THE EFFECT TEMPERATURE CHANGE TO WAX AND ASPHALTENE PRECIPITATION

IQBAL HAKIMI BIN MOHAMED

CHEMICAL ENGINEERING
UNIVERSITI TEKNOLOGI PETRONAS
JULY 2009

The Effect of Temperature Change on Wax and Asphaltene Precipitation

by

Iqmal Hakimi Bin Mohamed

Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Chemical Engineering)

JULY 2009

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.

IQMAL HAKIMI BIN MOHAMED

ABSTRACT

One of the well problems that are face by the operation is the formation damage occurs in the wellbore. The formation damage can be cause by several reasons which one of it is due to the formation of wax and asphaltene precipitation. This formation of organic precipitate will cause the flow of well to be disturb and suddenly depleted. The study of temperature effect on the formation of the precipitate will provide a solution to the operation in order to manipulate the production to minimize the formation. The study will cover the effect of temperature to the crude properties and also to define the range of temperature where the precipitation is tend to form. The study will be conducted in the lab size scale where crude from various field will be collected and then put under test for the purpose of study. The crude sample will be put under several range of temperature to observe the change that may occur to its properties and also any formation of precipitate. The study will be involving the knowledge of petroleum engineering together with chemical engineering. The outcome of the study will be use to manipulate the current operation practice to minimize the formation of the precipitation and hence, improve the production of the crude.

ACKNOWLEDGEMENTS

First and foremost, praises be to Allah S.W.T whom had poured His tremendous blessing and wisdom upon the author throughout his whole life as a student. Through Him everything is possible and this project can be completed despite of those obstacles and hardship.

The author would like to express his greatest gratitude to his project supervisor, Dr. Isa M. Tan for his guidance and supervision. The project gives author new valuable experiences during the period in finishing the project. Thank you for the time that you had spent to guide and supervise the author throughout the whole semester.

Special thanks are also conveyed to the Chemical Engineering Final Year Project Committee and those technicians involved ensuring this project is a successful run. Not forgetting to masters and PhDs students for their kindness and helps during the lab work.

Last but not the least, the author would like to thank his parents, Mr. Mohamed Bin Ismail and Mrs. Rosnani Bte Ahmad whom had supported and motivated him in many kinds of ways and for always being there to provide any needs to complete this project. The author could not have done it without them. Thank you for your endless love.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION

m	Mass
v	volume
SG	Specific gravity
ρ_{oil}	Density of oil
ρ_{water}	Density of water
m_{w+b}	Mass of wax and sample bottle
m_b	Mass of empty sample bottle
m_{s+b}	Mass of sample and sample bottle
API	American Petroleum Institude
FDS	Formation Damage System

CHAPTER 1 INTRODUCTION

1.1 Background of Study

This project study is intended to study the effect of temperature changes on wax and asphaltene precipitation of wax. Throughout the study, the will be two main part that need to be define which is the properties change of crude and also the range of temperature where crude start to form precipitation. Some of the properties that will be observed are viscosity, composition and density. This change observed will be studied to establish a define pattern of the crude behavior that will then be use to design a solution to precipitation problem. Since different reservoir poses different composition of crude, sample from various reservoirs will be collected and put under study. The finding of the study will be beneficial to the operation to establish a better practice of production that will minimize the formation of wax and asphaltene precipitation.

1.2 Problem Statement

The prevention of wax asphaltene precipitation formation is a major challenge for the oil and gas industries. Wax and asphaltene precipitation is normal problems that are face in the wellbore. The formation of this precipitation can cause the permeability and the flow of the crude through the production tubing to deplete. The precipitation are said to form at a certain range of temperature and pressure that consider being the ideal condition for it to occur. The identification of the range of the temperature and pressure as per claimed, can lead us to manipulate the production not be operated in that specific range. This will then lead to a way to prevent the formation of the precipitation from disturbing the crude production. This

can be a better solution rather than the conventional method of treating the precipitation by stimulating the well which may cause more money.

1.3 Objective

1. To identify the temperature range where the crude tend to form wax and asphaltene precipitation
2. To observe the behavior of the wax and asphaltene precipitation with the temperature change
3. To observe the behavior of the crude with the temperature change

1.4 Scope of Study

The study on effect of temperature changes on wax and asphaltene precipitation of crude will be completed in 1 year period (2 semesters). There will be 2 main phase of the study; phase 1, literature review and phase 2, laboratory scale experiment. The study will cover 2 main parts which is the study of temperature effect on the change of crude properties and also the study of temperature range that the crude will form to wax and asphaltene precipitate.

It will be an experimental based study done in the laboratory scale. The study will cover the knowledge of petroleum engineering along with the chemical engineering.

CHAPTER 2 LITERITURE REVIEW

Asphaltenes are the crude oil components that meet some procedural definition. A common definition is that asphaltenes are the material that is insoluble in n-pentane (or n-heptane) at a dilution ratio of 40 parts alkane to 1 part crude oil and re-dissolves in toluene. Asphaltenes are important constituents of petroleum and can cause problems related to crystallization and deposition of paraffin waxes during production and transportation as well as in the formation of tar mats.

2.1 Organic Precipitation

The paraffin deposition primarily occurs by temperature decrease, whereas asplhatene occur because of a number of complicated phenomena, including the polydispersivity, steric colloid formation, aggregation and electrokinetic deposition processes.

Probable causes of asphaltene flocculation are drop in the reservoir pressure below the pressure at which asphaltenes flocculate and begin to drop out and mixing of solvents with reservoir oil during enhances oil recovery. After flocculation asphaltenes exhibit an intrinsic change, which is usually positive. As a result, they show a strong tendency to attach to negatively charged surface such as clays and sand. This will then make the accumulation of a larger flocculation which will cause a great block to the flow. Organic deposits usually seal the flow constrictions because they are sticky and deformable. Therefore, the conductivity of a flow path may diminish without filling the pore space completely.

Organic damage in oil reservoirs is primarily caused by asphaltene deposition and the region of asphaltene deposition may actually extend over large distances from the wellbore. Asphaltene deposition is not only limited to the near wellbore

region, but it can occur throughout the reservoir formation, whereas the wax deposition is rather limited to a short distance from the wellbore, because wax deposition in the near wellbore region usually occurs by the cooling of the oil caused either by high perforation pressure losses during oil production or by invasion and cooling of the hot oil saturated with the wax dissolved from the well walls as a result of the overbalanced.

Asphaltene-induces damage can be explained by certain mechanisms. One of it is the increase of the reservoir fluid viscosity. The increment is affected by the increase of the asphaltene particle concentration in the near-wellbore region as the oil converges radially toward the wellbore.

The problems associated with organic deposition from the crude oil can be avoided or minimized by choosing operating conditions such that the reservoir oil follows a thermodynamic path outside the deposition envelope and therefore, the deposition envelope concept can provide some guidance in this respect.

2.1.1 Properties of Asphaltene

Asphaltene is a typical organic precipitates encounter in petroleum production along with the paraffin. They both are sticky, thick and deformable precipitates. It can seal the pore throats and reduce the permeability to zero without needing to redure the porosity to zero. **The deposition at the pore surface and tubing wall is reversible unless a solvent treatment is applied.**

There are highly condensed polyaromatic structures or molecules, containing heteroatom (S, O, N) and metals (Va, Ni), that exist in petroleum in an aggregated state in the form of suspension and are surrounded and stabilized by resins as peptizing agents. They are known to carry am electrical charge and thought to be polydisperse. Asphaltenes are a solubility class, hence, they are not pure, identical molecules.

Asphaltenes are not a specific family of chemicals with common functionality and varying molecular weight. An example of a family of chemically related homologs is the fatty acids. Molecules in the asphaltene fraction can have

many different sorts of polar functionality as well as varying molecular weight. Their only unifying property is insolubility in a specified n-alkane.

Asphaltenes separated with n-heptane typically are shiny black solids. From this appearance, they are often assumed to be crystalline, but in fact they are amorphous. Solutions containing visible asphaltene aggregates do not transmit any light through crossed polarizing filters, unless they also contain wax crystals.

2.1.2 Properties of Wax

Wax refers to deposits of paraffin, asphaltenes and resins, mixed with some inorganic matter, such as clays, sand and other debris. Organic deposition can occur both on the surfaces of well tubing and reservoir formation pores to reduce the flow efficiency and eventually to clog the flow paths completely.

These are primarily aliphatic hydrocarbons that change state from liquid to solid during conventional oil production and processing operations. In addition to aliphatic, field deposit usually contain aromatic, naphthenic, resin and asphaltenic molecules as well.

Wax crystallization is generally a reversible process. However, paraffin waxes more that often precipitates together with resins and asphaltene. This are said to be responsible for the observed irreversible thermodynamic phenomena. Hence, some wax precipitation is occasionally reported as irreversible. Temperature and composition have a large effect and pressure has a small effect on the solubility of wax in oil.

2.1.3 Problem Related With Asphaltene

Different reservoir will poses different composition of asphaltene. Oils with significant amounts of asphaltenes often can be produced without any asphaltene-related problems, whereas severe asphaltene problems have been reported for some oils with amounts of asphaltenes that are barely measurable.

Asphaltenes can cause problems in oil production, transportation, and processing. Whether or not asphaltenes cause problems is unrelated to the amount of asphaltene in the oil. What is important is the stability of those asphaltenes and

stability depends not only on the properties of the asphaltene fraction, but also on how good a solvent the rest of the oil is for its asphaltenes. Light oils with small amounts of asphaltenes are more likely to cause problems during production than heavy oil with larger amounts of material in the asphaltene fraction. The heavier oil also contains plenty of intermediate components that are good asphaltene solvents whereas the light oil may consist largely of paraffinic materials in which, by definition, asphaltenes have very limited solubility. Asphaltenes in heavier oils can also cause problems if they are destabilized by mixing with another crude oil during transportation or by other steps in oil processing.

Any injection of fluids and chemicals approaching the wellbore during production and variation of fluid saturations can alter the temperature, pressure and composition of the fluids in the near wellbore region and tubing. The change will consequently will affect the thermodynamic and chemical balance that may change in favor of precipitation separation, aggregation of precipitates, crystal growth and scale formation. Precipitates can cause formation damage by changing the wettability and permeability of petroleum bearing rock and cause scale formation and clogging in tubing and pore throats. The formation of the precipitates also will affect the surface facilities where it can cause the efficiency of the equipment to decrease and just in time to cause damage to the equipment. All of the problem caused, will surely cause a lost in income weather due to the loss of profit from the production or due to the cost to rectified the damage happen.

2.1.4 Problem Related With Wax

Wax in crude oil is comprised primarily of paraffin. Paraffin is a white, odorless, tasteless, chemically inert compound composed of saturated hydrocarbons. Wax before separation it can cause or magnify a number of problems in the processing of petroleum. It can aid emulsification of the crude in the production and refining of crudes, as well as in oil spills. These emulsions are difficult to study because of the variety of different crudes and crude waxes, the complexity of crude oil, and the lack of knowledge of the precise mechanism whereby wax stabilizes emulsions.

Since the wax precipitates out at low temperatures, it can cause plugging in drilling equipment and pipelines undersea and in the arctic. Because of its high viscosity, it can cause pumping problems in pipelines and when emptying tankers in regions where the water temperature is low.

2.2 Evolution of Wax Deposition Process

Wax deposition is initiated by the precipitation of wax directly on the pipe wall and the formation of a network of wax crystals (wax-oil gel), with significant amount of oil trapped in it, as temperature change super-saturate the system. When waxy crude is cooled, it gels due to the formation of a network of wax crystals, which exhibits strong physical interaction and affinity that precipitates in the formation of stable wax crystals that inter-lock to form a solid network. The high molecular weight paraffins (waxes) are known to be responsible for some of the problems that are encountered during crude production. At a high temperature and pressure similar to reservoir condition, the solubility of these compounds is sufficiently high to keep them fully dissolved in the mixture and the crude oil behaves as a Newtonian fluid with a low viscosity.

Once the crude oil leaves the reservoir and flows through the tubing and pipelines, its temperature begins to drop due to the ambient conditions. The fact that solubility of high molecular weight paraffins decreases drastically with decreasing temperature, leads to the formation of stable wax crystals at low temperatures. The wax particles start appearing in the crude oil, when the oil temperature drops below its solubility limit.

2.3 Wax Deposition Mechanism

A problem of paraffin wax may be described as a situation in which a predominantly organic deposit hampers the production of crude oil; the loss crude production from well depends on the severity and location of the deposition.

The mechanism of paraffin wax deposition area governed by molecular diffusion of wax molecules; shear dispersion of wax crystallites and Brownian diffusion of wax crystallites. Gravity settling of paraffin crystals in flow line conditions is negligible, because it's dominated by shear dispersion.

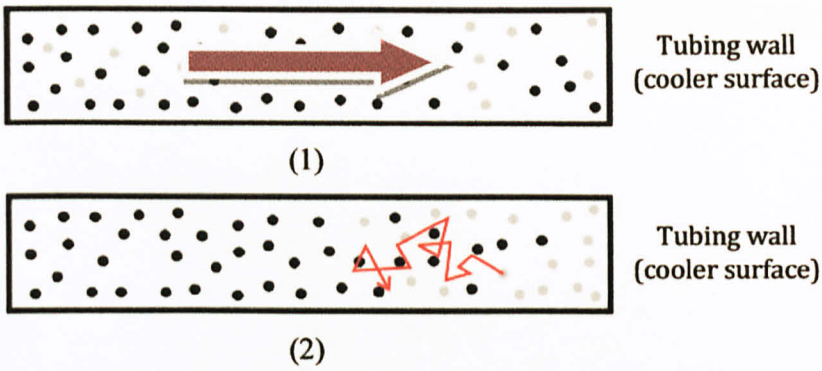

Figure 1, Molecular Diffusion of Wax Molecules

Deposition is enhanced as result of lateral transportation. In wax deposition mechanism process, a concentration gradient is produced in the oil as a result of temperature gradient profile, due to increasing solubility of waxes with increasing temperature. The concentration caused waxes in solution to diffuse from the warmer oil, which has a greater concentration of dissolved waxes, to the colder oil, which has a lower concentration, resulting to molecular diffusion of the paraffin crystals towards the surface wall.

2.4 Factors Relating to Paraffin Deposition Problems

The solubility of the paraffin waxes is very sensitive to temperature variation. Paraffin can precipitate from crude when equilibrium conditions change slightly, causing a loss of solubility of the paraffin in the crude. The point of deposition in the well producing system is normally determined by how close the crude is to its solubility saturation point and the amount of paraffin in the crude.

The temperature is probably the most common cause of paraffin deposition, though many other factors can affect the process, because paraffin solubility in crude decreases as the temperature is lowered. Cooling of crude occurs in many places in the well production system.

Expansion of oil and associated gas at the reservoir, through casing perforations, or through bottom whole screen causes cooling. As the crude moves upwards through the tubing, surface choke, through the flow line, it experiences additional cooling. At some point in the system, the temperature drops below the wax melting point, and paraffin may start to accumulate on production equipment.

Loss of gas and light hydrocarbons from crude also decreases paraffin solubility. This effect facilitates paraffin deposition in production system. High gas-oil ratio magnifies paraffin deposition problems.

Injecting cold fracturing or acidizing fluids into tan oil reservoir, for maintenance operation, can cause a significant cooling of the crude. However, methods of detection of wax deposition in the field include visual observation of produced crude in the stock tanks, abrupt decline of production rate.

CHAPTER 3 METHODOLOGY

In order to reach the completion of the research on Effect of Temperature Changes on Wax and Asphaltene Precipitations of Crude, several stage of work progress have been plan to ensure the research will complete as a success. Basically five stages have been plan which covered the work progress that will cover the duration of two semester of the Final Year Project course. The stage will cover the literature review, procedure identification, sample gathering, experiment and lab research and lastly, documentation.

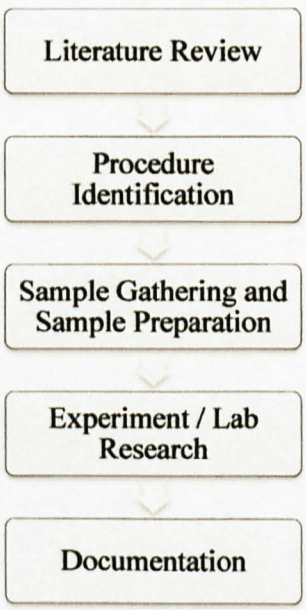

Figure 2, Flow chart for the overall methodology

3.1 Literature Review

Prior conducting any research and study, a great understanding on the concept and theory of the subject matter is vital. This will determine that the research

will leading to the right direction. The first step in conducting the research is by literature review. The step requires gaining all the sufficient data and information that are related to the research scope. By this step, the background study and problem statement can be further detailed. It also will provide a better understanding about the fact of the problem and research that were then will be conducted. This step covers the extra reading from various source of information that includes journals, reference books and research papers of others. The step will be mostly covered during the first semester of the course.

3.2 Procedure Identification

A clear and well define research procedure are needed to ensure that all the data that are required in completing the research are gained. Generally, the procedures are referring to the laboratory scale experiment where most of the research will be conducted. A clear procedure will ensure the smoothness of the research as it will act as a main guideline in ensuring the objective will be achieve. During this stage, some research and identification on laboratory equipment are needed to identify the equipment that will be used throughout the research. This is also conducted to ensure that all type of equipment that is required is available for usage in the laboratory.

3.3 Sample Gathering and Sample Preparation

Different reservoir will produce different composition of crude oil. It is vital to at least conduct the research and study which will cover some different type of crude oil as it will give the different behavior and change of the crude oil with the temperature effect due to different composition of it. This different source of crude oil will be gathered and then be put under test and study. It is most preferable to have the sample from various problematic well as the formation of wax and asphaltene precipitations are defined and can be studied. Numbers of crude oil from various location have been identify to be the potential sample for the research due to their different composition but all of them have the history of precipitation occurrence.

For the study, two crude samples have been gathered from two different fields in the Peninsular Malaysia water. Both field mentions are:

3.3.1 Tapis

- Peninsular Malaysia field, located at offshore of Terengganu
- Operated by the PETRONAS Carigali, Peninsular Malaysia Operation
- Produce a light crude with low number of wax content

3.3.2 Penara

- Peninsular Malaysia field, located at offshore of Terengganu
- Operated by the PETRONAS Carigali, Peninsular Malaysia Operation
- Produce a heavy crude with high number of wax content

3.4 Experiment / Lab Research

It is identify that the formation of the wax and asphaltene precipitation in the wellbore are occur due to the several reason. One of the main reason is it tend to form precipitation when the temperature of the crude is dropping from the reservoir condition. The change will be varies depending on the type and composition of the crude.

In order to achieve the data and information throughout the research, some procedure have been identify and will be further revise time by time throughout the research period. The laboratory experiment will cover:

3.4.1 Crude Oil Sample Properties and Composition

For this step, it is about getting all the detailed and sufficient data on the crude oil sample. This will be achieved by using all the related laboratory equipment that have been identify during the procedure identification stage. This step is important as the data will be use to compare and relate the effect of different crude oil properties to the temperature change. Some of the test that will be done on the crude oil sample:

a. Density Measurement

Density can be measured by know the two other properties of volume and density. It can be calculated by using the equation of:

$$Density, \rho = \frac{mass}{volume} = \frac{m}{v}$$

For the study, the densities were determined by the measuring the mass and volume to be later used for the calculation of the density. Although there is other measurement equipment available to give a direct reading of the density likes hydrometer and pycnometer, but a large quantity of sample were needed in order for the application of both equipment is possible. Most of the sample taken for the studies will be stored in a sample bottle will normally occupied about 25 ml hence, the method of calculation the density by known value of mass and volume are more applicable.

b. API Gravity Measurement

The American Petroleum Institute gravity, or API gravity, is a measure of how heavy or light petroleum liquid is compared to water. If its API gravity is greater than 10, it is lighter and floats on water and if less than 10, it is heavier and sinks.

For this study, API gravity values were gained by calculating it from the value of the density of the crude. The relationship between the density and API gravity is given by:

$$API\ Gravity = \frac{141.5}{SG} - 131.5$$

Where,

$$SG_{oil} = \frac{\rho_{oil}}{\rho_{water}}$$

API gravity were used a standard unit of unit that were used to define the density of any studies or cases on crude oil sample. The value of the API gravity should be between the values of 10 to 70.

c. Viscosity Measurement

In order to measure the viscosity that been poses by each of the crude oil sample, viscometer were use. The viscometer only measures the viscosity under one flow condition. The viscosity of the water at standard condition are use to calibrate the viscometer before been use to measure other sample. The viscosity of the crude oil samples are

needed to be measured as different sample will poses different value of viscosity. At different temperatures, viscosity also with have its certain behavior that can lead to better understanding of the precipitation phenomena. The viscosity also will have some effect on the precipitation formation as a more viscous crude oil are claimed to be more tend to form precipitates compare to a less viscous one.

d. Pour Point Measurement

Pour point is the lowest temperature at which it will pour or flow under prescribed conditions. The measurement of pour point is vital for the study as it will define the temperature at which the precipitated will taking the effect toward the crude oil until it will cause a problem to flow behavior. Identifying the value will give a better understanding on the behavior change and also for the ease of the data analysis and interpretation.

For the measurement of the pour point, the sample is cooled inside a cooling bath to allow the formation of paraffin wax crystals. At about 9°C above the expected pour point, and for every subsequent 3°C, the test jar is removed and tilted to check for surface movement. When the specimen does not flow when tilted, the jar is held horizontally for 5 second. If it does not flow, 3°C is added to the corresponding temperature and the result is the pour point temperature.

e. Wax Content Measurement

The effect of the precipitation of the crude oil also had been closely link with the value of wax content. The wax content of crude oil will give a significant impact to the viscosity and also pour point. Hence, it is a value that is needed to be taken in order to have a better understanding of the behavior change.

The measurement of the wax content can be done by first, weight the weight of the empty sample bottle and also the sample bottle with the crude sample. The sample were then were put under a storage at the ambient condition for the period time of 48 hour or 2 day. This is to ensure that all of the wax that was in the sample to be settling at the bottom of the bottle sample by the effect of gravity. After the storage

period, the liquid layer of the sample will then be discharge from the sample bottle leaving only the wax layer. The remaining of sample in the bottle was then being weight to get the weight of the wax in the crude.

From the weight that been gained for the empty sample bottle, wax precipitate and initial sample, the wax content for the crude oil sample can be calculated by applying the equation:

$$Wax\ content, wt\% = \frac{m_{w+b} - m_b}{m_{s+b} - m_b} \times 100\%$$

From the calculation, the wax content value will then be compare to the other data gained on the properties of the crude sample to get a relationship between each of the parameter.

For the effect of wax content to pour point study, the crude oil was saturated to a different level of wax content in term of weight percent. The wax content was manipulated by first letting the wax in the crude to settle down for a period of 24 hour. The wax that precipitates will accumulate at the bottom of the sample bottle. The crude that is still in the form of liquid will then be discharge to a certain level for a different trial to set a different wax content. Of the getting the different wax content, the sample were then be heated to ensure that the wax will dissolve back in the crude. After it is sure, the observation are done.

3.4.2 Temperature Effect Study

The main part of the research is the study of the temperature effect to the precipitation formation. The temperature is claimed to be one of the most important parameter which promote the precipitation formation. During this lab test, the crude oil sample will be filled in the container which will then be heated to a level where it will then be cooled down. The rate of the cooling will be varied to establish the rate that will shown the highest precipitates formation rate and amount of precipitates. As the precipitates formation is a irreversible process, the formed precipitates will then be put under test to identify the composition and its behavior. The precipitates also will be heated

to identify the temperature where the precipitates will melt and dissolve back into the oil form. Both temperature where it start to form precipitate and start to form oil back will be taken into account to verify the change behavior and to model the temperature effect on the wax and asphaltene precipitation. Several instruments have been identified to be used as an option for the study.

At initial, the PVT tank was planned to be the main equipment that will be used throughout the experiment. But due to some maintenance and availability problem, another set of equipment had been design to cope with the problem. As an alternative setup, the Formation Damage System (FDS) unit been used as the main equipment.

FDS system was a system that allows the sample to be injected to the core sample of a reservoir thru core flooding at a reservoir temperature and pressure. The temperature of the core can be set to be up to maximum of 200 °C and pressure up to 2000 kPa. By using the equipment, it is like performing the test at the reservoir itself that will give a better reading of the effect of the formation damage along with the temperature change towards the formation of the precipitate.

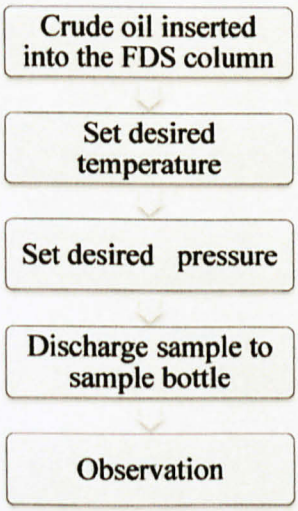

Figure 3, Flow chart for temperature effect study using FDS system

The studies on temperature effect using the FDS system were done by 5 steps that are shown by the flow chart above. The crude sample that to be studied were first been inserted into the FDS column by using the external pump that are available with the system. A maximum of 1 liter of crude sample can be stored in each of the three columns available in the system.

Figure 4, Picture of FDS control board

Figure 5, Picture of FDS unit

After the crude were been stored in the column, the column were first been heated to the desired set temperature. The temperature will

be set at the control board of the FDS system. For each of the crude sample, a set of temperature setting will be applied. The temperature that will be applied is at 80°C, 100°C, 120°C and 140°C.

After the desired temperature achieve, the desired pressure were then been set to the system. The pressure can also been set by the control board of the FDS system. The pressure that been applied to the crude sample were done by the pumping of the water into the column. But need to note that the water will not come into contact with the crude sample. As the studies were intended to overlook the effect of the temperature to the behavior of the crude, the pressure was set to be at 800 kPa at all temperature intervals. This will ensure that for all intervals, the same pressure influence was introduced.

After the desired temperature and pressure been achieved, the crude samples in the column were set to be maintained under the condition for a period of 3 hour. This is to ensure that the sample will take the effect that cause by the temperature and pressure that have been set. It also was to ensure that the setting condition will be applied to the overall sample for a better result during the analysis.

After that, the crude oil will be discharge into the sample bottle for a volume of 25 mL. The sample were discharge into the sample bottle from the column at its set temperature and pressure similar like the production activity that been experience from the reservoir to the surface.

After been discharge from the column, the crude sample were then been cooled to ambient by a standard temperature room cooling. The samples were stored at a closed cupboard for the period of two days to allow the effect of storage to take place. After that period, all of the samples were taken for the observation on the formation of the precipitate analysis.

3.4.3 Observation and Data Interpretation

There will be two part of interpretation of data that will be involved two type of result and data. This is to ensure a better understanding of the behavior of the crude and how the effect of temperature will affect its properties. The two type of interpretation:

a. Behavior of the Crude Oil Properties at Different Temperature

For this first part of data interpretation, the data of the properties of the crude were taken at a certain range. The data will cover the change of viscosity at different temperature and also the data of pour point value for a different wax % in crude.

The relationship between both temperature with viscosity and also wax % with pour point were then be represent in the table and graph for each of the crude sample. This will give a further understanding and clearer relation on the effect that been taken place.

b. Behavior of the Precipitate Formation to Temperature Change (Cooling Effect)

The data interpretations for the effect on the temperature change were done to the extent of the effect of the temperature gradient or temperature different between the initial temperatures of the crude sample to the ambient temperature to the precipitation behavior. The studies were intended to see whether the different gradient that been cooled during the production did give any effect to the precipitation of the crude sample or not.

The data will be obtained by the test that been conducted on the crude sample using the FDS system. The result and analysis of the data will be presented in form of table and graph.

3.5 Documentation

After the research have been completed with the experiment and lab research, all the data gained and modeling that have been done need to be document into a report which will be submitted to programme coordinator. The report also will cover the entire research element from the start of the research until all the works completed.

CHAPTER 4 RESULT AND DISCUSSION

Throughout two samples that have been gained from the local Peninsular Malaysia field, certain behaviors of the crude properties have been observed. Before the crude sample been put under the temperature effect study, the sample properties were observe first for the sake of comparison after undergoing the study procedure.

Table 1, Physiochemical properties of Penara and Tapis crude sample

Sample Location	Density (g/cm^3) @ 15°C	Viscosity (cSt) @ 40°C	Viscosity (cSt) @ 70°C	API Gravity	Pour Point (°C)	Water Content (% vol.)	Wax Content (% wt)
Penara	0.9165	37.50	32.50	22.8	36	0.5	18
Tapis	0.8036	3.831	2.251	44.5	18	0	1.0

Prior to the study, some initial assumption or hypothesis been developed to act as a set point to the study. Based on some referred literature, difference in the wax content (%wt) amongst the various crudes was responsible for the difference in viscosity behavior as temperature decrease. Another assumption that can be made is the more wax content, the more increase in wax appearance temperature (WAT) of crude oil and the higher the cloud point of a crude oil is the more paraffin problems will be encountered in a well or oilfield.

From the study of the temperature effect on the crude, two approach of result have been design to give a clear understanding on the changes on the precipitation. The two way of analyzing the data will help to improve the understanding on the precipitate attribute. The data that been gained throughout the studies can be manipulated into tables and graph for the sake of analysis and interpretation.

4.1 Behavior of the Crude Oil Properties at Different Temperature

Both crude oil samples were put under properties study at a different temperature. The interactions between temperature with viscosity and wax content (weight percent) with pour point were put under study.

Table 2, Viscosity at different temperature for Penara crude sample

Temperature (°C)	Viscosity (cSt)
40	38.5
45	37.5
50	36.3
55	35.5
60	34.4
65	33.5
70	32.5

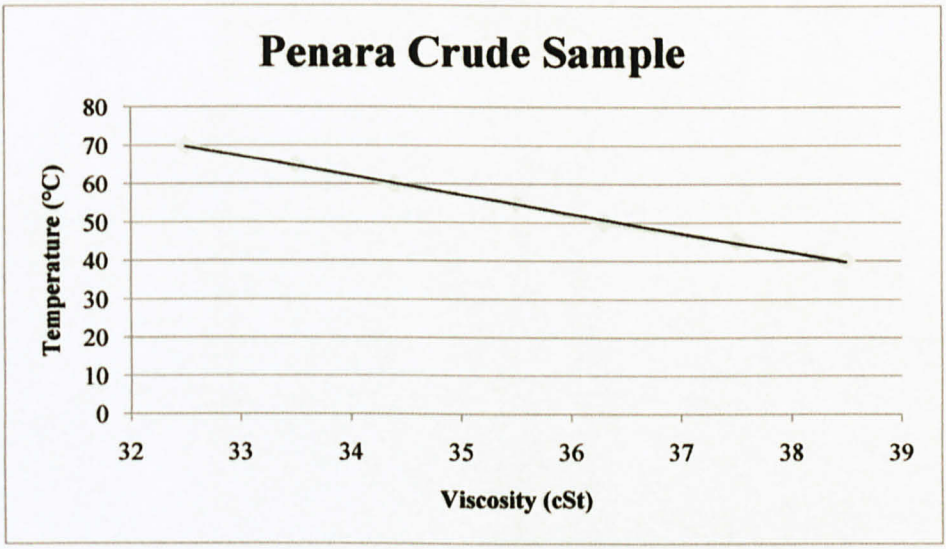

Figure 6, Graph plot of viscosity at different temperature for Penara crude sample

Table 3, Viscosity at different temperature for Tapiscrude sample

Temperature (°C)	Viscosity (cSt)
70	1.9
60	2.6
50	3
40	3.8
30	4

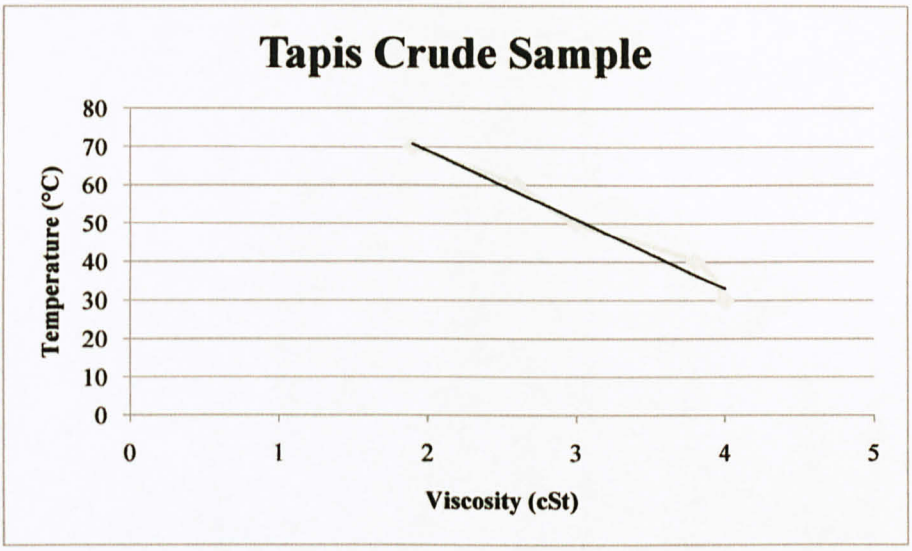

Figure 7, Graph plot of viscosity at different temperature for Tapis crude sample

From the result gained on the viscosity at the different temperature setting, both crude samples show a significant similar trending of viscosity behavior towards temperature. The viscosity of the crude oil sample for both field tend to increase as the temperature decrease. Although the magnitude of the viscosity is different between both of the sample due to the different properties of crude but it still resemble a similar interaction toward the temperature change.

Viscosity behavior of both crudes was very sensitive to temperature change. A slight change of temperature can give a significant impact to the crude and the impacts are greater during the production. As viscosity act as the resistance to flow, a high value of viscosity during the production can cause the well to have a problem in

flowing the crudes. A proper control of temperature hence will allow the viscosity change to be monitor in order to prevent for any problem to occur.

Table 4, Pour point at different wax content for Penara crude sample

Wax Content (% wt)	Pour Point (°C)
7.1	10
21	20
35.2	30
50	40

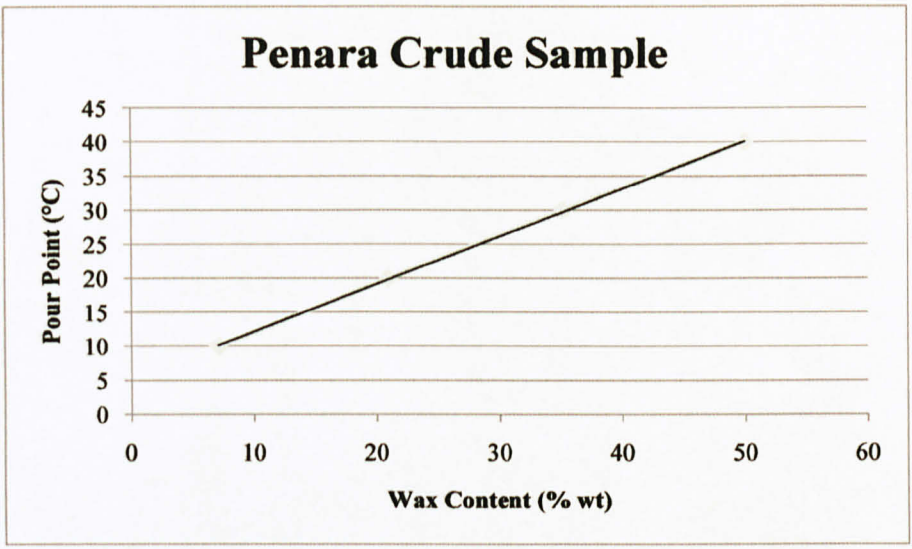

Figure 8, Graph plot of pour point at different wax content for Penara crude sample

Table 5, Pour point at different wax content for Tapis crude sample

Wax Content (% wt)	Pour Point (°C)
8	4
25	7
41.5	10
58	12
75	15
91.5	18

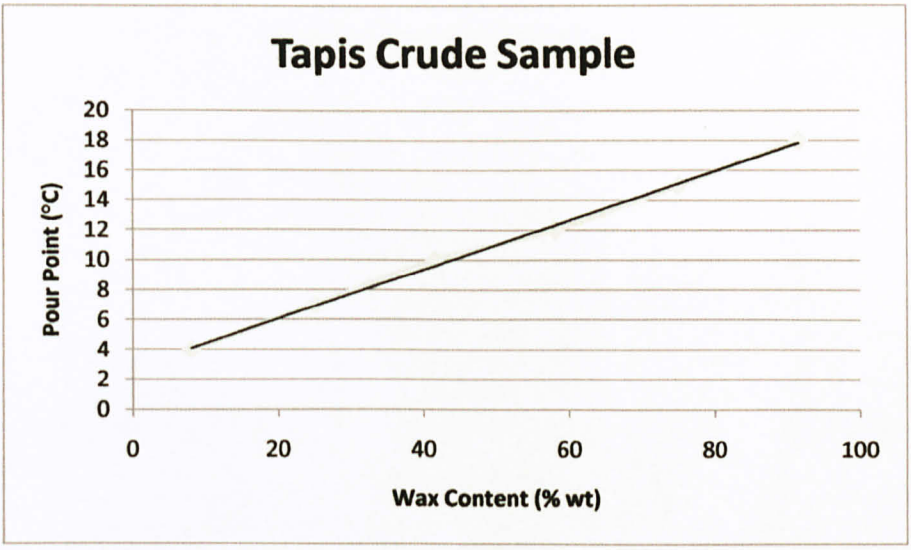

Figure 9, Graph plot of pour point at different wax content for Tapis crude sample

As the second properties study, it can be observe from the result that different wax content give a different pour point. For both crude samples, as the wax content increase, the pour point increase. In the other word, as the wax content in the crude increase, the lowest temperature for the crude to pour or flow under prescribed conditions will also increase. A significantly high pour point is not desirable as the crude need to be stabilized at a higher temperature to ensure an undisturbed flow of production.

4.2 Behavior of the Precipitate Formation to Temperature Change (Cooling Effect)

Another study that was done to understand better on the precipitation behaviors of crude were by examining the relation between the temperature gradient with the amount of precipitate form. This detailed study were done by develop an environment that similar like the reservoir in term of temperature and pressure. Decrements of the temperature were done to the crude sample just like during the production to see the effect that will undergo by the sample.

Table 6, Effect of temperature gradient to the percent precipitated formed for Penara crude sample

T (°C)	ΔT (°C)	% Precipitate (%wt)
80	55	18.331
100	75	18.975
120	95	20.01
140	115	20.532

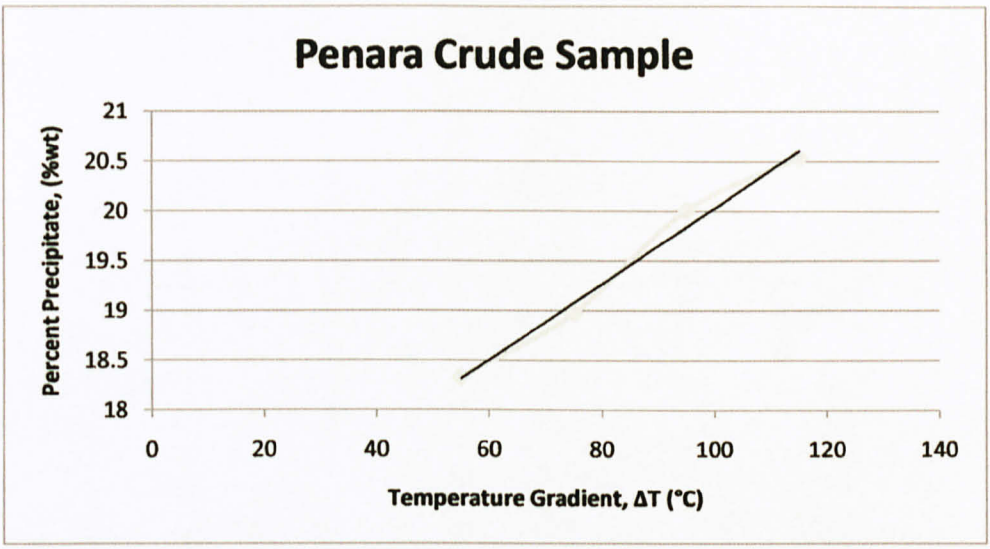

Figure 10, Graph plot of effect of temperature gradient to the percent precipitated formed for Penara crude sample

Table 7, Effect of temperature gradient to the percent precipitated formed for Tapis crude sample

T (°C)	ΔT (°C)	% Precipitate (%wt)
80	55	1.041
100	75	1.243
120	95	1.313
140	115	1.401

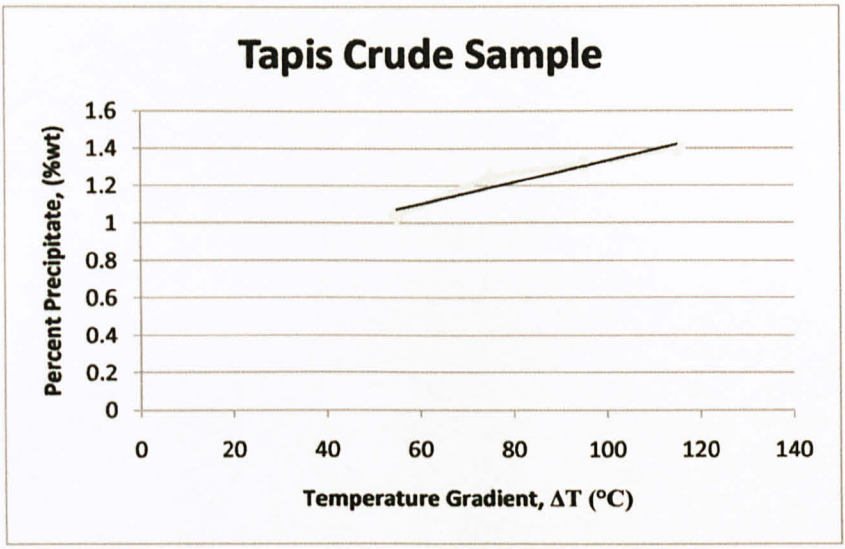

Figure 11, Graph plot of effect of temperature gradient to the percent precipitated formed for Tapis crude sample

From the result gained, both sample shown a same trend of increasing the temperature cooling interval will resulting in increment of the precipitate formation. A larger temperature gradient between the simulated reservoir temperature and the ambient temperature, the more portion of the crude will tend to form precipitate. This condition is undesirable because it could lead to a blockage during the production time. This blockage can cause the production to decrease and in some worse case, shutting the production.

4.3 Discussion

For the relationship between the temperatures with the viscosity, it has been proven to poses a linear relationship. Although the value of the viscosity and the rate of change were different between both crude samples due to the different properties of the crude, but it exhibits the nature of decrement of viscosity as the temperature was increase.

This change also was support by the fact that for a fluid matter, the viscosity increase as the temperature decrease. The change also were happen as the fact that as the temperature decrease the crude oil particles were tend to be more rigid and closed to each other. This will resulting in the increment of the viscosity as the interaction between the crude oil particle act as a resistance to the flow.

As for the relationship between the wax content to the pour point, the pour point of the will give a significant increase as the wax content in the crude were increase. This were been proven by both of the crude sample throughout the testing. High pour points were not desired for the production of the crude as it resembles a problem to flow at a high temperature.

It can be resolve by controlling both temperature and also wax content parameter during the production. Temperature can be easily being manipulated as it is by controlling the heat to ensure the temperature of the production will not fall to the pour point of the crude. If it is happen, the crude will start to form precipitate and hence, act as a blockage to the flow. Although it is said that the precipitate formation can be controlled by controlling the wax content but up to the current production technology, the effort to control the wax content were seem to be impossible as it is highly related to the crude properties of the various field itself.

From the study also, it have been proven that temperature gradient that been cooled from the reservoir condition to the ambient were also have an impact to the formation of the precipitate. Although the magnitude of the change is not very large but to be consider in the well that produce for thousand of barrel per day, this slight change will give a big impact to the production and also the well integrity.

The study have shown that as the temperature gradient were increase, the precipitate content of the crude will increase gradually. This may be cause by the fact that the more rapid the cooling of the crude oil, the more precipitate will formed. To ensure that the same thing will not occur to the production well, a proper control of the gradient need to be consider as to control the additional precipitate formation. This will then, ensure the chance of creating a problem in the well to be in control.

From the overall study, it is proven that the temperature change play a great role in the formation of the precipitate in the crude oil. Its relationship between various parameters has give a better understanding in order to design the counter measures to overcome the precipitate problem that will cause a problem to the production later on.

CHAPTER 5 CONCLUSION

It can be conclude that the study on the effect of temperature change on wax and asphaltene precipitations of crude will provide a better knowledge on the behavior of the crude, wax and asphaltene precipitations. The study also will provide a solution in order to control the formation of the precipitation. The identification of the temperature range that makes the formation of the precipitation to occur will be very useful for the industries.

Project will be proceed with the development of the modeling that will aid the operation side of the production in order to sustain high production without facing any wellbore problem.

5.1 Recommendation

Throughout the studies conducted, there are some recommendation that would like to be suggest as to improvement for any future studies or continuity of the project:

- To conduct the study in the wider range of temperature and pressure

  Current studies are limited to the capability of the FDS system that can only withstand to a certain limit of temperature and pressure setting

- To have more variety crude sample for comparison

  Different crude sample exhibits different composition and behavior towards change that been apply. Various sample to study will ensure the better understanding on the properties change effect by the composition difference.

- To apply the effect of flow to model the flow of production

  The effects of flow also give a great impact to the formation of precipitation. If the effect can be model along with the temperature change, a better set of result that exhibit the reservoir condition will be gained.

- To consider the effect of the high temperature cooling to the formation of wax and asphaltene precipitation

  The studies have given a comparison between the different cooling temperature gradient to the formation of the precipitation. As to prove that it is the properties that really effecting the formation of precipitation, the effect of high temperature cooling were needed to establish.

REFERENCES

Long, R.B.: "The Concept of Asphaltenes," *Chemistry of Asphaltenes*, J.W. Bunger and N.C. Li (eds.), ACS, Washington, DC (1981) 17-27.

Molecular Characterization of Wax Isolated from a Variety of Crude Oils, Barbara J. Musser and Peter K. Kilpatrick, Department of Chemical Engineering, North Carolina State University, Raleigh, North Carolina 27695-7905

The Physical Chemistry of Wax, Hydrates and Asphaltene, B. T. Ellison, Petrel Consulting; C. T. Gallagher, L. M. Frostman Baker Petrolite; S. E. Lonmer, Shell Deepwater Development

Wang, J.X., Creek, J.L., and Buckley, J.S.: "Screening for Potential Asphaltene Problems," paper SPE 103137 presented at the 2006 ATCE, San Antonio, 24-27 Sep.

Wang, J.X. and Buckley, J.S.: "Asphaltene Stability in Crude Oil and Aromatic Solvents- The Influence of Oil Composition," *Energy & Fuels* (2003) **17**, 1445-1451.

Reservoir Formation Damage, *Civan, Faruk,* Gulf Professionl Publishing, 30 Corporate Drive, Suite 400, Burlington, MA 01803, USA

Sanjay, M., B. Simanta and S. Kulwant. 1995. Paraffin Problems in Crude Oil Production and Transportation: A Review. SPE, Oil and gas corp. Ltd., SPE prod. And Facilities, Feb.

Garcia, M. C. 2001. Paraffin Deposition in Oil Production. SPE 64992, SPE int. symposium. On Oilfield Chemistry, Houston, TX, Feb. 13-16.

Weingten J. S., J. A., Euchner. 1986. Methods for Predicting Wax Precipitation and Deposition. SPE 15654, 61st Annual Technical Conference and Exhibition – New Orleans, Oct.

Buger, E. D., T. K. Perkins, J. H. Striegler. 1981. Studies of Wax Deposition in the Trans Alaska Pipeline", JPT, June.

Wardhaugh, L. T., D. V. Boger. 1991. Flow Characteristics of Waxy Crude Oils: Application to Pipeline Designs, AIChe Journal, June.

Hunt, E. B., Jr. 1962. Laboratory Studies of Paraffin Deposition, JPT. 1259-1269.

Jorda, R. M. 1966. Paraffin Deposition and Prevention in Oil Wells. JPT. 1605-1612.

Victor, A. Adewusi. 1997. Prediction of Wax Deposition Potential of Hydrocarbon Systems from Viscosity-Pressure Correlations.

Zulkania, A., B. Pramudono, H. B. Mat, A. K. Idris and M. Manan. 2001. Malaysian Crude Oil Emulsions:Physical and Chemical Characterizations.

Elsharkawy, A. M., T. A. Al-Shhaf, M. A. Fahim. 2000. Wax Deposition from Middle East Crudes.

Maria Del Carmen Garcia. 2001. Paraffin Deposition in Oil Production.

Nagar, A., V. K. Mangla, S. P. Singh and J. Kachari. 2006. Paraffin Deposition Problems of Mumbai High.

Thomas, S. Golezynski. 2006. Understanding Wax Problems Leads to Deepwater Flow Assurance Solutions:Interpretation of Lab Measurements Provides Pigging and Treating Rules of Thumb.

Norman, F. Carnahan. 1989. Paraffin Deposition in Petroleum Production.