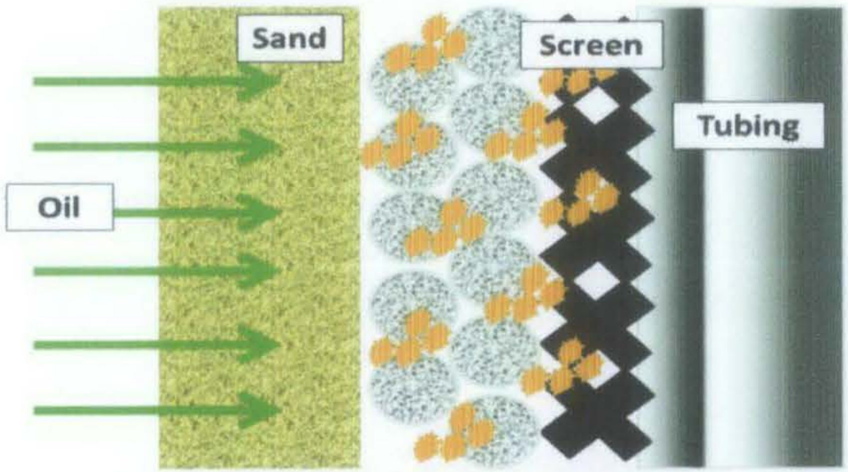


Figure 5: Standard P4 Propellant Downhole Tool Configuration.[1]

- **Electric Line Shooting Collar** is used to apply power to detonate a low explosive in the setting tool. The gas pressure created by the deflagrating low explosive exerts a large force on a piston holding back oil. The pneumatic pressure of the piston pushes the oil, which hydraulically separates the setting tool from the plug or packer. After that, the downhole completion is now set in place.

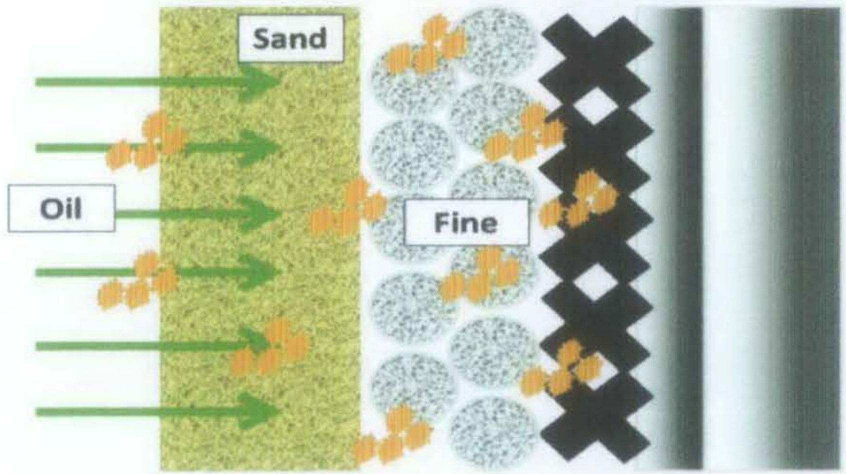
- **Centralizer Tandem** helps to centralize the tool inside the borehole or between the casing walls.
- **Scalloped Perforating Gun** is a perforating gun with a recess profile in the perforating gun body adjacent to the shaped charge. The scallop profile reduces the external burrs created as the perforating jet exits the gun body, thereby reducing the risk of hang-up or damage as the gun assembly is retrieved.
- **Propellant Sleeve** is a hollow tube of propellant that is positioned outside of a standard perforating gun and held into place by retaining rings.

2.4. P4 propellant stimulation at gravel pack



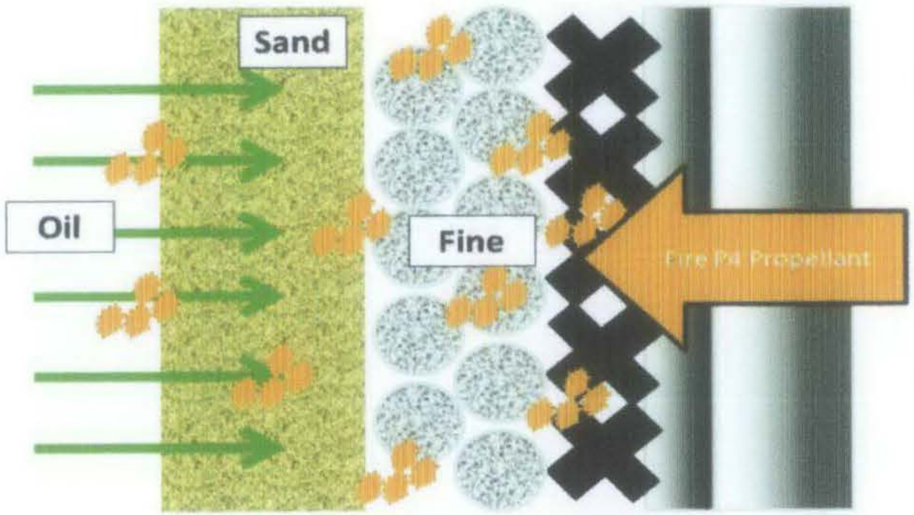
1

During production, the oil will flow with debris, fine and sand from the perforation zone



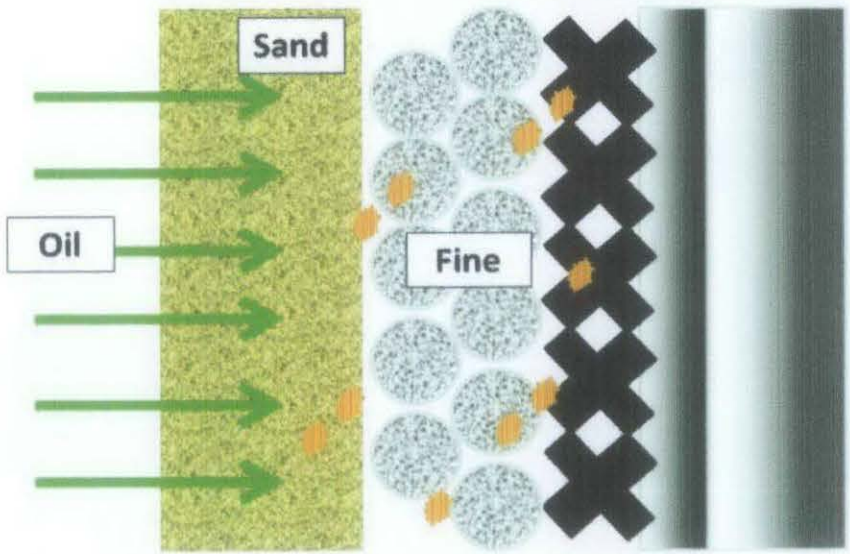
2

At one time, the fine will create a bridge/ arc that plug the screen and the gravel pack. This is where the start of production decrease in one well



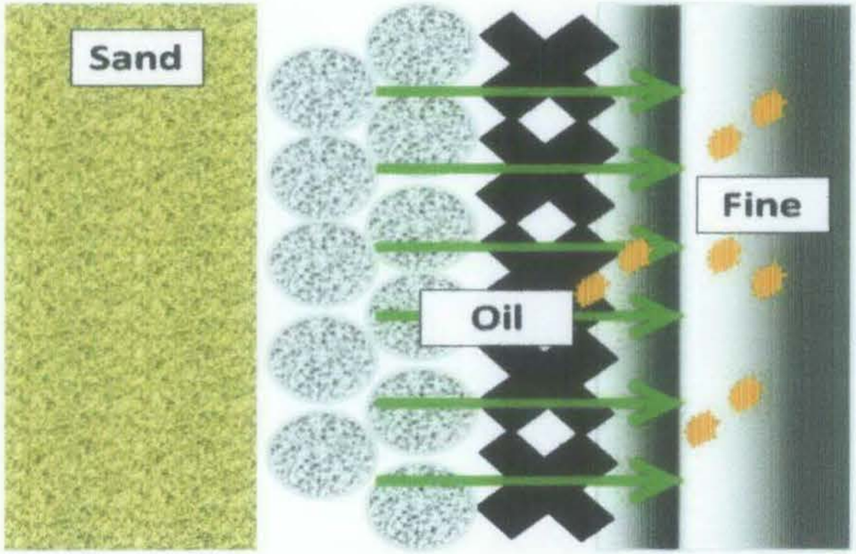
3

As the P4 fire and propellant burns which produce a hot gas, a low frequency pulse is generated and vibrates the gravel.



4

The fine that plug the screen and the gravel pack will be dislodge and cause the porosity of the gravel to become as usual again.



5

Oil can flow again and production of the well increases.

2.6. How does P4 Propellant work?

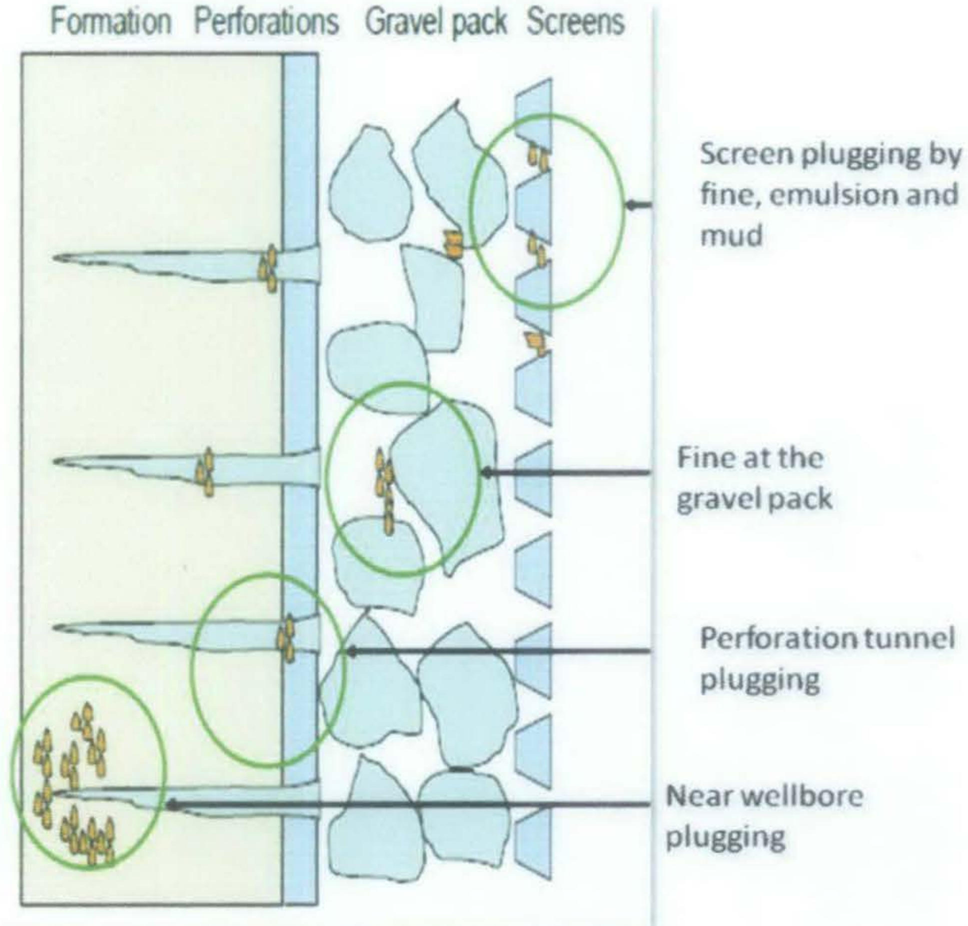


Figure 6: Example of poor permeability scenario in gravel pack formation.[15]

Propellants are positioned over the zone-of-interest and ignited. Gases generated by the deflagration exert a pressure load on the formation that is less than the compressive yield strength of the formation rock. As burn pressure increases, short fractures are created in the formation. Fracture growth is maintained by continued gas generation from the tool burn. Once the tool is spent, differential pressure creates a surge into the wellbore, backflushing the near-wellbore region. In gravel pack clean-out, a low frequency pulse is generated and vibrates the gravel pack. It is believe that the vibration will caused fine to dislodge, and differential pressure between the wellbore and the formation will help to remove the fines and sand into the wellbore and filtered on the surface.

CHAPTER 3.1.: REPORT ON COMPARISON BETWEEN P4 PROPELLANT AND ROTARY JETTING HEAD IN GRAVEL PACK CLEAN OUT APPLICATION.

3.1.1. P4 Propellant Overview

P4 Propellant stimulation system by Schlumberger used the solid energetic material (propellant) to increase productivity and injectivity.[1] For the period of the combustion progression the propellant generates a significant amount of gas which amplifies the pressure in the well.

The chemical effect from the gas product generated, dissolved into the water and form an acidic fluid that reacts with the formation rock similar to the usual acidizing job.[12]

While the pressure builds up by the propellant gases, it spread along the length of the well and reflects from wellhead, bottom of the well or packers and overlay to the oncoming pressure waves. This creates pressure oscillations of low frequency wave which is of assistance in removing pore plugging near the well.[11]

3.1.2. Rotating Jetting Head Overview

The gravel pack cleaning method involving the use of rotating jetting head [7]that said will create specific pressure pulsations combined with angled nozzles to create a "circulation current" within the gravel pack.

It is believed that the process (circulation current) will result in temporary increase in gravel pack permeability to allow the treatment fluid to respond more efficiently in the applied area.

3.1.3. Efficiency

The P4 Propellant simulation in gravel pack clean out application efficiency has already been present in the report before. (Refer to Case Study section)

The effectiveness of the Rotating Jetting Head application in gravel pack cleaning out method has been proven in a test presented in paper by Doug Brunskill, SPE, Bj Services Company by the title of Gravel Pack Cleaning: A New Solution (SPE 81736).

Below are the extracted information's from the above mentioned paper.

Rotating nozzles with a forward component promised a better result in placing the treatment fluid and remove the insoluble fines due to the circulation currents created which vibrate the gravel pack.

Test 1

- **Nozzle – 4x0.5" tangential wash nozzle**
- 4" Base pipe o.o12" gap wire wound screen
- 20/40 ceramic – clean gravel pack
- Rotational speed – 0 rpm

There is no damage in gravel pack nevertheless the efficiency of treatment fluid was very low at 12-20 gl/ft. There is no vibration to the proppant observed.

Test 4

- **Nozzle – R-J R45C**
- 4" Base pipe 0.012" gap wire wound screen
- 20/40 Ottawa sand – clean gravel pack
- 6" I.D. acrylic casing
- Rotational Speed – 400 rpm

There is an increased in treatment fluid efficiency (7 gl/ft) and fines removal. It is observed that the proppant was vibrating and this may resulting in helping the process of removing the insoluble fines.

As a result, it is substantiate that by placing the treatment fluid via rotating jetting head allow longer respond time for the treatment fluid in the gravel pack earlier than it can be flushed out before it can damage the proppant.

3.1.4. Conclusion

The rotating jetting head methods can be run via coiled tubing, which is known to cost more than wireline operation. But it is claimed, that with the rate of efficiency achieved by this method, the operational cost could be minimized by optimizing the amount of treatment fluid to be used. Nevertheless, P4 propellant stimulation has yet to be confirmed for the application in the field testing, thus it is not conclude that this method is the best solution for gravel pack cleaning. However from the first well candidate (Refer to Case Study section) well test data result, it has the prospect of being employ again in the near future.

CHAPTER 3.2.: CASE STUDY: WELL CANDIDATE #1

The case study for well candidate #1 was done using the information extracted from "Bokor Project Propellant Post Job Review" [14] and Locked-in Potential Reactivation Propellant Stimulation [15].

3.2.1. Well History

Well candidate #1 was completed as a dual string (long string & short string) producer in April 1983 with the initial rate of 600 bopd with 0% water cut and flowed through the long string from the bottom zone (R1.0/R2.0/R3.0).

3.2.2. Problem Statement

The production then declined to 400 bopd dry oil by 1987. An acid stimulation job was performed in December 1987 and successfully increased the production to 2100 bopd with 0% water cut. In 1990 the well was observed with 12% water cut. After then, a sharp decline in production aligned with escalating percentage of water cut was observed and gas lifting was employed. By the end of 2002, the rate was only 250 bopd with 45% water cut. Following the problem, a second acid stimulation job was performed and only increased the production to 340 bopd but short lived. The well then was shut-in and considered as an idle well.

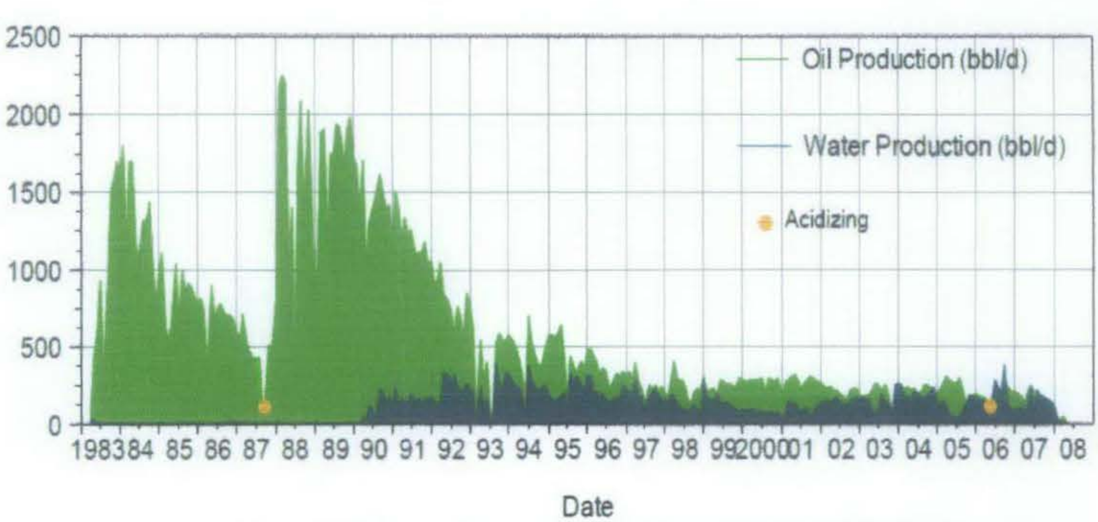


Figure 7: Production Performance History of Well Candidate #1.

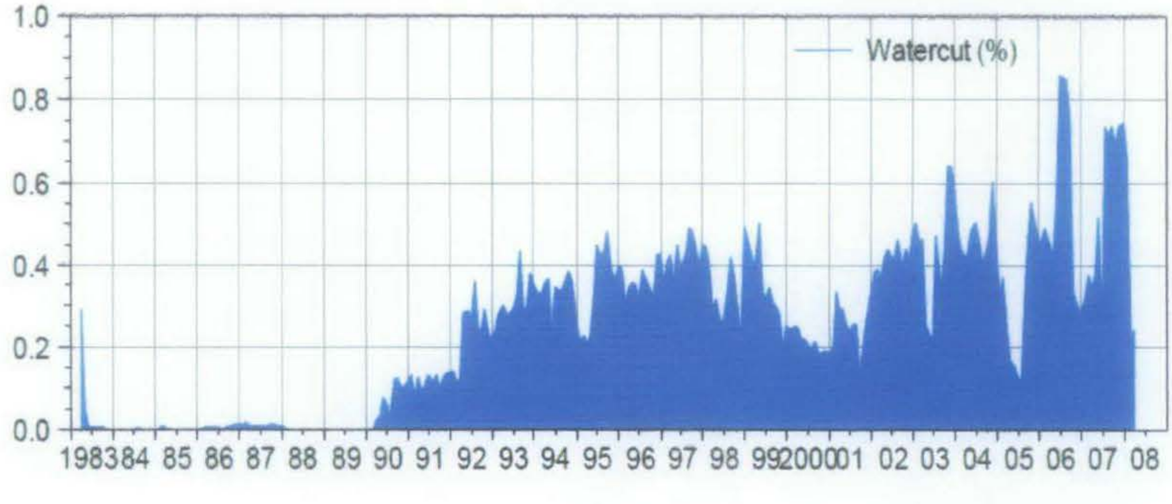


Figure 8: Water cut History of Well Candidate #1.

3.2.3. Proposed Solution

The FBUS (Flowing Build-up Survey) was conducted in July 2008, and the result have shown a skin value of +83, thus confirming the production decrease due to the skin across the poor permeability near wellbore area and the gravel pack by fine or solid movement during production along the water influx. This idle well can be reactivating by executing a stimulation job. It is expected to produce at 400 bpd gross liquid with 120 bopd net oil and 70% water cut, assuming 50% current skin removal. Propellant stimulation was selected over acid stimulation considering it is more cost effective. Logistically, propellant stimulation operation is much simpler because it eliminates the need for work barge. This technology application is new to this region and it was the first time application at gravel pack completion.

Zone	Reservoir Pressure (psi)	Skin	API	GOR	Water cut	Tubing Head Pressure (psi)	Perforation Length (ft)
R1.0/2.0/3.0	**1400**	**+83**	**19**	**300**	**73%**	**75**	**52**

Table 1: Parameter Used For Nodal Analysis.

3.2.4. Interval of Interest

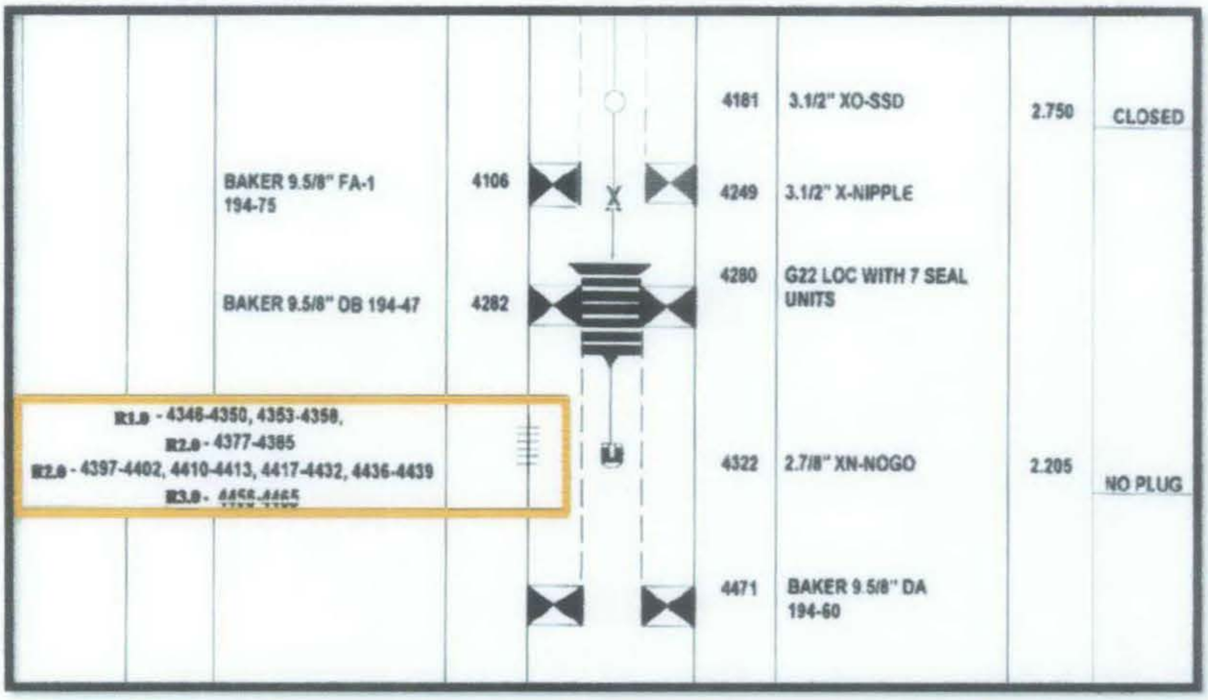


Figure 11: Extracted from the wellbore diagram of well candidate #1.

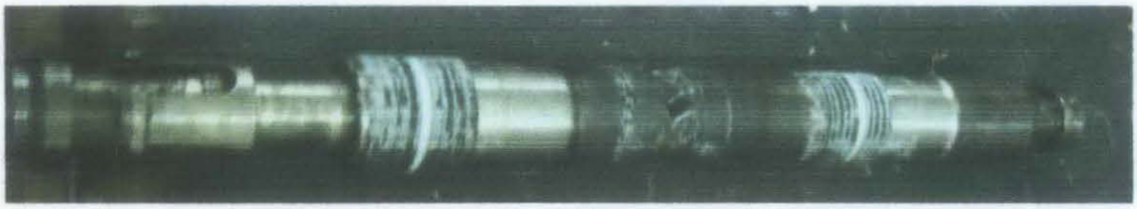
3.2.5. Job Execution

The job was successfully executed in August 2009, with the duration of 6 days compared to acid stimulation job that usually take about 14 days to complete.

3.2.6. Result

After the job completed on August 2009, the well flow for a day before close-in again. To follow-up this event, an investigation had been done. Based on the first observation, the reason on why the well was unable to flow was because of the gas lift valve mechanical failure. Thus a well intervention was conducted to retrieve the gas lift valves.

Gas Lift Valve Inspection Findings



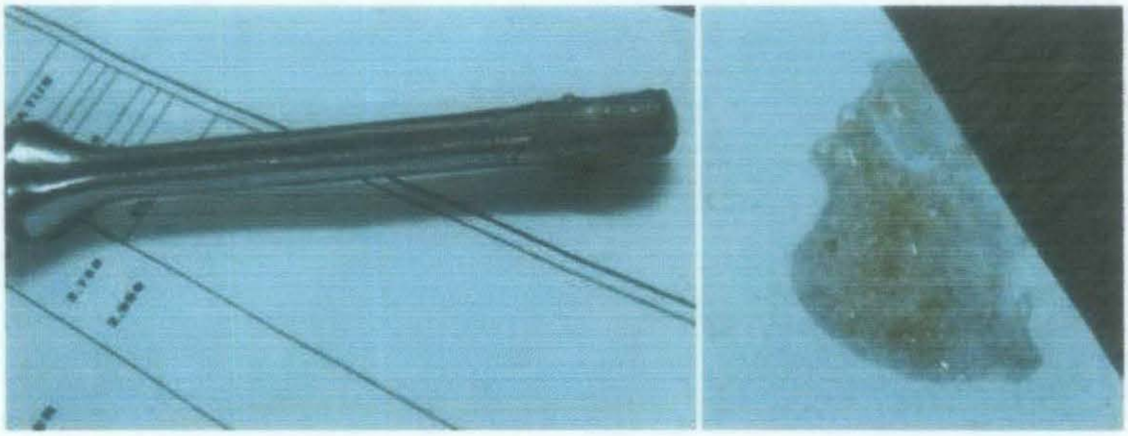
Physical Inspection

a) No major wear or damage on the surface of the valve.
b) Gas lift valve ports were clear of debris.
c) Packers were slightly worn. (Expected)

Tail Plug

a) Not secured/slightly loose.
b) Suspected entry of pressure from well into the valve.

Dome



a) The Domes was succesfully hold pressure.
b) Check valve was in good condition and free of debris.
c) After depressurised, there were traces of crude oil (Not common; Should only contain hydraulic fluid)

Gas lift valve changes was then done on October 2009 to replace the used valve. The well currently flowing with 149 barrel oil per day (last production report taken on 10 December 2009).

	Before	After
Gross production (bbl/d)	117	330
Water cut (%)	70	55
Net oil (bopd)	35	149

Table 2: Comparison result before and after the project.

3.2.7. Conclusions

Indication of succesfully P4 propellant stimulation job;

a) Short period of flow after P4 propellant ignites.
b) Well currently producing with higher tubing head pressure (180 psig) than expected (100psig).

c) Gradual reduction percentage of water cut since it was kicked off.

d) High increase in gross production.

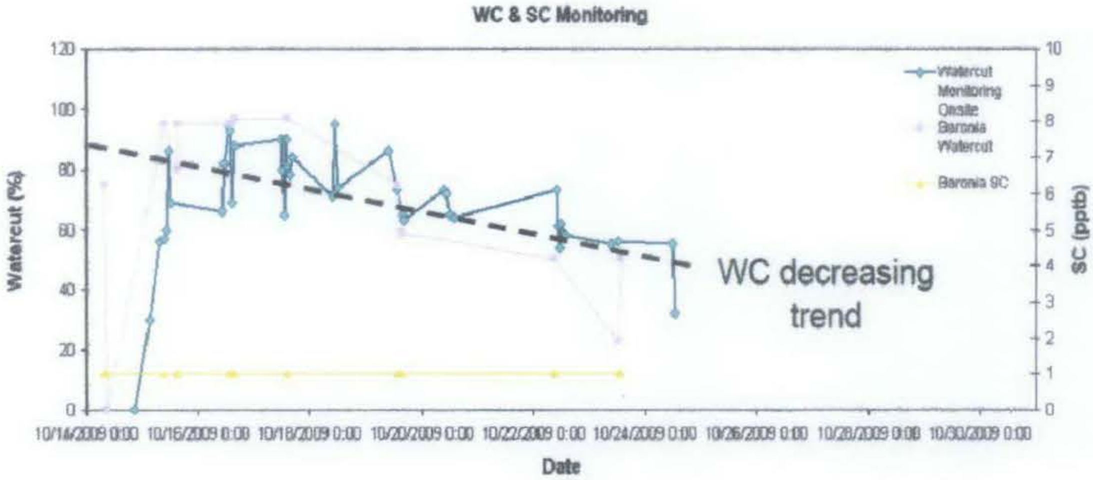


Figure 12: Well Candidate #1 Water cut monitoring graph.

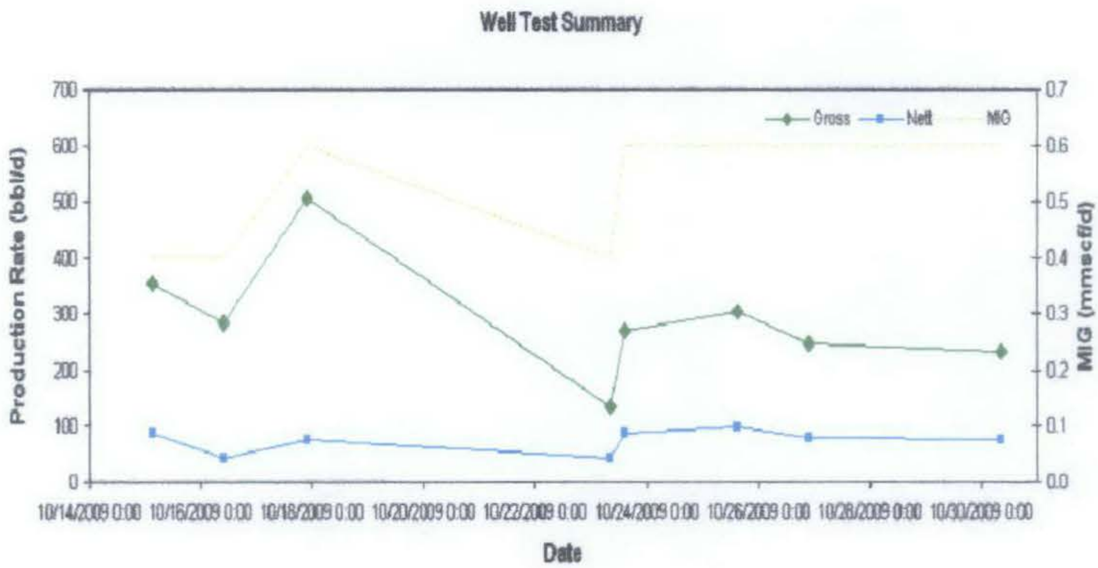


Figure 13: Well Candidate #1 well test summary graph.

3.2.8. Discussion

Referring to the case study, it is too early to conclude the effectiveness of P4 propellant stimulation in gravel pack completion since there are needs to gather more well test data such as; Flowing Build-up Survey (FBUS) to rectify the current skin in the interval. Upon the success of this job, another two well candidates was confirmed for P4 propellant stimulation in gravel pack completion.

CHAPTER 4
METHODOLOGY

4.1. PROJECT GANTT CHART

No	Details	Week 1	2	3	4	5	6	7		8	9	10	11	12	13
1	Study on Pressure Build-up survey analysis	■	■	■					MID SEMESTER BREAK						
2	Research on new technology to clean-out gravel pack completion			■	■	■									
3	Report on comparison between different gravel pack clean-out methods					■	■	■							
4	Preparation of Progress Report							■		■					
	Progress Report Submission									●					
5	Analysis on pressure build-up survey data										■	■			
6	Final report preparation												■	■	■
	Final report submission														●
7	Preparation on final presentation													■	■

● Suggestion milestone ■ Process

Figure 14: Gantt chart.

4.2. PROJECT FLOW CHART

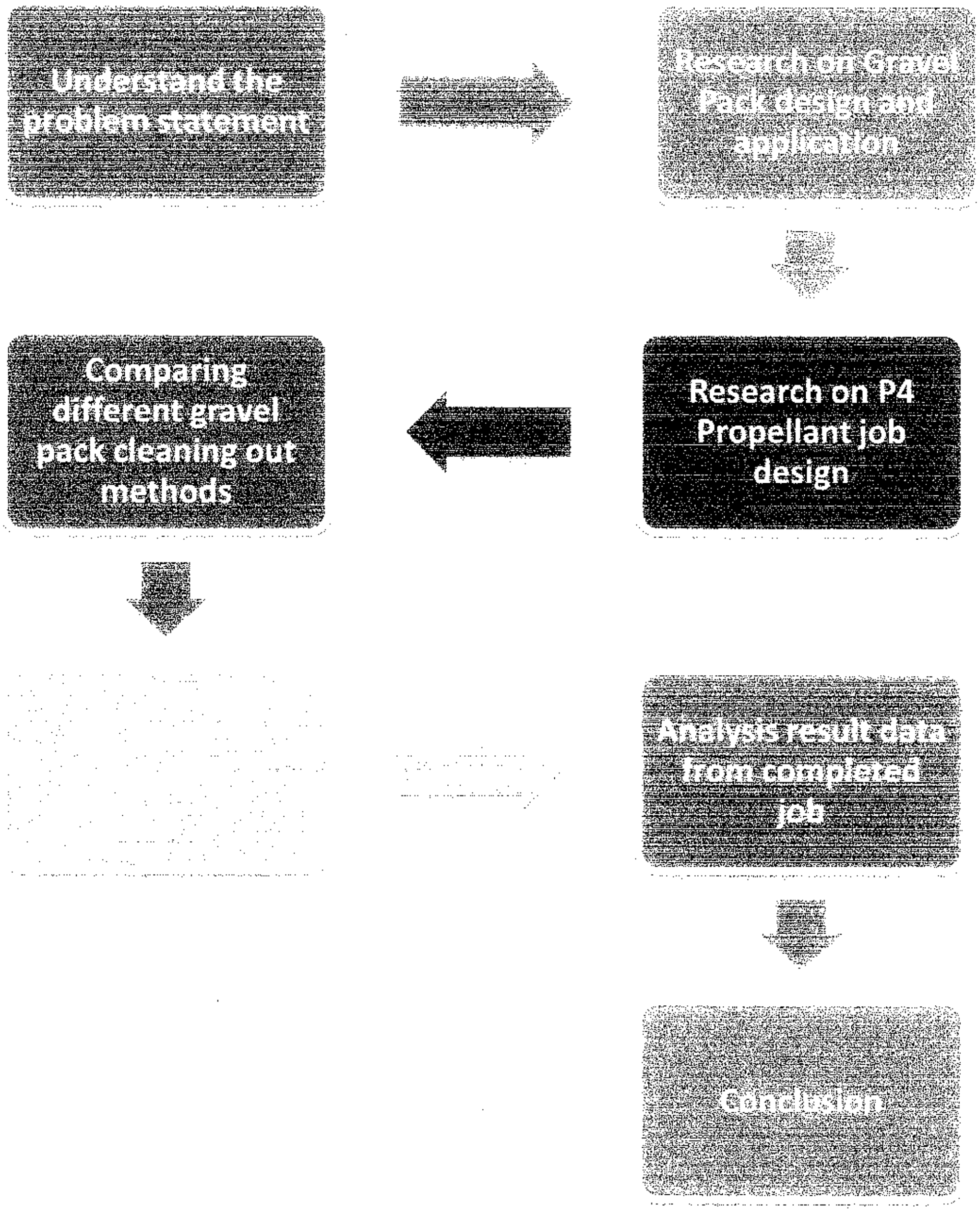


Figure 15: Project Flow Chart

CHAPTER 5
CONCLUSION

The usage of gravel pack completion is proven to reduce the sand production thus it is very common to find a well with the completion. Consequently, it is essential to find a better cleaning out method to sustain the maximum production while maintaining the optimum cost. The P4 propellant stimulation is yet to be recognized as one of cheapest and most reliable methods in cleaning out the gravel pack. However, this method steadfastness will be confirmed after the execution of all the well candidates and the follow-up well test.

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