# Effect of Drag Reducing Agent on Water injection Well

by

Lim Win Shen

Dissertation submitted in partial fulfillment of
the requirement for the
Bachelor of Engineering (Hons)
(Petroleum Engineering)

SEPTEMBER 2012

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

# CERTIFICATION OF APPROVAL

# Effect of Drag Reducing Agent on Water Injection Well

by

Lim Win Shen

A project dissertation submitted to the
Petroleum Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(PETROLEUM ENGINEERING)

Approved by,

_______________________

(Nur Fitri bin Ismail)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
September 2012

# 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.

____________________________________

LIM WIN SHEN

**Table of Contents**

# CONTENTS

**List of Figures**

**List of Tables**

## Abstract

Drag reducing agents (DRA) has been used to inject the produced water into the producing reservoir and to inject produced water into an abandoned reservoir or aquifer. By introducing DRA into water injection well, the differential pressure drop in the water injection tubing is reduced thereby increasing water injection capacity. However, DRA is also suspected to bring about some damage on the reservoir and there are very less study being conducted to look into the effect of DRA on the formation, especially the near wellbore zone. This project will be looking more into the matter by evaluating the effect of commercial drag reducing agents on water injection well. This project will utilize the coreflooding technique and low range of core permeability around 30md and below will be used. The test will be conducted at standard temperature using a polymer type DRA.A fix concentration of 50ppm will be used for the DRA and the solution is to be mechanically degraded under high shear rates before injected into the core to simulate field situation. Different injection rate which will be 1cc/min and 5 cc/min and commercial drag reducing agents will be used to test their relationship with reduced permeability. Reverse flow will be conducted to restore the permeability.

# 1.0 INTRODUCTION

## 1.1 Background Study

Primary recovery utilizes the natural energy of the reservoir itself to produce hydrocarbon from the wellbore in the early stage of oil field's production life. The natural energy utilize in primary recovery will slowly reduce and deplete as time goes by. Secondary recovery will then be introduced to continue produce the well. Several methods of enhanced oil recovery are available including water flooding and water injection technique. DRA is usually used in assisting both of the techniques. DRA is also known as flow improver which constitutes of long chain polymer chemical used in non-potable water pipelines and crude oil. Drag reduction is a reduction in the pressure drop over some length of a pipeline when traces of high molecular weight substance are dissolved in the pipeline fluid. DRA reduces the loss of energy due to friction as fluid travels through the pipeline. Significant pressure drop can be achieved, therefore increasing the volume of oil transported. Good drag or friction reduction performance can be achieved if the drag reducing agent is well dispersed which leads to optimal dissolution in the pipeline fluid. Good drag reduction performance also depends on the molecular weight and concentration of the DRA itself: The higher the concentration or molecular weight of the DRA the greater the drag reduction performance that may be achieved.

D.Mowla and A.Naderi, (2008), had their work on "Experimental Investigation of Drag Reduction in Annular Two-Phase Flow of Oil and Air" published. One of the experiments shows result on how the concentration affects the performance of drag reduction. Polyalphaolefin (polyisobutylene) is selected to be used as the DRA for the experiment. The end of the experiment results in increase of drag reduction percentage when the polymer concentration increases. However, when the critical concentration is reached, any further increase in the polymer concentration will not increase the drag reduction. It is also found that the optimum concentration of polyisobutylene is 18ppm irrespective of any diameter or type of pipe used in the system.

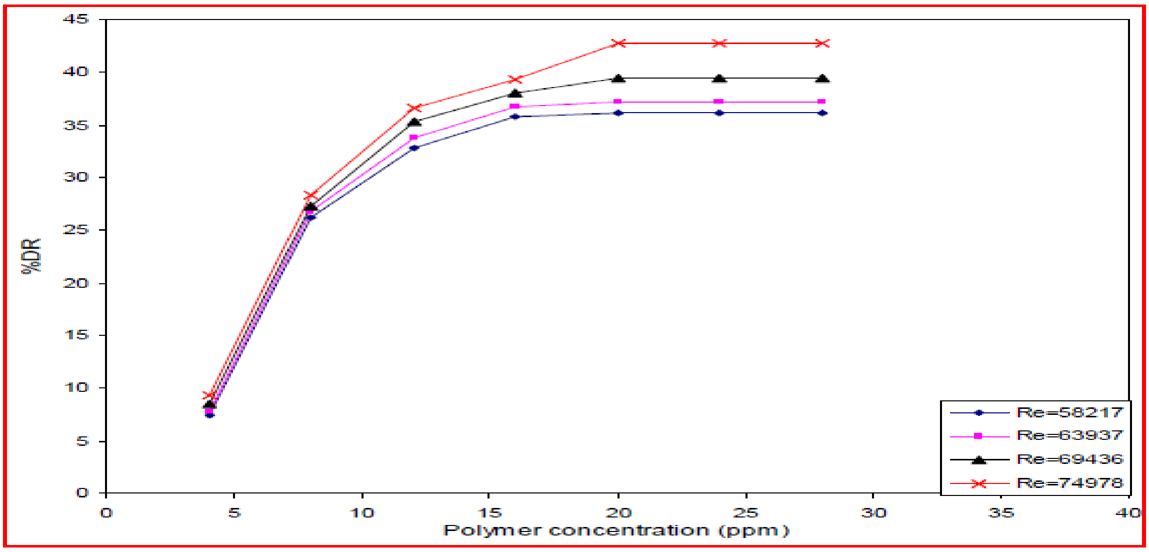

**Figure 1.0 : Variation of % DR versus DRA concentration for annular flow**

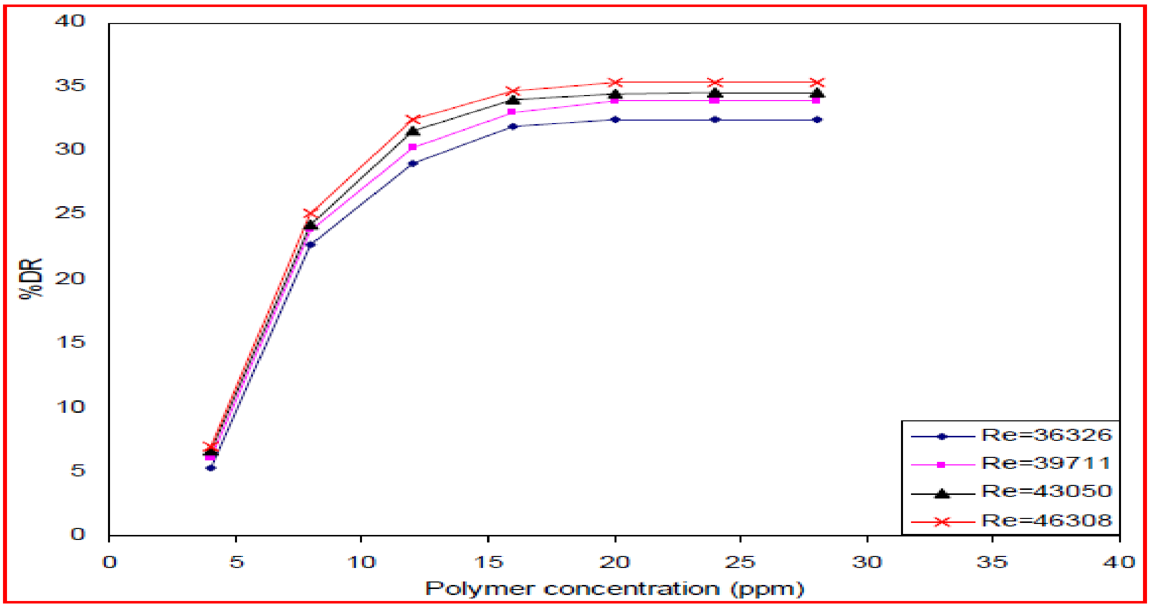

**Figure 2.0 : Variation of % DR versus DRA concentration for annular flow**

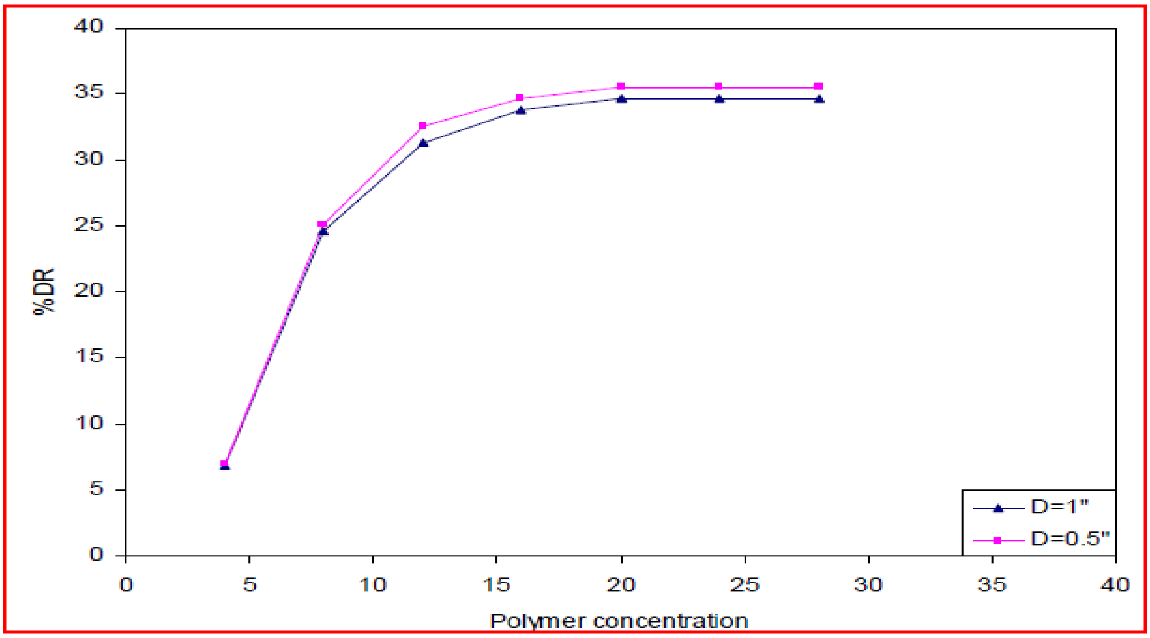

**Figure 3.0 : Variation of %DR versus DRA concentration**

Among the benefits of DRA application in an oilfield are as follow:

1) Increase rate of water injection
2) Increase rate of oil production
3) Increase of field production life
4) Energy saving
5) Increase in pipeline throughput

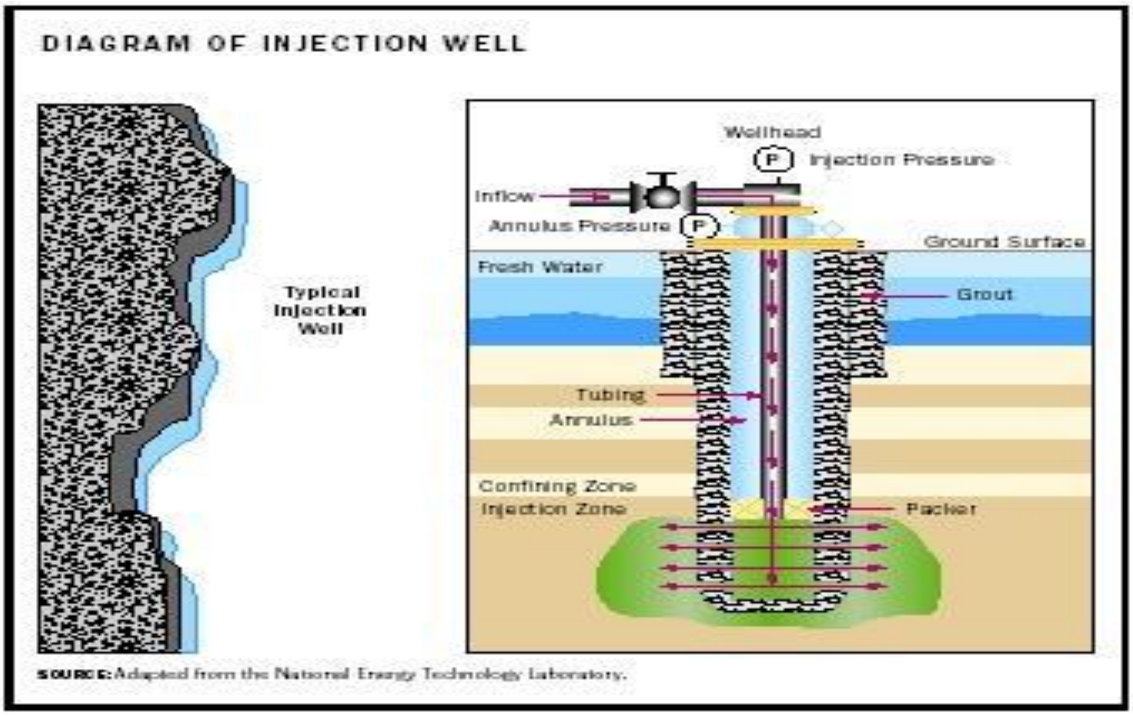
DIAGRAM OF INJECTION WELL

**SOURCE:** Adapted from the National Energy Technology Laboratory.

**Figure 4.0:Overview of Water Injection Well**

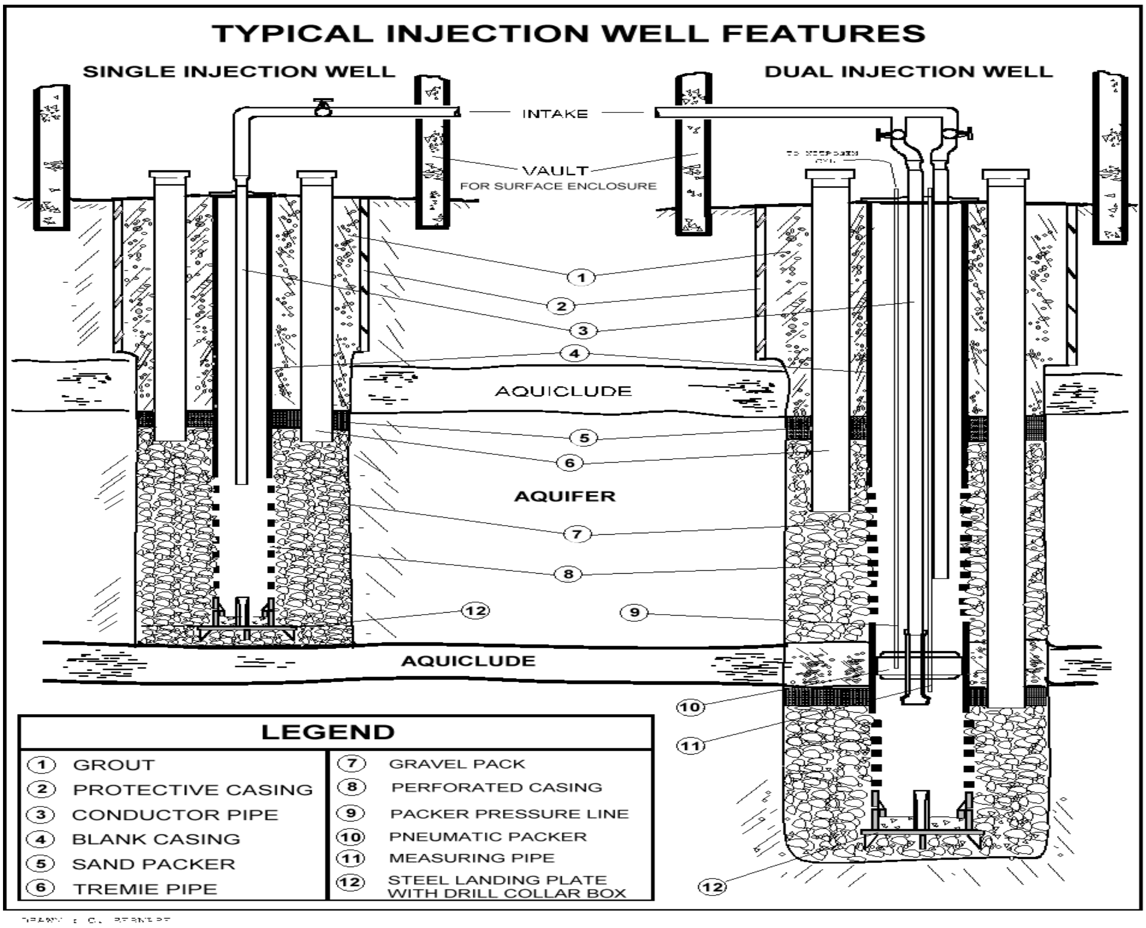

**Figure 5.0: Injection Well Features**

## 1.2 PROBLEM STATEMENT

Despite many studies conducted on DRA, there are very less focus given on the effects of DRA on the formation or wellbore itself. This area remains grey and commercial DRA might not be economically feasible to be utilized in the oilfield if it does a considerable amount of damage to the formation. The cost of repairing the damage inflicted by the DRA to the well might even outweigh the benefits of the DRA usage at the first place. This paper is therefore very important to clarify this matter as commercial

## 1.3 OBJECTIVE & SCOPE OF STUDY

### 1.3.1 Objectives of Project

- To study the effects of commercial DRA on water injection well
- To identify the relationship between injection rate and formation permeability

### 1.3.2 Scope of Studies

The scope of study in the project extends to the study the effects of commercial drag reducing agents on water injection wells which laboratory test will verify findings on the relationship correlations that could show proper interactions between DRA and formation this will in turn pave way for the criteria that drives decision on choosing the appropriate DRA to be used. Below show the list of model study and laboratory test that is within the scope of study of this project:

1. Coreflooding

## 1.4 THE RELEVANCY OF PROJECT

This project is relevant to the author as the author is an Petroleum Engineering student which already completed most of major and core courses in Petroleum Engineering. Besides that, the knowledge regarding Drilling fluids and Rock mechanics during drilling operation is one of core courses offered and this help the author to have more understanding in theory.

This project also could widen up the view of people regarding this technology and in the same time exposing the effects towards the formation.

## 1.5 FEASIBILITY OF PROJECT

Author had been given full two semesters of studies to complete the final year project which divided into Final Year Project I and Final Year Project II. The time given is almost 8 months and sufficient for the author to complete the project. During Final Year Project I, the author will spend more time for research and do background studies for materials which are related to the project and during Final Year Project II, the author will implement all the theories and knowledge he obtain from his research in finding out the effects of commercial DRA on water injection wells.

## 2.0 LITERATURE REVIEW

In most petroleum pipelines, the liquid flows through the pipeline in a turbulent regime. The current class of DRAs does not change fluid properties and hence they are effective in turbulent flow. Therefore, current DRAs can perform very well in most pipelines. The fluid molecules in a turbulent flow regime move in a random manner, causing much of the energy applied to them to be wasted as eddy currents and other indiscriminate motion. DRAs work by an interaction of the polymer molecules with the turbulence of the flowing fluid. In the very centre of a pipe is a turbulent core. This is where the eddy currents and random motions of turbulent flow. The laminar sub layer is nearest to the pipeline wall where fluid moves laterally in sheets. Nearest to the pipeline wall is the laminar sub layer. In this zone, the fluid moves laterally in sheets. Between the laminar layer and the turbulent core lies the buffer zone. The buffer zone is where the turbulence is formed first. A portion of the laminar sub layer constantly oscillates and moves to the buffer region and approaches the turbulent core. It becomes unstable and breaks up as it approaches the core and the ejection into the turbulent core is known as the turbulent burst.

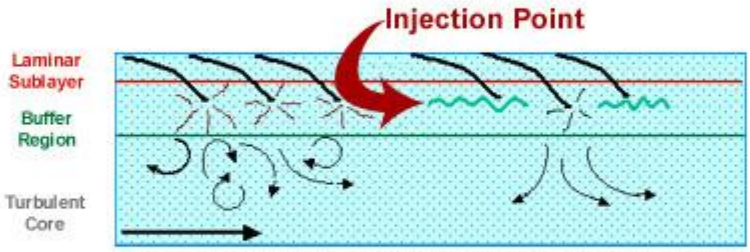

**Figure 6.0: Turbulent flow in pipe**

Drag reducing agents acts like a shock absorber and interferes the turbulent burst. It reduces the turbulence in the core by absorbing the energy in the buffer zone.

Water injection systems maintain reservoir pressure and oil production level by injecting water into the reservoir through water injection well. Centrifugal pumps aids in transporting the water downstream. However, the volume of water injected is limited by the capacity of the injection pump, the size of the injection tubing and the characteristics of the reservoir. By introducing DRA, the differential pressure drop in water injection tubing is reduced. The water injection rate may be increased until the maximum allowable operating pressure in the injection system is again reached.

Water flooding technique is where water is injected down injection wells into the oil zone creating a vertical water front pushing oil in front of the water to be produced. The key in water flooding is the mobility ratio of the driving fluid, water should be less than the mobility ratio of the driven fluid, oil. In most cases, water mobility ratio is always the greater one compared to oil. In such, water tends to channel or finger through the hydrocarbon and
bypasses the hydrocarbon in the smaller permeability channels leaving the hydrocarbon behind. Presence of DRA in water flooding will reduce the effective water mobility ratio by increasing the viscosity of water to a much lower value compared to oil mobility ratio. After the treatment, oil will be driven to the wellbore for production.

Despite all the benefits that are come with application of DRA, it is believed that the DRA also affect the wellbore negatively. A study was conducted in Galley Field situated 145km east-north-east of Peterhead, Scotland to look into the effects of DRA to the formation. A core sample was taken from the field and water is flowed through the core and the permeability is measured. Permeability test is conducted on the core sample by using water and untreated water with 100ppmv of DRA concentration. A small reduction in permeability can be seen and it was accepted within the limits set by Chevron Texaco.

| YEAR | AUTHOR | TITLE |
|---|---|---|
| 1969 | F.A Seyer and A.B Metzner | Turbulence Phenomena in Drag Reduction System |
| 1982 | Burger, E.D., Munk, W.R., Wahl, H.A | Flow Increase in Trans Alaska pipeline through use of polymeric drag reduction adddititive |
| 1985 | C.B Lester | Basics of Drag Reduction |
| 1986 | Ohlendorf D. | Effects of surfactant on crude oil drag reduction |
| 1988 | Bewersdorff H.W. Berman N.S. | The influence of flow-induced Non-Newtonian Fluid Properties on turbulent drag reduction |
| 2003 | Nelson J | Optimizing Production using DRA in water injection wells |
| 2006 | H.A. Al-Anazi and J.Gillespie | Evaluation of DRA for Seawater Injection System |
| 2008 | H.Oskarrson, I. Uneback & M.Hellsten | Surfactants as Flow Improver in Water Injection |
| 2008 | M. Allahdadi Mehrabadi and K. Sadeghy | Simulating Drag Reduction Phenomenon in Turbulent Pipe Flows |
| 2009 | I. Henaut, M. Darbouret, T. Palermo, P. Glenat and C. Hurtevent, | Experimental Methodology to Evaluate DRA: Effect of Water Content and Waxes on Their Efficiency |

**Table 1.0: List of literature reviews from 1969-2009**

This is the list of authors that have done research, publish book and papers that are relevant to the topic I’m pursuing in my Final Year Project. F.A Seyer and A.B Metzner, (1969) came out with an analysis based on the Townsend-Bakewell model of the eddies in the wall regions of turbulent shear flows. Significant reduction in the rate of production of turbulent energy is caused by viscoelastic fluid properties. This analysis in turn leads to the proper form of the similarity laws for drag reducing fluids, therefore deduced empirically. Alternating laminar and turbulent fluid is found in transitional flow and the flow characteristics are approximately similar to those of Newtonian fluids. At high Reynolds number conditions with the turbulent field fully developed the velocity profile in the core is flatter under drag-reducing conditions than for turbulent Newtonian fluids, a change dependent on the increased isotropy of the turbulent field of the drag-reducing fluid. Drag reduction may not be attainable under conditions of practical interest until fluids having relaxation times an order of magnitude larger than those presently available.

C.B Lester, (1985) writes a paper reviewing the fundamental and application of DRA, DRA role in passive and active drag and incidence as specific products and hardware. DRA-solvent solution behaves like an ordinary hydrocarbon except in turbulent flow when the reduced friction becomes evident. DRA have no effect on refining process or refined product as DRA themselves are hydrocarbon. He found that the amount of DRA required to produce a reasonable drag reduction is little in amount: a drag reduction of 30% requires about 24 weight ppm of DRA.

Bewersdorff H.W. Berman N.S., (1988) published paper about "The influence of flow-induced Non-Newtonian Fluid Properties on turbulent drag reduction". When the shear viscosity at the wall shear rate is used for the Reynolds number and the local shear viscosity is used for the non-dimensional wall distance, Friction factors and velocity profiles in turbulent drag reduction can be compared to Newtonian fluid turbulence. Drag reduction asymptote is found which is independent of Reynolds number and type of drag reducing additive. Despite that, no shear viscosity is able to account for the calculated Reynolds stress from mean velocity profile and measured Reynolds stress. However if elongation components are included with the use of velocity fluctuation correlation the problem can be solved. It is found that by taking the maximum drag reduction asymptote as a non-Newtonian fluid flow leads to agreement with the concept of an asymptote only when the solvent viscosity is used in the non-dimensional wall distance.

Nelson J,(2003) came up with "Optimizing Production using DRA in water injection wells", shared similarities with my FYP topic which look into the effects of DRA in water injection well. DRA is used in re-injection of produced water into the producing reservoir and abandoned reservoir. The article covers an overview of drag reduction technology and details on water injection technology and water flooding. Four factors governing the amount of drag reduction are solubility of DRA in the continuous phase, effectiveness in dispersing the DRA, molecular weight of the DRA and concentration of the DRA. By injecting DRA, downstream via the pump in water injection system, the differential water pressure drop may be reduced resulting increase in water injection rate. Meanwhile, the effect of treating flood water with DRA is to increase the viscosity of water thus reducing the effective water mobility ratio. Therefore, oil is more likely to be produced than water resulting in enhanced oil production. The case study implemented on Galley field by ChevronTexaco shows increase in water injection rate when DRA is introduced. ChevronTexaco was able to re-pressurize the reservoir and continue operation at 39000b/day from 29000b/day. Besides, the expected life of the reservoir has been extended by 3 years and the total amount of recoverable reserve is estimated to increase 1.5 million barrels that the initial estimate of 28 million barrels. Other benefits found are DRA has no souring effect on crude oil, DRA reduces the effect of corrosion up to 30% and DRA reduces the number of water injection wells needed.

H.A. Al-Anazi and J.Gillespie, (2006) publishing an article entitled “Evaluation of DRA for Seawater Injection System”. Compatibility tests, corrosion rate measurements, flow through tube tests and coreflood experiments were conducted to access the effectiveness of a Drag Reducing Agent to increase the flow capacity of transfer line that supplies treated water to power water injectors in carbonate reservoirs and ensure it has no adverse effect on water well injectivity. It is shown that its compatible with biocides in seawater and DRA reduces corrosivity of seawater by 50%. Higher DRA concentration produces more drag reduction in turbulent flow. However, the effectiveness of DRA decreases with high shear due to polymer chains degradation. Permeability reduction can be seen when high concentrations of DRA is used. Broken DRA give less damage compared to a fresh one. In low permeability cores, the damage inflicted is more substantial. The damage caused can be removed by reversing flow direction but more volume of seawater is required to restore core permeability. No adverse impact on wells injectivity can be seen when DRA is implemented in field cases.

H.Oskarrson, I. Uneback & M.Hellsten, (2008) wrote an article entitled “Surfactants as Flow Improver in Water Injection”. In offshore operation, high cost is needed to lay down an additional water pipe to the injection site, therefore flow improvers will be a more cost effective way to increase the flow rate when the oil well deteriorates. Drag reducing polymers biodegrades at a slow rate and this opens room for development of readily biodegradable surfactants as flow improvers for injection water. 75% to 80% drag reduction is achieved with a combination of 200ppm of zwitterionic and anionic surfactants blend at an average velocity of 1.9 m/s and between 50 and 55% at 2.9 m/s. This was tested in a 5.5 inch, 700m long flow sloop containing sulphate brine with salinity similar to sea water. The self-healing properties of drag-reducing structures formed by surfactant enable them to be added before the pump section. Due to higher dosage needed, surfactant flow improver will cost more than polymer. The author still promotes surfactant as the improvement of flow might be significantly greater due to a smaller pressure drop in the tube and easier penetration of the oil-bearing rock. A cleaning operation is also done which will lead to an improve oil recovery. The other advantages over polymer are surfactants are easier to be handled and more biodegradable. However as for now, no surfactant flow improvers have been used in injection system probably due to the fact that no environmentally acceptable product has been offered to the petroleum industry.

M. Allahdadi Mehrabadi and K. Sadeghy, (2008) published “Simulating Drag Reduction Phenomenon in Turbulent Pipe Flows”. The authors suggest low-Reynolds number $k$–$\varepsilon$ turbulence model are required in order for the time-averaged turbulence formulation to function. They also attempt to predict the huge drag reduction which has been observed for several polymer solutions with turbulence model called “Launder–Sharma” (1974). As far as the $f$–$Re$ curve is concerned, it was concluded that the performance of the Launder–Sharma turbulence model is better than the Nagano–Hishida model. The adjusting parameter $C$ better meets the order-of-magnitude analysis used to formulate turbulent flows of generalized Newtonian fluids (GNF).

In 2009, I. Henaut, M. Darbouret, T. Palermo, P. Glenat and C. Hurtevent published a paper entitled “Experimental Methodology to Evaluate DRA: Effect of Water Content and Waxes on Their Efficiency”. The drag reduction study can be divided into two parts. The first part is to evaluate the effectiveness of polymeric additives. The second part of the study is dedicated to the effect of transported crude oil on the performance of the DRA. Waxy crystals and emulsified water are items being focused on in this second part. It was concluded that with addition of small amount of long chain polymers, drag reduction in turbulent flow is obtained. The presence of waxy crystals is believed to cause loss in drag reduction. DRA effectiveness is reduced when water droplets are present.

# 3.0 METHODOLOGY

## 3.1 Project Planning

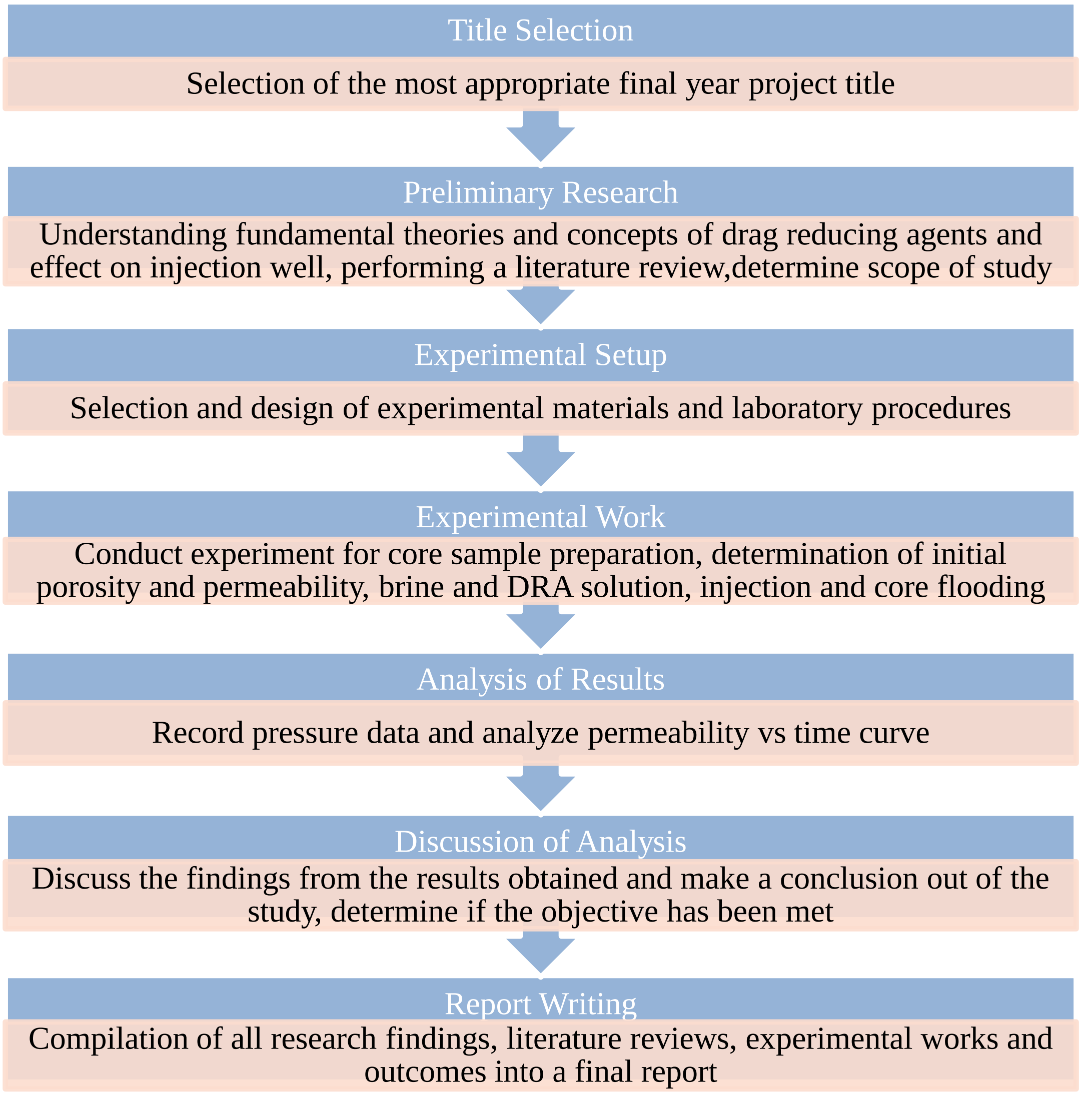

**Figure 7.0: Project Activities Flow**

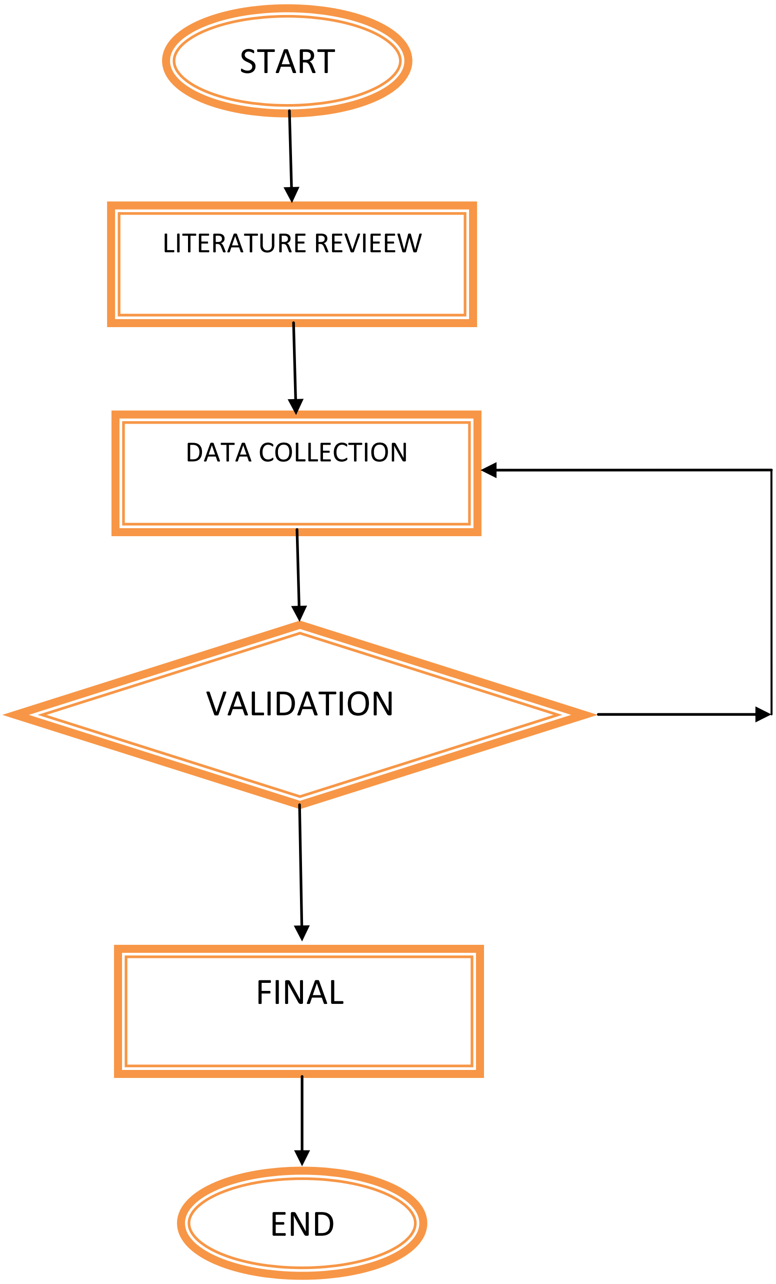

**Figure 8.0: Project Flow Chart**

## 3.2 Research Methodology

The experiments were done by using coreflooding process. For coreflooding process, polyacrylamide is the DRA chosen. The injection rate is varied to compare the effect of different injection rate on permeability reduction. In the beginning of the experiment, the properties of the core samples such as porosity, permeability, pore volume, bulk volume, grain volume, grain density are tested and identified by using the POROPERM instrument.

**Figure 9.0: POROPERM instrument**

### Experimental Procedure

List of Materials

1) Polyacrylamide (PAM)
2) Brine
3) Barea sandstone core samples
4) Distilled water

## List of Apparatus and Equipments

1) Core flooding Equipment
2) POROPERM instrument
3) Desiccators with vacuum pump
4) Beaker

## Chemical Preparation

Brine solution with salinity of 11000ppm is prepared by mixing 11g of salt to 1 liter of distilled water. DRA solution was prepared by adding 0.05g of polymer into 1 liter of brine, having salinity of 11000ppm. This will results in a solution of 50ppm DRA. After that, the polymer was mixed under maximum shear rate using standard magnetic stirrer for about 6 hours, in order to create a broken DRA solution. Then, the DRA solution was mixed at low shear rate over 18 hours for complete hydration in brine. New DRA solution is made before each run is conducted so that the result will not be affected by the shelf time degradation.

## Material Preparation

Barea sandstone is chosen as the core sample for this experiment. The core sample is cut into 3 samples with each length up to 3 inches and diameter of 1.5 inches.

**Figure 10.0: Core samples**

## Coreflooding experiment

Figure 11.0 shows a schematic diagram of the experiments setup for the coreflooding experiments. Positive displacement pump were used to deliver fluids at constant injection rate with variable speed. A core holder can accommodate a core plug with length up to 3 inches and diameter of 1.5 inches. Pressure transducer was used to measure the pressure drop across the core. A backpressure valve was position at the downstream side and was set to 500psia.

The core used in this experiment is a low permeability core, ranging around 8md to 26md. Before using the core for the experiment, saturation process was conducted using desiccators, to make sure the core was 100 percent saturated with brine. The minimum time required for the saturation process is 6 hours. In this experiment, the core undergoes saturation process about a week for better results.

**Figure 11.0: Desiccators with vacuum pump**

After the core was saturated with brine, the core was loaded into the core holder, and the end caps were screwed tightly. The experiment was conducted by setting the positive displacement pump at desired injection rates. For this experiment, injection rates used were 2cc/min, 4cc/min and 6cc/min.

Core permeability was measured initially when the core is flooded with 11000ppm of brine. Then the core was flooded with 100ml of brine containing 50ppm of DRA polymer at the same flow rate used in the initial permeability measurement. Pressure drop across the core was recorded as a function of time, and permeability versus time plot was derived from the results. Backflowing process was carried out by injecting 200ml of brine to core in reverse, at high injection rate which was 8 cc/min. After the backflowing process, the core was loaded again in its initial condition and was flooded with brine to get the final permeability after treatment.

Percentage of permeability reduction was calculated by dividing the difference in the initial permeability of the core during brine flooding and during the DRA flooding over the initial permeability of the core during brine flooding.

$$K_{reduction} = (K_{initial} - K_{DRA}) / K_{initial} \text{ x } 100\% \qquad (1)$$

Percentage of permeability recovered was measured by dividing the difference in permeability after treatment and during the DRA flooding over the difference in initial permeability of the core during brine flooding and during the DRA flooding.

$$K_{recovered} = (K_{final} - K_{DRA}) / (K_{initial} - K_{DRA}) \text{ x } 100\% \qquad (2)$$

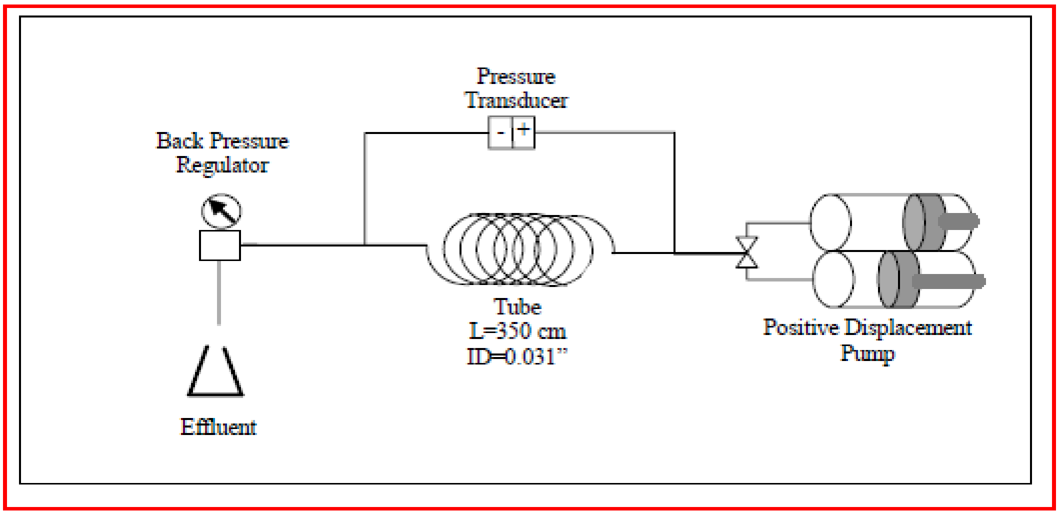

**Figure 12.0: Schematic Diagram for coreflood apparatus**

### 3.3 Gantt Chart and Key Milestones

| No | Detail/Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **Selection of Project Topic:**<br>Effect of Drag Reducing Agent (DRA) on water injection wells | 🟨 | 🟨 |  |  |  |  | **Mid Sem Break** |  |  |  |  |  |  |  |
| 2 | **Preliminary Research Work:**<br>Research on literatures related to the topic |  | 🟨 | 🟨 | 🟨 | 🟨 |  |  |  |  |  |  |  |  |  |
| 3 | Submission of Preliminary Report |  |  |  |  |  | ● |  |  |  |  |  |  |  |  |
| 4 | Proposal Defense (Oral Presentation) |  |  |  |  |  |  |  | 🟨 | 🟨 |  |  |  |  |  |
| 5 | Project work continues: Further investigation on the project and do modification of necessary |  |  |  |  |  |  |  |  |  | 🟨 | 🟨 | 🟨 |  |  |
| 6 | Submission of Interim Draft Report |  |  |  |  |  |  |  |  |  |  |  |  | ● |  |
| 7 | Submission of Interim Report |  |  |  |  |  |  |  |  |  |  |  |  |  | ● |

**Table 2.0: Activities Gantt chart for FYP 1**

| No | Detail/Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Project Work Continues | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | **Mid Sem Break** | | | | | | | |
| 2 | Submission of Progress Report | | | | | | | | ● | | | | | | |
| 3 | Project Work Continues | | | | | | | | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | | |
| 4 | Pre-SEDEX | | | | | | | | | | ● | | | | |
| 5 | Submission of Draft Report | | | | | | | | | | | ● | | | |
| 6 | Submission of Dissertation (soft bound) | | | | | | | | | | | | ● | | |
| 7 | Submission of Technical Paper | | | | | | | | | | | | ● | | |
| 8 | Oral Presentation | | | | | | | | | | | | | ● | |
| 9 | Submission of Project Dissertation (Hard Bound) | | | | | | | | | | | | | | ● |

**Table 3.0: Activities Gantt chart for FYP 2**

| DETAIL/WEEK | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DRA PAM: Injection rate 2 cc/min** | | | | | | | | | | | | | | |
| Porosity and Permeability test | | | | | | 🟦 | | | | | | | | |
| Core undergo saturation process with brine | | | | | | | 🟦 | | | | | | | |
| Measure initial core permeability | | | | | | | | 🟦 | | | | | | |
| Flood with 100ml of brine containing 50ppm DRA using 2cc/min injection rate & Record pressure drop and permeability | | | | | | | | 🟦 | | | | | | |
| Backflow process & Record final permeability | | | | | | | | 🟦 | | | | | | |
| **DRA PAM: Injection rate 4 cc/min** | | | | | | | | | | | | | | |
| Porosity and Permeability test | | | | | | 🟦 | | | | | | | | |
| Core undergo saturation process with brine | | | | | | | 🟦 | | | | | | | |
| Measure initial core permeability | | | | | | | | 🟦 | | | | | | |
| Flood with 100ml of brine containing 50ppm DRA using 4cc/min injection rate & Record pressure drop and permeability | | | | | | | | 🟦 | | | | | | |
| Backflow process & Record final permeability | | | | | | | | 🟦 | | | | | | |
| **DRA PAM: Injection rate 6 cc/min** | | | | | | | | | | | | | | |
| Porosity and Permeability test | | | | | | 🟦 | | | | | | | | |
| Core undergo saturation process with brine | | | | | | | 🟦 | | | | | | | |
| Measure initial core permeability | | | | | | | | 🟦 | | | | | | |
| Flood with 100ml of brine containing 50ppm DRA using 6cc/min injection rate & Record pressure drop and permeability | | | | | | | | 🟦 | | | | | | |
| Backflow process & Record final permeability | | | | | | | | 🟦 | | | | | | |

**Table 4.0: Activities Gantt Chart for experiment**

## Key Milestone

1) Porosity and Permeability test for for 3 core samples
2) Saturation process using brine
3) Core flooding at injection rate 2cc/min, 4 cc/min and 6cc/min for PAM
4) Backflow process and retrieve all results

## 4.0 DISCUSSIONS and RESULTS

### Discussion

1) Core sample undergoes saturation process using desiccators to make sure the core was 100 percent saturated with brine. Minimum time required for saturation process is 6 hours. In this experiment, the core is saturated for a week to ensure that the core is fully saturated with brine for better results.
2) Polyacryamide (PAM) should be mixed under maximum shear rate using standard magnetic stirrer for about 4 hours, in order to create a broken DRA solution. For this experiment, an additional time of 2 hours is added to the duration of mixing the DRA under maximum shear rate to give us a better broken DRA solution. Then, the DRA solution was mixed at low shear rate over 18 hours for complete hydration in brine.
3) New DRA solution is made before each run is conducted so that the result will not be affected by the shelf time degradation.
4) For 2cc/min, 4cc/min and 6cc/min injection rate, the core was flooded with a constant 100ml of brine containing 50ppm of DRA polymer at the same flow rate used in the initial permeability measurement. The relationship between injection rate and permeability reduction can best be tested when a constant volume of 100ml of brine containing 50ppm of DRA polymer at all flow rates. There is a different proposed method which is by keeping the amount of time constant for all injection rates when the core is flooded with DRA solution. However, this does not justify the relationship between injection rate and permeability reduction as more volume of DRA solution floods the core at a higher injection rate.
5) Low injection rate used shows a high permeability reduction in the core sample and vice versa.

Coreflooding Results

Figure 13.0, 14.0, and 15.0 shows the permeability curves versus time for the flooding of brine with PAM DRA solution, while Figure 5 summarize the results of the experiment. Experiment results shows permeability reduction of 56.38% for 2cc/min injection rate, 29.52% for 4cc/min injection rate, and 5.61% for 6cc/min injection rate. While for recovery process, permeability recovered was found to be 13.45% for 2cc/min injection rate, 24.26% for 4cc/min injection rate, and 56.23% for 6cc/min injection rate.

| Injection rate | 2cc/min | 4cc/min | 6cc/min |
|---|---|---|---|
| K initial | 26.344 md | 14.199 md | 7.288 md |
| K DRA | 11.659 md | 10.007 md | 6.879 md |
| K final | 13.504 md | 11.024 md | 7.109 md |

**Table 5.0: Permeability data for injection rate 2cc/min, 4cc/min and 6cc/min**

Permeability Reduction and Permeability Recovered Calculation

Injection rate (2cc/min)

K reduction = (26.344 – 11.659) / 26.344 x 100%

= 56.38%

K recovered = (13.504 – 11.659) / (26.344 – 11.659) x 100%

= 13.45%

Injection rate (4cc/min)

K reduction = (14.199 – 10.007) / 14.199 x 100%

= 29.52%

K recovered = (11.024 – 10.007) / (14.199 – 10.007) x 100%

= 24.26%

Injection rate (6cc/min)

K reduction = (7.288 – 6.879) / 7.288 x 100%

= 5.61%

K recovered = (7.109 – 6.879) / (7.288 – 6.879) x 100%

= 56.23%

### Effect of Injection rates

The results obtained indicate that as injection rate increases the reduction in permeability decreases. This is due to the fact that at higher shear rate, more polymer chain is broken, thus easing the fluid flow through inlet and the permeability channel inside the core. On the other hand, the shear rate of the fluid flowing at the inlet of the core is small at lower injection rate. Small shear rate tends to make the polymer molecules plug at the inlet face of the core. As shown by the results calculated, permeability reduction of 56.38% is observed at low injection rate 2cc/min while only 5.61% reduction in permeability is shown when high injection rate 6cc/min is used.

In contrast, the core which flooded with DRA at higher injection rate shows higher percentage of recovery when backflow with brine compared to the core flooded at lower injection rate. The permeability channels which consist of highly sheared polymer chain, which a result from flooding at higher injection rate, make it easy to be flushed backwards. At low injection rate, the permeability channel plugged with polymer molecules, thus make it hard to flush out in backflow process.

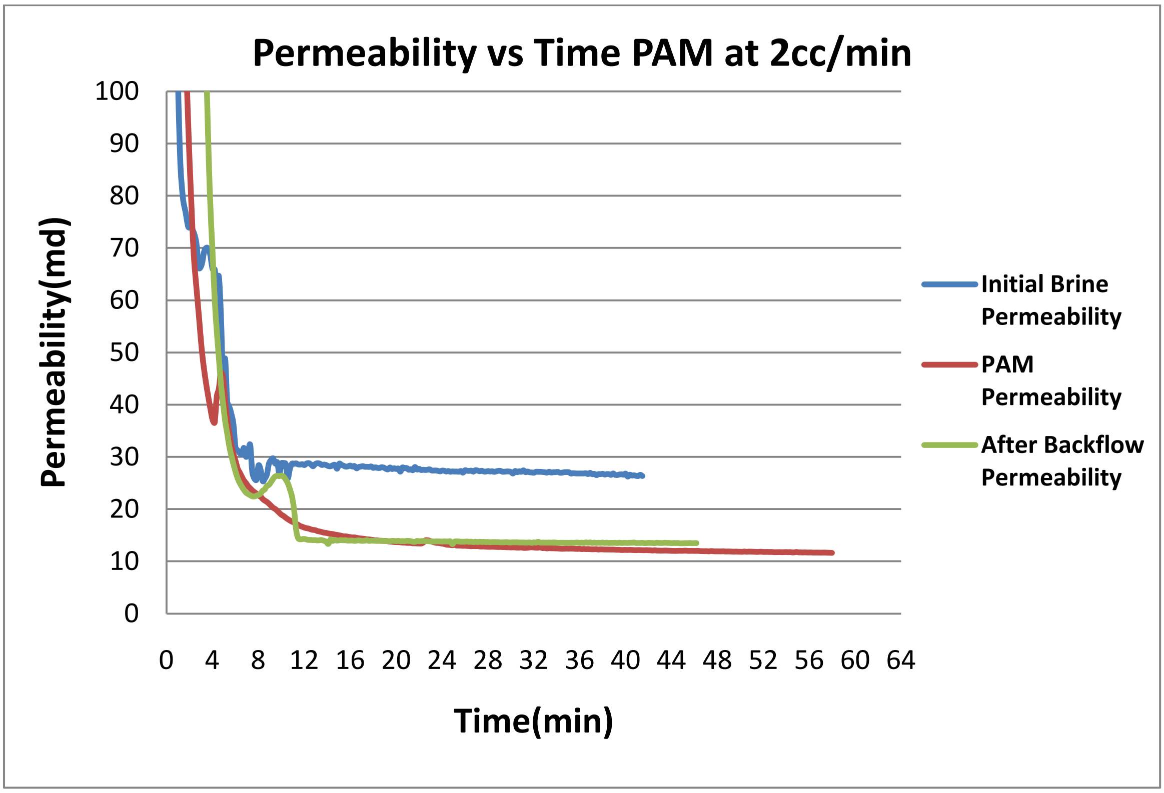

**Figure 13.0: PAM performance at 2cc/min**

When the core is initially flooded with brine at 2cc/min, the stabilized permeability is recorded at 26.344md. After flooding with DRA solution at the same injection rate it reduces to 11.659md. This shows a permeability reduction of 56.38%. The core is then reverse and back flow process is carried out at 8cc/min in order to restore the permeability. The core is then flooded with brine again and the final permeability is recorded at 13.504md. This shows that 13.45% permeability restoration is managed to be obtained. The pressure profile shows that the pressure increases in the beginning of each run and becomes constant as the permeability reaches a constant value.

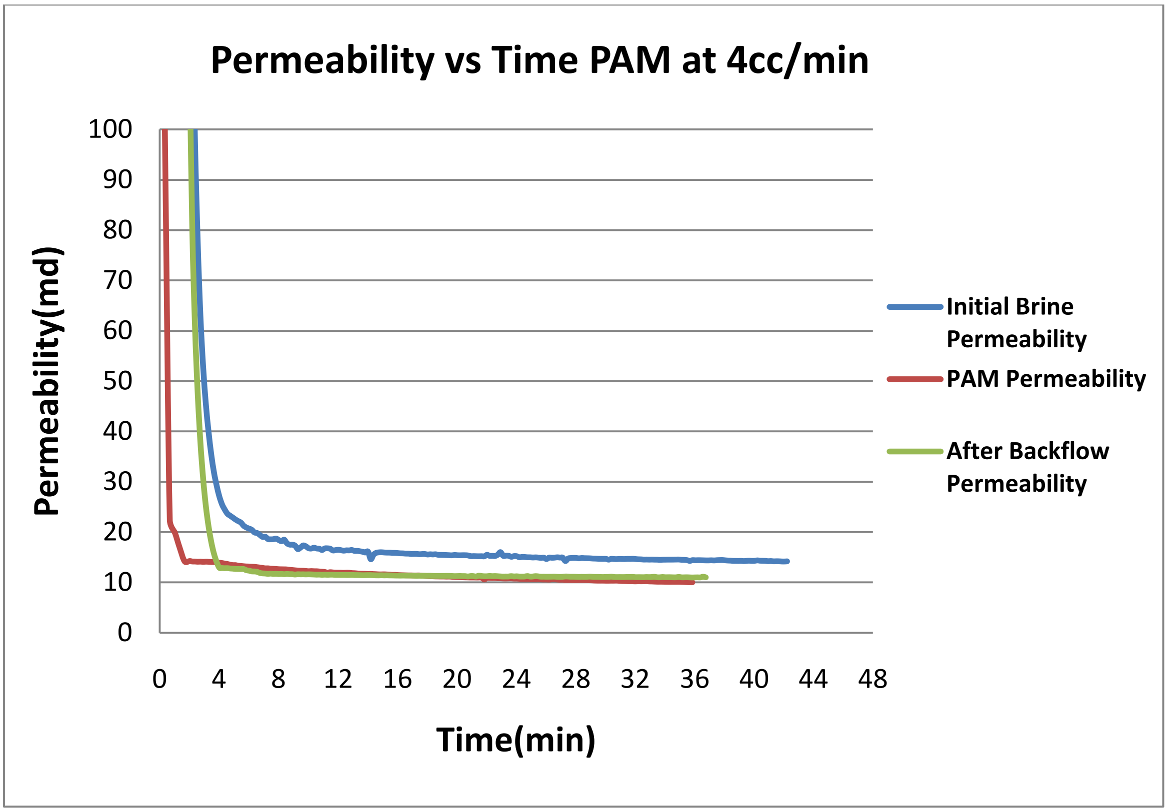

**Figure 14.0: PAM performance at 4cc/min**

When the core is initially flooded with brine at 4cc/min, the stabilized permeability is recorded at 14.199md. After flooding with DRA solution at the same injection rate it reduces to 10.007md. This shows a permeability reduction of 29.52%. The core is then reverse and back flow process is carried out at 8cc/min in order to restore the permeability. The core is then flooded with brine again and the final permeability is recorded at 11.024md. This shows that 24.26% permeability restoration is managed to be obtained. The pressure profile shows that the pressure increases in the beginning of each run and becomes constant as the permeability reaches a constant value.

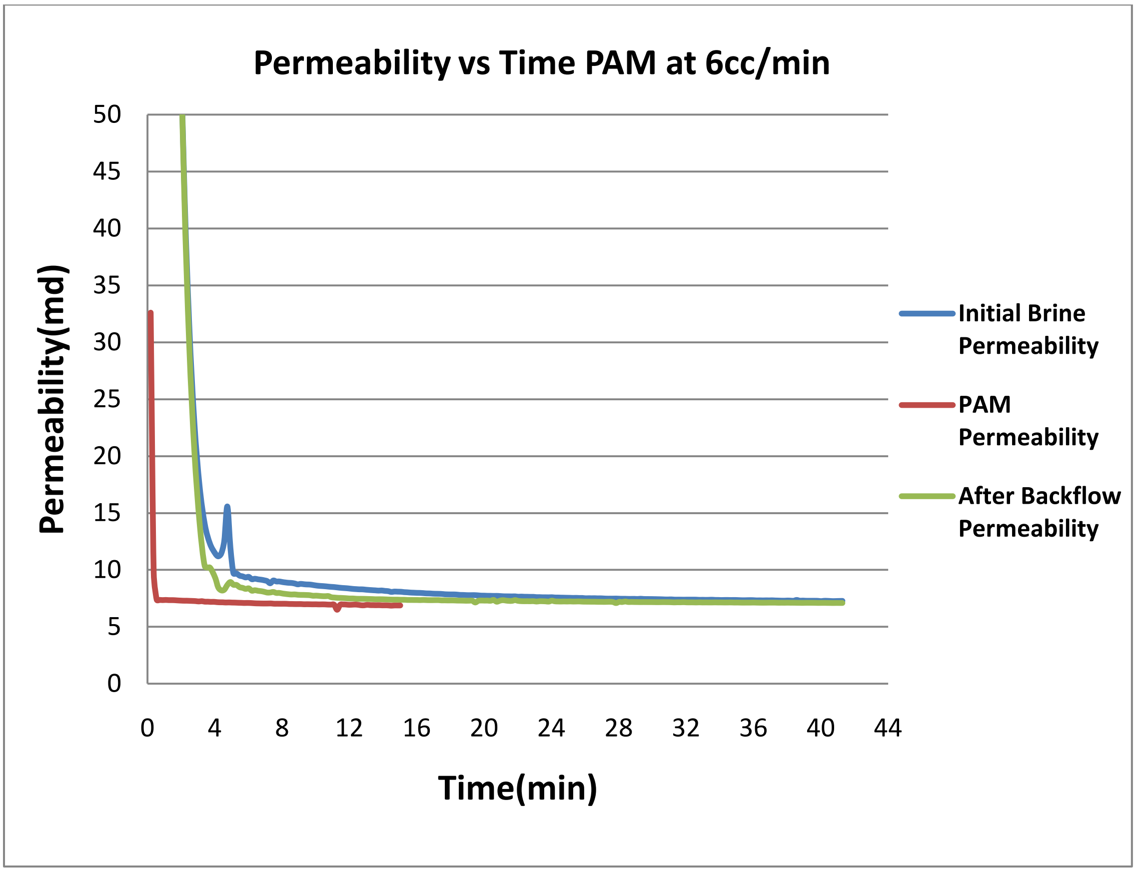

**Figure 15.0: PAM performance at 6cc/min**

When the core is initially flooded with brine at 4cc/min, the stabilized permeability is recorded at 7.288md. After flooding with DRA solution at the same injection rate it reduces to 6.879md. This shows a permeability reduction of 5.61%. The core is then reverse and back flow process is carried out at 8cc/min in order to restore the permeability. The core is then flooded with brine again and the final permeability is recorded at 7.109md. This shows that 56.23% permeability restoration is managed to be obtained. The pressure profile shows that the pressure increases in the beginning of each run and becomes constant as the permeability reaches a constant value.

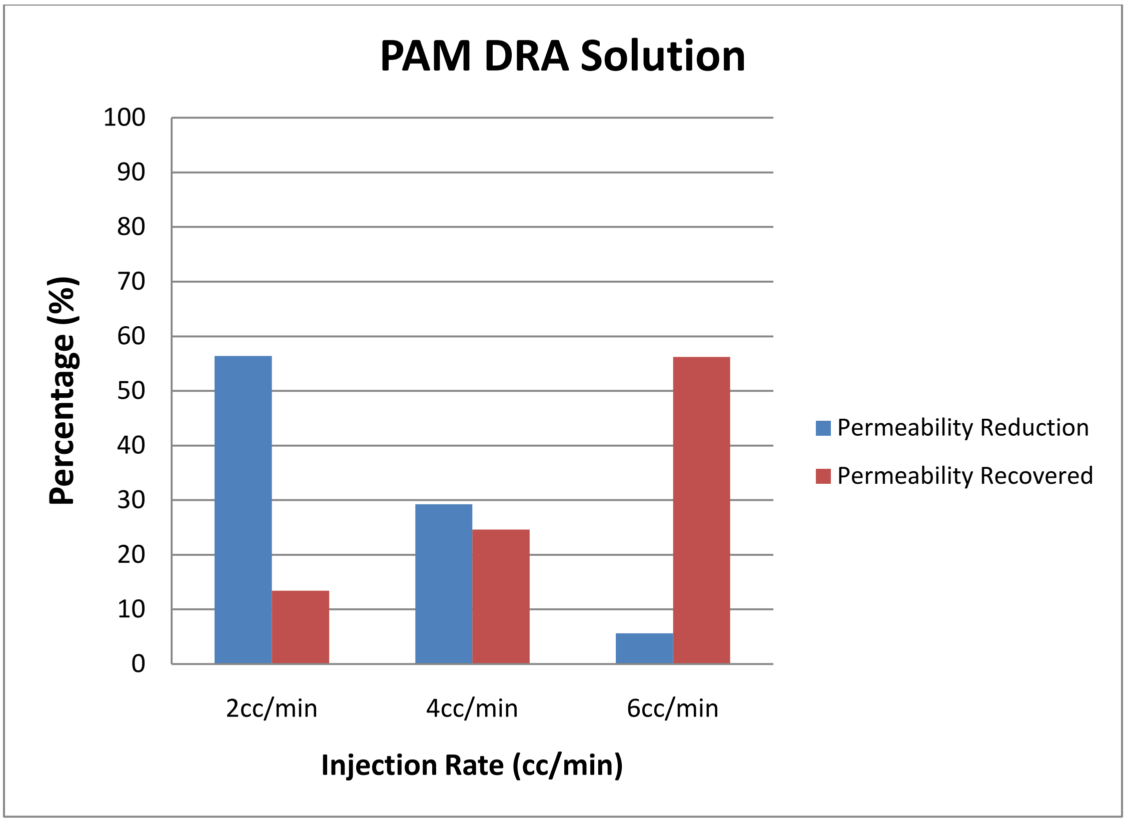

**Figure 16.0: Permeability reduction and recovered versus injection rate of PAM DRA Solution**

The bar chart shows that highest permeability reduction of core sample is achieved when the rate of injection used is 2cc/min which is 56.38% while the lowest permeability reduction is detected at injection rate of 6cc/min which is 5.61%. This shows that as the rate of injection increases, the reduction in permeability decreases. In contrast, the permeability recovered is found to be highest at the highest injection rate 6cc/min where 56.23% of the permeability is restored followed by 4cc/min achieving 24.26% and finally 2cc/min with only 13.45% permeability restoration.

## 5.0 CONCLUSION and RECOMMENDATION

Introducing DRA into water injection well brings both benefits and harm to the injection well as well if not control within its limit. DRA does help to increase the water capacity of a well; however it also causes reduction in permeability at the same time. Precaution need to be taken to ensure the reduction in permeability is negligible. As a summary, permeability reduction is a function of injection rates; high injection rate has low reduction in permeability. High permeability restoration can be achieved when high injection rate is used. Treatment in restoring the near well bore permeability of the injection well from time to time also needed to ensure the reduction in permeability near well bore is minimize.

The experiment can be further improved by testing with other types of DRA besides polymer type. Then we would be able to compare the effects of different types of drag reducing agents (DRA) on permeability reduction. The author would also like to suggest the usage of CT scan to monitor closely the permeability reduction behavior in the core.

# 6.0 REFERENCES

1. Boatright, K.E.,2002.Basic Petroleum Engineering Practices,9.6.
2. Bewersdorff H.W., and Berman N.S. (1988), The Influence of Flow Induced Non-Newtonian Fluid Properties on Turbulent Drag Reduction, Rheol. Acta 27, p. 130-136
3. Savins, J.G., 1964, Soc. Pet. Eng. J., 4, 203 (1964)
4. Nelson, J., (2003), Optimizing production using drag reducing agents in water injection wells
5. H.A. Al-Anazi, M.G. Al-Faifi, F. Tulbah, and J.Gillespie, (2006) Evaluation of Drag Reducing Agent (DRA) for Seawater Injection System: Lab and Field Cases, SPE 100844
6. Toms,B.A., 1948. Some observation on the flow of linear polymer solution through straight tube at large Reynolds numbers. In: Proceeding First Congress in Rheology, North Holland, Amsterdam, vol.2, pp. 135-141.
7. C.B Lester, 1985. Basics of Drag Reduction. In: Oil & Gas Journal, February, pp. 51-56.
8. F.A Seyer and A.B. Metzner, 1969. Turbulence Phenomena in Drag Reducing System. In: AIChe Journal, May, pp. 426-434.
9. M. Allahdadi Mehrabadi and K. Sadeghy, 2008. Simulating Drag Reduction Phenomenon in Turbulent Pipe Flows. In: Mechanics Research Communications (35), pp. 609-613.
10. I. Henaut, M. Darbouret, T. Palermo, P. Glenat and C. Hurtevent, 2009. Experimental Methodology to Evaluate DRA: Effect of Water Content and Waxes on Their Efficiency. In: SPE International Synposium on Oilfield Chemistry, Woodlands, Texas, USA.
11. Burger, E.D., Munk, W.R., Wahl, H.A., 1982. Flow increase in Trans Alaska pipeline through use of polymeric drag reduction addictive. In: J. Petrol. Eng., pp. 377-386.