

**Comparative Study Of Different Types Of Inlet Diverter
To The Emulsion Stability**

By

MOHD AZRAAI BIN ZANAL ABIDIN (9977)

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

January 2011

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

CERTIFICATION OF APPROVAL

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Approved By,



(Pn. Mazlin Bt Idress)

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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 concept as specified in the references and acknowledgement ,and that the original work contained herein have not been undertaken or done by unspecified sources or persons



(MOHD AZRAAI BIN ZAINAL ABIDIN)

ABSTRACT

Emulsion will create a lot of operational challenges when separation failed to separate emulsion and water effectively. It will overloading of surface equipment ,increase cost of pumping wet crude ,risk of corrosion and etc. Thus, effective separation of emulsion is crucial to reduce operational challenges. As the objective of this Final Year Project(FYP) is to study of different Inlet Diverters (ID) to the emulsion stability. Basically Plate ID, Half Pipe ID and Hydrocyclone ID are tested upon separation effectiveness. This FYP is about to set up an experiment for crude oil mixture separation using gravity separator retrofit with Plate ID, Half Pipe ID and Hydrocyclone ID. In addition, this FYP also study on effect of different ID at fixed flow rate, different operating temperature and water cut towards emulsion stability. From the study conducted, the author found that the most preferable ID for effective separation is Half Pipe ID. Some modification have to be made for better improvement of the experimental result. The area of improvement includes more sophisticated design of ID, material used to construct ID, and flow rate that can be representative of actual field condition.

ACKNOWLEDGEMENT

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CHAPTER 1

INTRODUCTION

1.1)PROBLEM STATEMENT

Crude oil are complex mixtures of oil ,water,gas & even solids (sands,scale,silts called basic sediment).Although,water can be of great importance in the reservoir ,it can be problem especially when it reaches the surface.This mixture at surface usually forms water in oil (W/O) emulsion after passing through shearing environments & then stabilized by emulsifying agents presents in the fluid. Figure below showing various agitation points where shearing action take place during production.

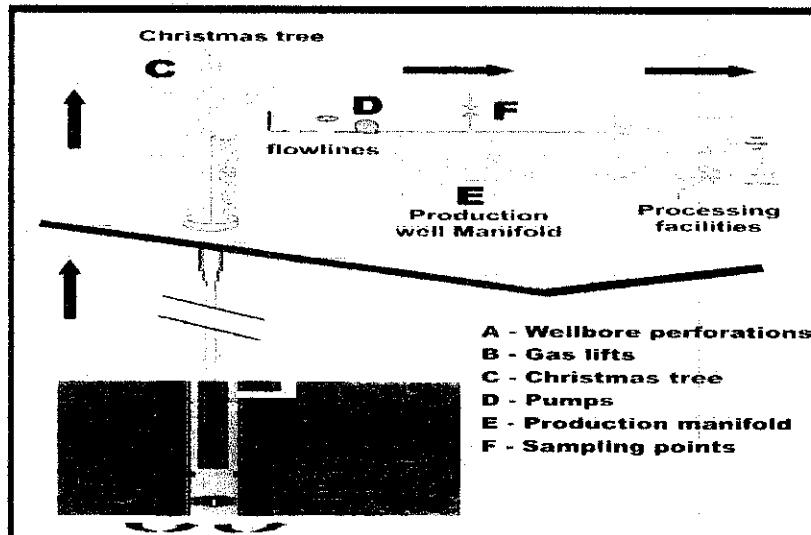


Figure 1 : Source of agitation during production

For emulsion to formulate ,it has to fulfill 3 condititons ,which are :

- 1) Two liquids forming the emulsions are immicible.
- 2) There must be sufficient agitation to disperse one liquid droplets in another
- 3) Presence of emulsifying agent to stabilize the dispersed water droplets.

Failure to separate emulsions efficiently can result in a number of commercial & operational challenges such as overloading of surface equipment, increase cost of pumping wet crude, fouling, tubing pressure build-up resulting from high viscous fluid, increase vessel heating cost, risk of corrosion in export lines and poisoning of refinery catalyst. Currently, several methods are being used to resolve emulsion problem. There are use of heaters, chemical application, electricity and separation equipments.

1.2) OBJECTIVE

The main objective of this project are :

- a) To set up an experiment for oil and water separation using gravity separator retrofit with HID, Plate ID & Half Pipe ID.
- b) To study effect of different ID at fixed flow rate, different operating temperature and water cuts towards emulsion stability.

1.3) SCOPE OF STUDY

The scope of study for this project is to investigate the effect of HID, Plate ID & Half Pipe ID towards the crude oil and water separation at different flow rate and operating temperature by measuring the thickness of layers formed after the gravity settling.

CHAPTER 2

LITERATURE REVIEW

2.1) SEPARATION PROCESS

2.1.1 Introduction

Produced wellhead fluids are complex mixtures of different compounds of hydrogen and carbon, all with different densities, vapour pressure and other physical properties. Pressure and temperature reduction will occur as well stream start to flow from the hot high-pressure up to the surface. The well stream will change in character and gas will evolve from liquids. Physical separation of these phases is one of the basic operations in the production, processing and treatment of oil and gas.

In current oil and gas industry, separator design play an important role to mechanically separate liquid and gas from hydrocarbon stream that coming from wellbore. Proper design is extremely crucial because a separation vessel is normally the initial processing vessel in any surface facilities. Improper design of this process component can "bottleneck", thus reduce the capacity of entire facility.

When oil and gas are mixed together with some intensity and allowed to settle, a layer of clean water will form at the bottom. After a range of three to thirty minutes, the change of water height will be negligible. "Free water" is water fraction that obtained from gravity settling. This free water is beneficial if separated before treating the remaining oil and emulsion layers. Pressure vessels has been designed to separate and remove this free water from a mixture of crude oil and water. "Three phase separator" and "free water knockout" are two terms that are suitable with pressure vessels. "Three phase separator" generally used when there is a large amount of gas to be separated from liquid. "Free water knockout" is normally used when the amount of gas is small relative to the amount of oil and water.

2.1.2 Factors affecting separation

Design of separation are greatly influenced by the flow stream. Several factors must be take into consideration before any separator design started. There are :

- i. Gas and liquid flow rate (minimum , average , peak)
- ii. Operating and design pressures and temperatures
- iii. Slugging tendencies of feed streams
- iv. Physical properties of fluids such as density and compressibility
- v. Designed degree of separation
- vi. Presence of impurities (paraffin , sand ,scale)
- vii. Foaming tendencies of crude oil
- viii. Corrosive tendencies of liquids or gas.

2.2) THREE PHASE GRAVITY SEPARATOR

Recently , gravity separator widely used in oil and gas industry for separation of hydrocarbon fluid (oil and gas) and water by using gravity settling. Separator can be categorized into two types which are :

- Two - phase separator to separate gas from oil in oilfields or gas from water from gas fields.
- Three -phase separators to separate the gas from the liquid phase , and water from oil.

Gravity separator available in horizontal or vertical pressure vessel with separation phase , internal components and control device as shown in the figure below

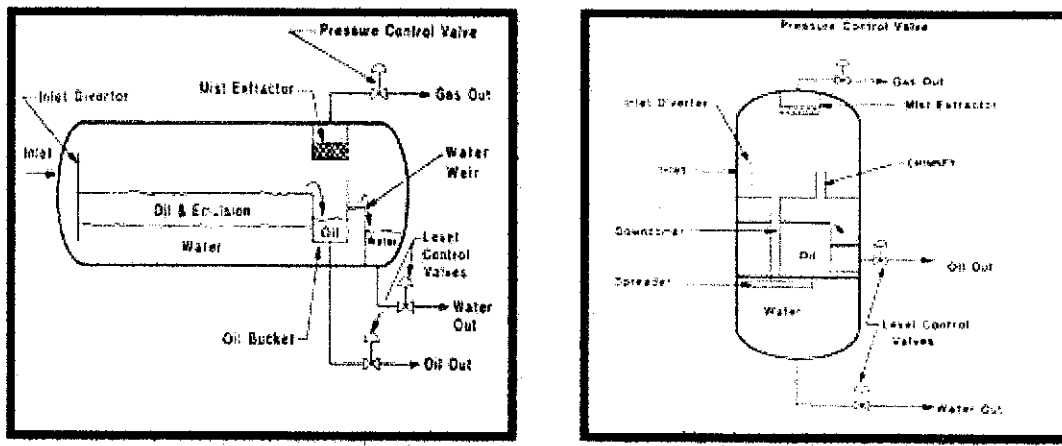


Figure 2.1 : Horizontal and vertical separator

2.2.1) Horizontal separator

Horizontal separator is more practical rather than vertical separator when it comes to three phase separation. Greater interface area for horizontal separator enhanced phase equilibrium between oil and water by gravitational settling thus provides more surface area for bubbles to escape.

Separator components:

- Primary separation section (Inlet Diverter) :- for bulk separation of gas from oil
- Secondary separation section – intersection area above the liquid for gas by means of gravity
- Mist extractor – to remove small liquid particles from the gas
- Liquid settling section , provide an intersection area for water and oil to settle by gravitational settling and remove gas from liquids

- c) Gas outlet
- f) Oil outlet
- g) Water outlet

FUNCTION OF SEPARATORS

- a) Make a primary phase separation of the predominantly liquid hydrocarbons from those which are predominantly gaseous
- b) Refine the primary separation by removing the entrainment remnant mist of liquid hydrocarbons from the gas
- c) Further refine the separation by providing for the removal of entrained gas phase bubbles from the liquid phase.
- d) Assume proper control, by devices which will provide for the removal of this separated liquid phase from the vessel without allowing an opportunity for re-entrainment of one phase into other.

Separation Process Description :

For gravity separator, there are 4 main sections which are inlet diverter, gravity settling, mist extractor and liquid content. Inlet diverter is a primary separation section which will control or dissipate the energy of fluids as they leave flowline and enter vessel when fluid from wellbore enters the separator and hits an inlet diverter, the change in momentum occurs. Change in momentum leads to gross separation between liquid phase and gas phase. The principle of gravity occurs at the gravity settling section where liquid with lower density (gas) is on top of the liquid (oil and water) while the liquid sumps to the liquid collecting section at the bottom of the separator. Some of the drops are such a small diameter that they are not easily separated by the gravity settling section. A gravity settling section is to ensure that the gas and liquid flow rates are always within the maximum allowable superficial velocity limits which will allow adequate separation. Before gas leaves the vessels it passes through a coalescing section or mist extractor. A mist extraction or coalescing section will minimize turbulence in the gas section. This section uses elements of vanes, wire mesh or plates to coalesce and remove the very small droplets of liquid in one final separation before the gas leaves the vessels. At this coalescence section, 99 percent of droplets size more than 10 microns are removed when the gas flows through it. Finally, liquid content applies the principle of equilibrium. It

provides an intersection area for water and oil to settle by gravitational settling and remove gas from liquids. Liquid collecting and removal section will prevent re-entrainment from separating process.

Comparison of horizontal and vertical separator:-

| HORIZONTAL | VERTICAL |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><u>ADVANTAGES:</u></p> <ul style="list-style-type: none"> -Greater control of turbulence -Better use of retention volume -Easier to service and maintain <p><u>DISADVANTAGES:</u></p> <ul style="list-style-type: none"> -More installation space required -Not as good for handling sand or mud | <p><u>ADVANTAGES:</u></p> <ul style="list-style-type: none"> -Can handle larger quantity of sand or mud -Good surge capacity -Can be cleaned easier <p><u>DISADVANTAGES:</u></p> <ul style="list-style-type: none"> -Expensive gas operation -Not good for foam -Lower liquid capacity with high GOR |

Table 2.1 : Comparison of horizontal and vertical separator

2.2.2 SEPARATION THEORY

Stokes law

if the particles are falling in the viscous fluid by their own weight due to gravity, then a terminal velocity, also known as the settling velocity, is reached when this frictional force combined with the buoyant force exactly balance the gravitational force. The resulting settling velocity (or terminal velocity) is given by:

$$V_s = \frac{2(\rho_p - \rho_f)}{9\eta} g R^2$$

where :

- V_s is the particles' settling velocity (m/s) (vertically downwards if $\rho_p > \rho_f$, upwards if $\rho_p < \rho_f$),
- g is the gravitational acceleration (m/s^2),
- ρ_p is the mass density of the particles (kg/m^3), and
 - ρ_f is the mass density of the fluid (kg/m^3).

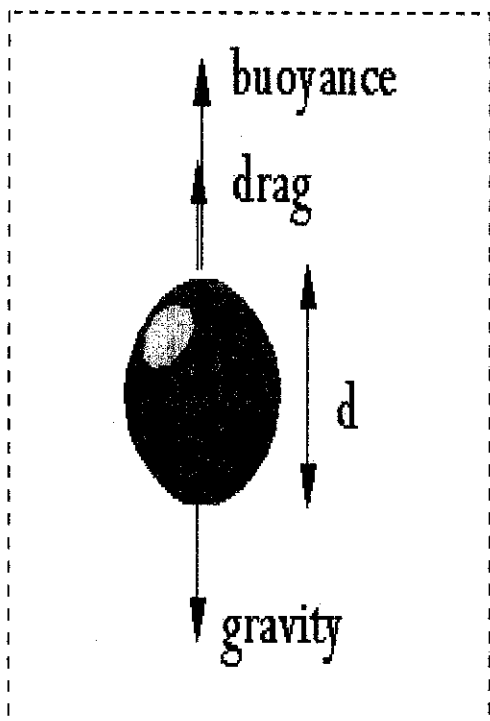


Figure 2.2 : Force exerted on a particle

The FBD in this figure lists three forces acting on the sphere; F_b , F_d , and mg . The first two forces arise from the buoyancy effect of displacing the fluid and from the viscous drag of the fluid on the sphere, respectively. Both forces act upwards -- buoyancy tending to 'float' the sphere (F_b) and the drag force (F_d) resisting the acceleration of gravity. The only force acting downwards is the body force resulting from gravitational attraction (mg).

Retention Time

To assure that the liquid and gas reach equilibrium at separator pressure a certain liquid storage is required. This is defined as "retention time" or the average time a molecule of liquid is retained in the vessel assuming plug flow. The retention time is thus the volume of the liquid storage in the vessel divided by the liquid flow rate.

For most applications retention times of between 30 seconds and 3 minutes have been found to be sufficient. Where foaming crude is present retention times up to four times this amount may be needed.

2.3) WELL FLUIDS AND THEIR CHARACTERISTIC

This section will briefly describe some of physical characteristics of well fluids handled by oil/gas separators.

Crude Oil: Crude oil is a complex mixture of hydrocarbons produced in liquid form. The API gravity of crude oil can range from 6 to 50° API and viscosity from 5 to 90000 cp at average operating conditions. Viscosities are nearly always smaller in the reservoir. Color varies through shades of green, yellow, brown and black.

Condensate: This is a hydrocarbon that may exist in the producing formation either as a liquid or as a condensable vapour. Liquefaction of gaseous components of the condensate usually occurs with reduction of well fluid temperature to surface operating conditions. Gravities of the condensed liquids can range from 50 to 120° API and viscosities from 2 to 6 cp at standard condition. Colour may be water-white, light yellow, or light blue.

Natural gas: A gas is a substance that has no shape or volume of its own. It will completely fill any container in which it is placed and will take the shape of the container. Hydrocarbon gas, associated with crude oil is referred as a natural gas and may be found as “free gas” or “solution gas”. Specific gravity of natural gas may vary from 0.55 to 0.90 and viscosity from 0.01 to 0.024 cp at standard condition.

Free gas: Free gas is hydrocarbon that exists in the gaseous phase at operating pressure and temperature. Free gas may refer to any gas at any pressure that is not in solution or mechanically held in liquid hydrocarbon.

Solution gas: It is homogeneously contained in oil at a given pressures and temperature. A reduction in pressure and temperature may cause the gas to be evolved from oil.

Water: Water produced with crude oil and natural gas may be in the form of vapour or liquid. The liquid water may be free or emulsified. Free water reaches surface separated from the liquid hydrocarbon. Emulsified water is dispersed as droplets in the liquid hydrocarbon. The water can be fresh or briny in nature and may contain undesirable gases such as CO₂.

Impurities or Extraneous gas: Produced well fluids may contain such as gaseous impurities such as nitrogen, carbon dioxide, hydrogen sulfide and other gases that are not hydrocarbon in nature or origin. Well fluid may also contain liquids such as water and paraffins. They may also contain solids such as drilling mud, sand, silt and salt.

2.4) EMULSION

2.4.1 Forming Emulsion

Emulsion are stabilized by emulsifiers (surface active agents or surfactants) that tend to concentrate at the oil-water interface where they form interfacial films. This generally leads to lowering of the interfacial tension (IFT) and promotes dispersion and emulsification of droplets. Naturally occurring emulsifiers in the crude oil include higher boiling fractions, like asphaltenes and resins, organic acids and bases. These compounds are believed to be main constituents of interfacial films which form around water droplets in an oilfield emulsion. Other surfactants that may be present are from chemicals that are injected into the formation or well bore such as drilling fluids, stimulation chemicals, injected inhibitors for corrosion, scale, waxes and asphaltene control. Fine solids can also act as mechanical stabilizers. These particles have to be much smaller than emulsion droplets, collect at oil-water interface and are wetted by both the oil and water. The effectiveness of these solids in stabilizing emulsions depend on number of factors such as particle size, particle interactions and the wettability of particles. Emulsion will exist when there are two mutually immiscible liquids, an emulsifying agent and sufficient agitation to disperse the discontinuous phase into the continuous phase. Oil and water are two immiscible fluids in oil production from oilfield. Small solids particles, paraffins, asphaltene, etc are emulsifying agents that always present in formation fluids. Fluid from well bore will go through tubing, up to surface choke then will enter the separator, along the way there are sufficient agitation that leads to emulsion forming.

2.4.2 Emulsion stability

From Thermodynamic point of view, an emulsion is an unstable system. This is because natural tendency for liquid-liquid system to separate and reduce its interfacial area and hence its

interfacial energy. Most of emulsion are stable over period of time ,it involved kinetic stability. Produced oilfield emulsion are classified into 3 main parts based on their kinetic stability:

- a) Loose emulsions: Emulsion that will separate in a few minutes. The separated water sometimes refer as free water
- b) Medium emulsions : Those that will separate in the matter of ten minutes.
- c) Tight emulsion : Emulsion that will separate in the matter of hours or even days.

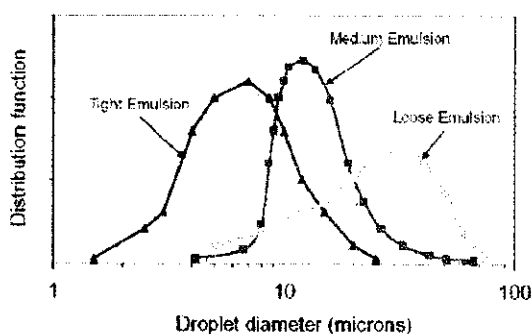


Figure 2.3 : droplet size distribution of crude oil emulsion

Kinetic stability is a consequence of small droplets size and the presence of an interfacial film around water droplets. This emulsion kinetic stability is achieved by stabilizing agents (or emulsifiers) which could be naturally occurring in the crude oil or added during production.

Interfacial Films:

Produced emulsion are stabilized by films that are produced around water droplets at oil-water interface. This Interfacial Films results from adsorption of high molecular weight polar molecules that are interfacially active. This interfacial films can enhance emulsion stability by reducing interfacial tension or increasing interfacial viscosity. These films are classified into two categories:

- a) **Rigid or Solid Film** : This film like insoluble skin on water droplets. These film play significant role in hampering the drop coalescence process by providing a structural barrier to droplet coalescence and increase emulsion stability.
- b) **Mobile or Liquid Film**: Formed when demulsifiers is added to an emulsion. They are less stable thus coalescence of water droplet is enhanced.

Factors affecting emulsion stability

“Emulsion stability” is one of the crucial factor that must be considered when separating the emulsified water from the oil. The more stable the emulsion is , more difficult to separate it from fluid. As for emulsion stability , it depends on several factors :

- *Density difference between oil and water phases* : The greater the difference in density, the more quickly water droplets will settle from the oil phase.
- *Viscosity of oil* : As viscosity increases , more agitation required to shear water particles down to smaller size in oil phase (difficult separation)
- *Interfacial tension* : Less interfacial tension needed for easier separation
- *Size of dispersed water particles* : Larger water particle will settle out faster of the oil phase
- *Presence and concentration of emulsifying agents* : When no emulsifier is present, interfacial tension between oil and water is high, thus water particles coalescence easily upon contact.
- *Heavy polar fraction in crude oil*: These include asphaltenes, resins and oil soluble organic acids (e.g naphthenic, carboxylic, acids) & bases. These compound are main constituents of interfacial films surrounding the water droplets that give the emulsions their stability.
- *Solids*: Fine solids present in the crude oil are capable of effectively stabilizing emulsion.
- *Temperature*: Temperature can greatly influence emulsion stability.
- *pH*: pH of water have significant effect on emulsion stability (interfacial film).

2.4.3 Types of emulsion

Two types of emulsion are readily distinguished in principle, depending on which kind of fluid forms continuous phase :

- **Oil-in-water (O/W)** for oil droplets dispersed in water

- Water-in-oil (W/O) for water droplets dispersed in oil

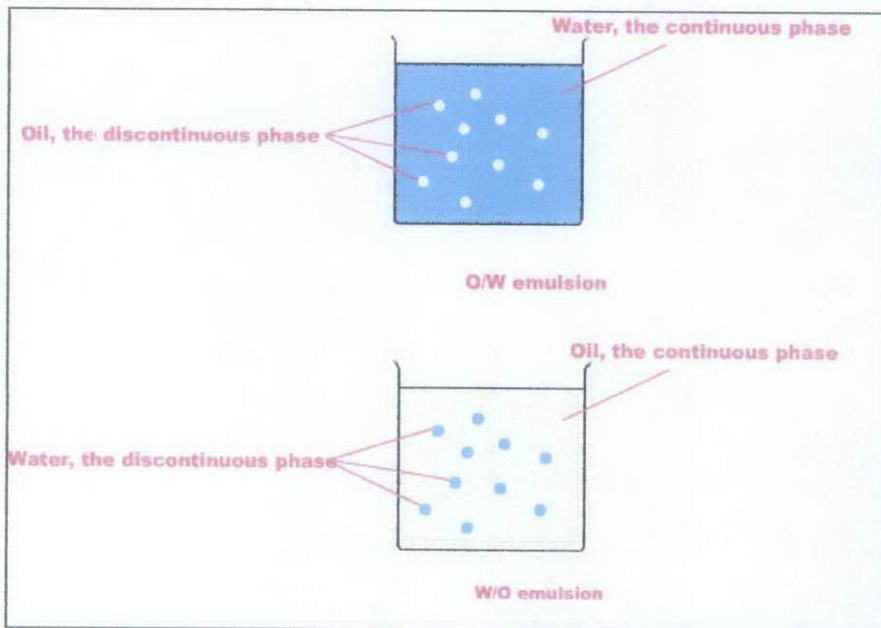


Figure 2.4 :Types of emulsion

Rule of thumb to determine the types of emulsion formed is component with smaller fraction will be dispersed phase and component with larger volume fraction will be continuous phase. In oil and gas industry, water in oil (W/O) are more common (most produced emulsion coming from this type) and therefore oil in water (O/W) are sometimes called "reverse" emulsion. Practical situations are not always so simple and one may encounter double emulsion that is, emulsions that are oil-in-water-in-oil (O/W/O) and water-in-oil-in-water (W/O/W). For instance, O/W/O denotes double emulsion, containing oil droplets dispersed in aqueous droplets can be quite large (tens of μm) and can contain many tens of droplets of the ultimate internal phase.

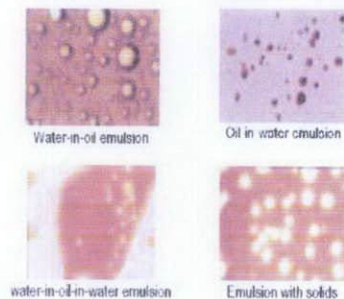


Figure 2.5 : Types of emulsion

There can even be more complex emulsion type. This type of emulsion is formed depends on number of factors. If the ratio of phase volumes is very large or very small, then the phase having a smaller volume is frequently the dispersed phase. If the ratio is closer to one, then other factors will come into place. Figure below show an example of a crude oil W/O/W/O emulsion.

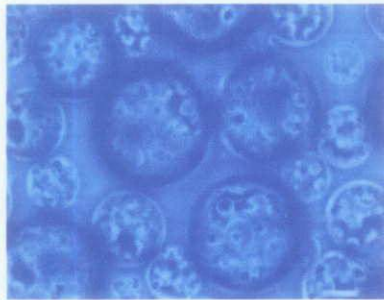


Figure 2.6 : W/O/W/O emulsion

2.4.4 Characterization of emulsion

Appearance and Emulsion Type

Appearance is depending on the droplet sizes and the difference in refractive indices between the phases. Emulsion can be transparent if either the refractive index of each phase is same or alternatively, if the dispersed phase is made of the droplets that are sufficiently small compared with the wavelength of the illuminating light.

Texture

The texture of emulsion usually reflects that of external phase. O/W emulsion will feel “watery or creamy” while W/O emulsion will feel oily or “greasy”.

Mixing

An emulsion readily mixes with a liquid that is miscible with the continuous phase. For example, milk (O/W) can be diluted with water while mayonnaise (W/O) can be diluted with oil.

Dyeing

Emulsions are most readily and consistently coloured by dyes soluble in continuous phase.

Conductance

O/W emulsion have very high specific conductance while W/O emulsion have very low specific conductance

Inversion

If the emulsion heavily concentrated, it will probably invert when diluted with additional internal phase.

2.4.5 Emulsion treatment

Failure to separate emulsion effectively can result in a number of commercial and operating challenges such as:

- i. Overloading of surface separation equipment
- ii. Increase cost of pumping wet crude
- iii. Fouling
- iv. Tubing pressure build up resulting from high viscous crude
- v. Increase vessel heating cost
- vi. Risk of corrosion in export lines
- vii. Poisoning of refinery catalyst

2.4.6 Destabilizing emulsion

Kinetic stability of emulsion comes from formation of interfacial films encapsulating in water droplets. To separate emulsion into oil and gas, we need to destroy interfacial film first and the droplets have to be coalescence. The factor that enhance emulsion breaking are :

- i. Increase temperature
- ii. Reduce agitation or shear
- iii. Increase retention time

- iv. Solid removal
- v. Controls of emulsifying agents

2.4.7 Mechanism involved during demulsification

Demulsification means breaking emulsion into its component phase. There are two mechanisms involved which are :

- i. **Flocculation** : The first step in demulsification is flocculation of water droplets. The rate of flocculation depends on water cut, temperature, viscosity of oil and the density difference between oil and gas.
- ii. **Coalescence** : This is an irreversible process that can reduce water droplets. Coalescence enhances by low oil viscosity, high rate of flocculation, high water cuts and high temperatures.

To resolve or break the emulsions, several ways can be applied :

- i. The use of heaters (to increase process temperature then reduce crude oil viscosity)
- ii. Adding chemicals (using demulsifiers)
- iii. Electricity(applying electrical field to promote coalescence)
- iv. **Separation equipment**. (reducing flow velocity that allows gravitational separation of oil and gas)

As for this project which is entitled “*Comparative study of different inlet diverter to the emulsion stability*”, we will try to resolve or break emulsion stability by means of separation equipment (Inlet Diverter).

Physical problems in the separation of oil and gas :-

1. Delivery of stable oil into the stock tanks.
2. Clean gas available for gasoline plant and fuel.
3. If oil and gas mixture flow directly into stock tank without being separated, gas in leaving the oil would carry lighter hydrocarbons along as a spray, which in the end would result in a decreased volume and gravity of the oil.

Thus, effective separation means (using inlet diverter) lead to better separation and greater profit margin.

2.4.8 EFFECT OF TEMPERATURE TO EMULSION STABILITY

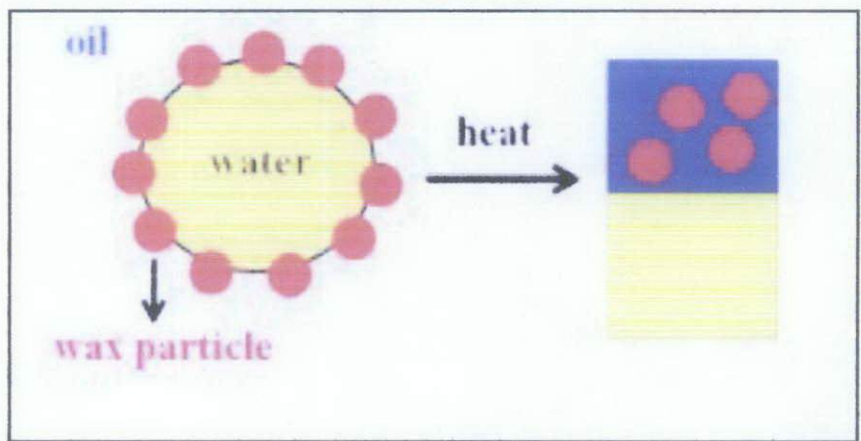


Figure 2.7 - Effect of temperature to emulsion stability

Based on the Figure 2.7, we decided to choose a particle concentration which yields stable emulsions at room temperature and investigate what happens to their stability upon increasing the temperature gradually. The question here was whether the coalescence stability was sensitive to the physical state of the adsorbed particles below and above the melting point range. Two emulsions were prepared from a dispersion of 10 wt% of Microklear 418 or Aquawax 114 particles in oil and an equal volume of water by hand shaking for 2 min at room temperature. Using a water bath, the temperature was increased in 10° steps to 95 °C, with the vessels being hand shaken gently and then held for 1 h. at each temperature. Between each temperature, the rate of temperature increase was close to 2 °C/min, comparable to that in DSC studies.

Emulsion stabilities are plotted *versus* temperature in for both wax-stabilised systems.

The overall trend in both is that the sedimentation (\dot{V}_0) and coalescence (\dot{V}_w) extents increase with temperature as particles are transformed from solid to liquid. The increase in sedimentation may be due in part to the decrease in the viscosity of the continuous oil phase with temperature, which falls by over a factor of three between 20 and 60 °C. This may be coupled to the increase in coalescence as drops become more concentrated. As the stabilising wax particles begin to melt,

molecular species desorb from the oil-water interface and dissolve in the oil phase. The drops lose their protective armour and fusion between them proceeds. Phase separation is nearly complete at 95 °C for Microklear 418 emulsions (well above the melting range) and 75% complete for those of Aquawax 114 (below the end of the melting range). It can be seen that significant coalescence occurs in a narrow temperature range above 80 °C for Microklear 418 emulsions, whereas it is more gradual between 50 and 95 °C for Aquawax 114 emulsions. This difference is related to the relatively narrow melting point range determined earlier for the former and the much wider range measured for the latter, suggesting that the dominant influence of temperature in the emulsions is on the properties of the wax particles themselves.

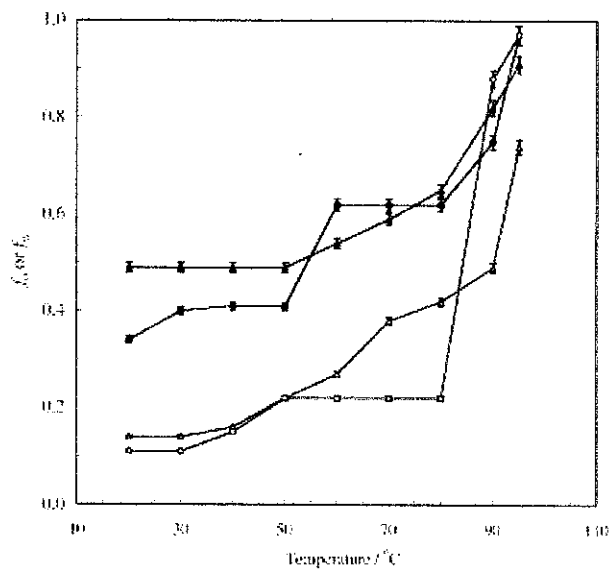


Figure 2.8 : Emulsion stability increased with increasing temperature

Microscope images of selected emulsions at low and high temperature are given in On warming the Microklear 418 emulsion, (a) and (b), we notice that some of the drops become non-spherical. This is a characteristic of particle-stabilised emulsions subjected to coalescence and is linked to the irreversible nature of particle adsorption. In the Aquawax 114 case, (c) and (d), although this shape change is less prominent, it is clear that particle aggregates at the surface of drops are more numerous at the low temperature than at the high one..

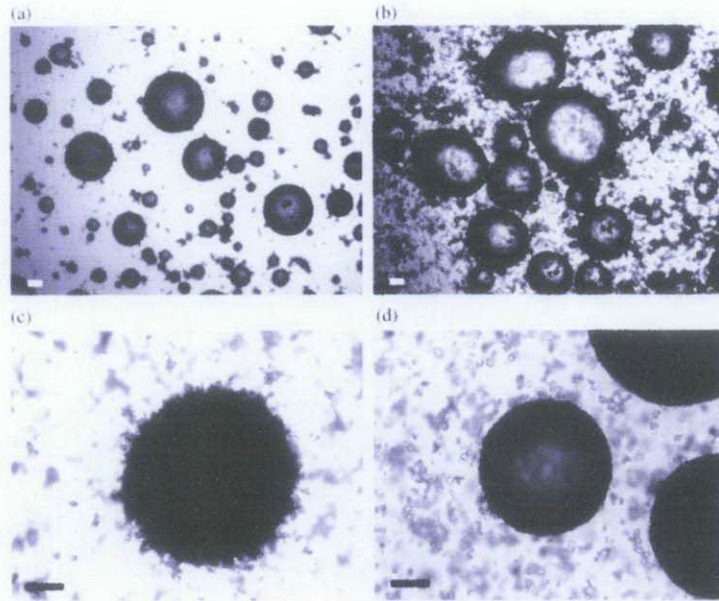


Figure 2.9 : Micronize picture of emulsion at low and high temperature

2.5 INLET DIVERTER

2.5.1 Introduction

When fluid with high flow rate enter the separator , this flow stream will firstly hit Inlet Diverter that mounted in the separator. Change in momentum will occurred at the time of fluid stream hit Inlet Diverter. Momentum of incoming fluid will be reduced drastically when it hit Inlet Diverter. These change involve fluid flow distribution where gross separation of gas from fluid happened. The concept of Inlet Diverter is to change stream momentum thus enable liquid droplet to fall and gas bubble to rise.

2.5.2 Types of conventional Inlet Diverter

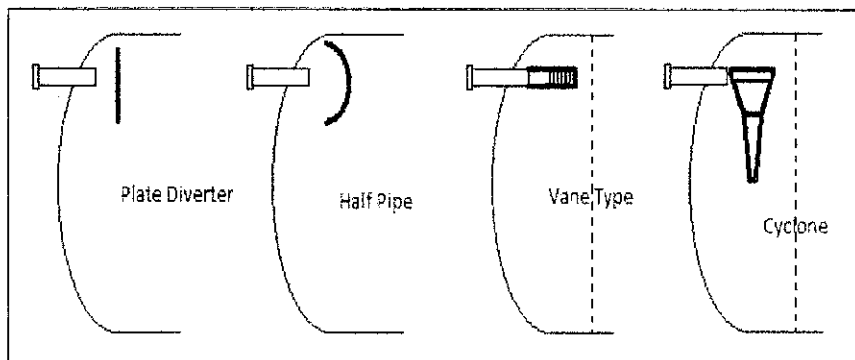


Figure 2.10 : Types of Inlet Diverter

As referred to Victor van Asperen et Al , there are four main function that an Inlet Diverter should perform :

- i. *Reduce the feed stream momentum to ensure good gas and liquid distribution.*
Ineffective momentum change will lead to longer retention time and separation efficiency are affected.
- ii. *Separate bulk liquid.*
Good bulk liquid separation will greatly reduced the load on the rest part of separator.
- iii. *De-foam the incoming fluid*
Separation process will boost greatly if an inlet device can breakdown the foam.
- iv. *Prevent re-entrainment of already separated liquid –liquid shattering*

2.5.3 Comparison of conventional inlet diverter

| Inlet Device Functions | Plate Diverter | Half Pipe | Vane Type | Cyclone |
|---------------------------------|----------------|-----------|-----------|---------|
| 1) Reduce feed stream momentum. | Good-Poor | Good-Poor | Good | Good |
| 2) De-foam incoming fluid. | Poor | Poor | Average | Good |
| 3) Bulk separation. | Poor | Average | Good | Good |
| 4) Re-entrainment prevention. | Average-Poor | Average | Good | Good |

Table 2.2: Comparison of conventional inlet diverter

From this table, Cyclone Inlet Diverter have outermost advantage as compared to Plate diverter, Half pipe and vane type. As for this project, Plate diverter, HID, Half pipe will be used and the emulsion thickness which represent emulsion stability will be calculated.

2.5.6 Plate Diverter design :

Materials to be used : Prospex

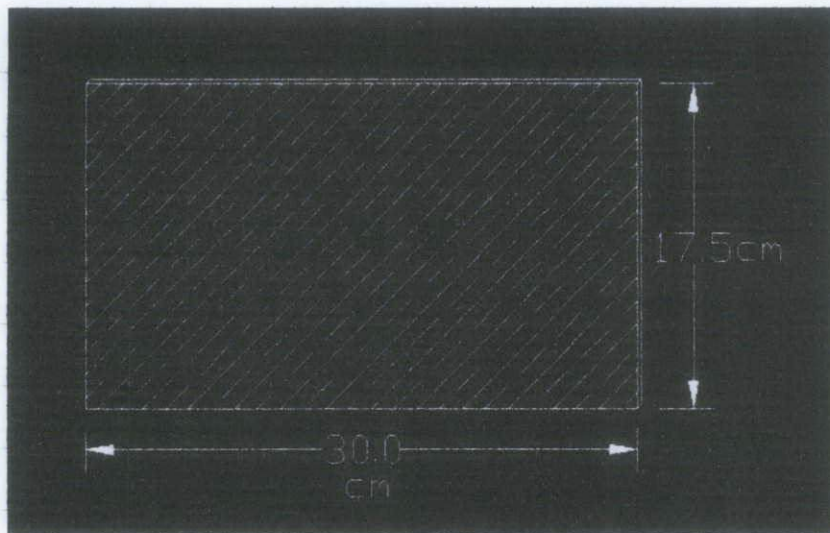


Figure 2.15 : Plate Diverter Design

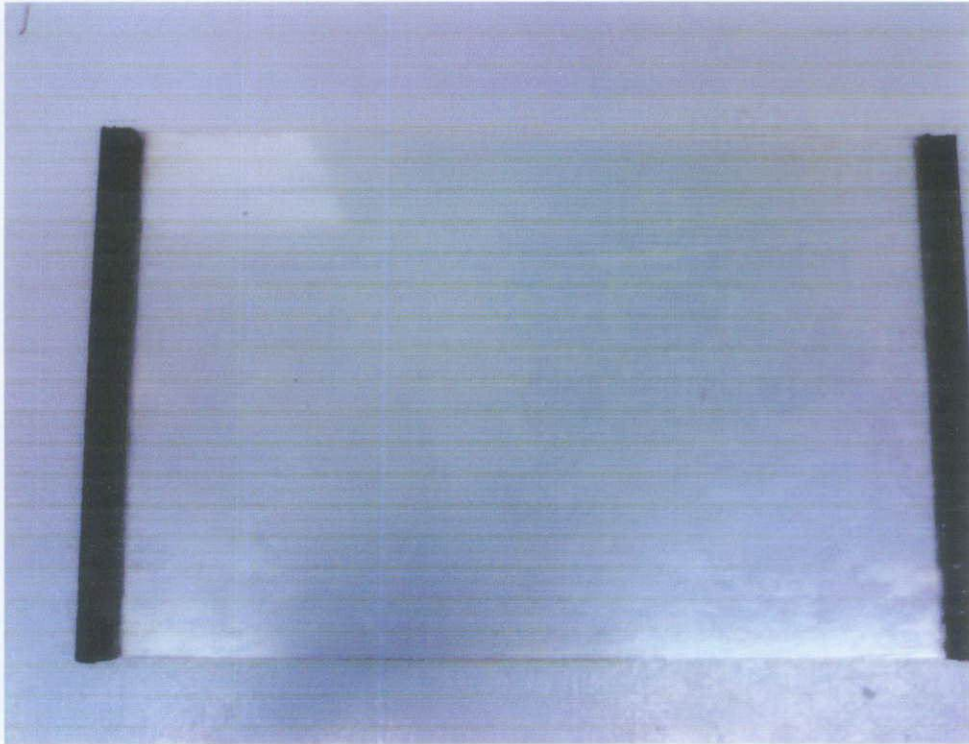


Figure 6.12 : Plate Diverter

2.5.7 : Half Pipe Inlet Diverter Design :

Material used: PVC Pipe

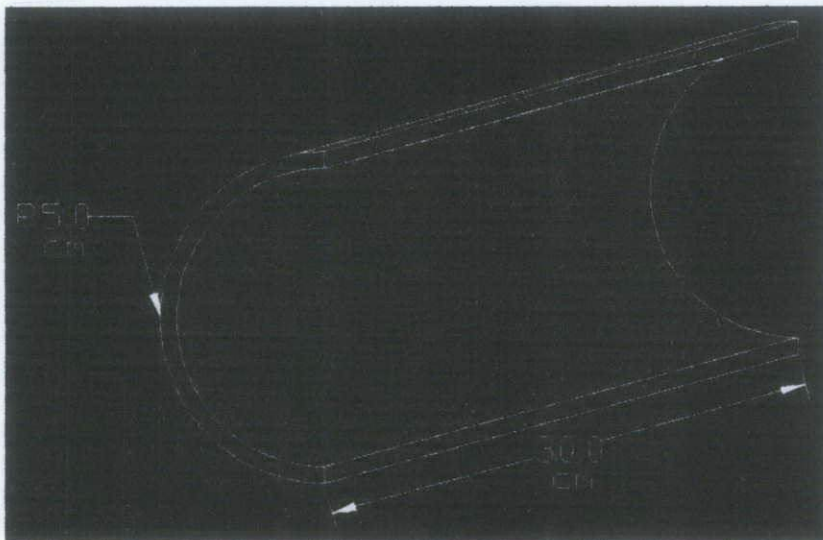


Figure 2.13 : Half Pipe Design.

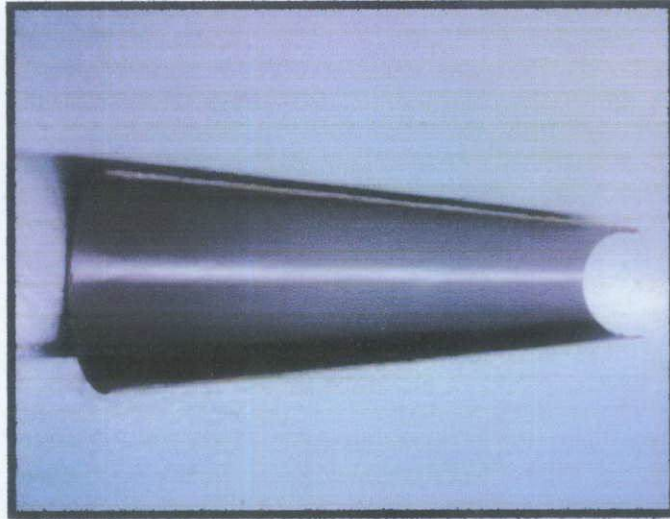


Figure 2.14 : Half Pipe Inlet Diverter

2.6.7 Hydrocyclone Inlet Diverter Design:

Material to be used : PVC pipe , aluminium (previous model will be take into consideration)

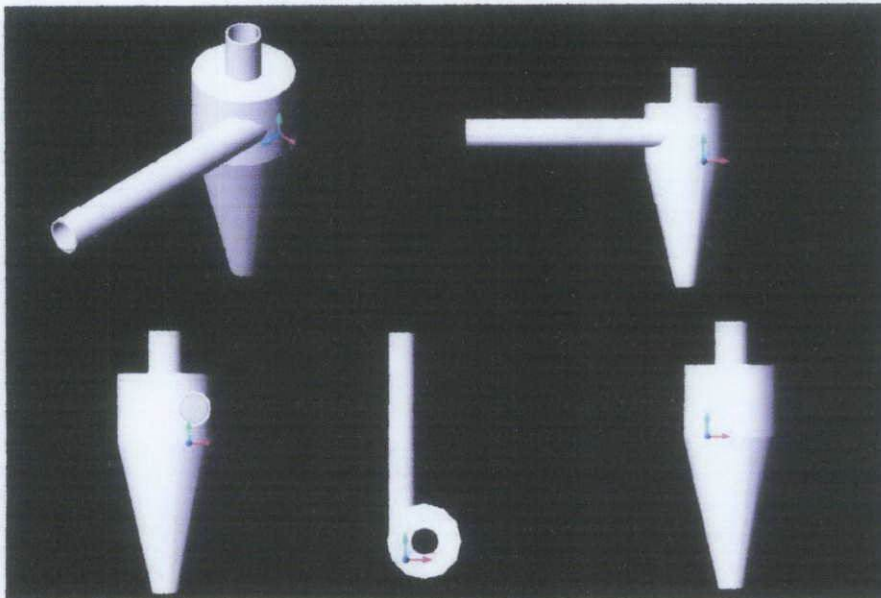


Figure 2.15 CAD draw of HID

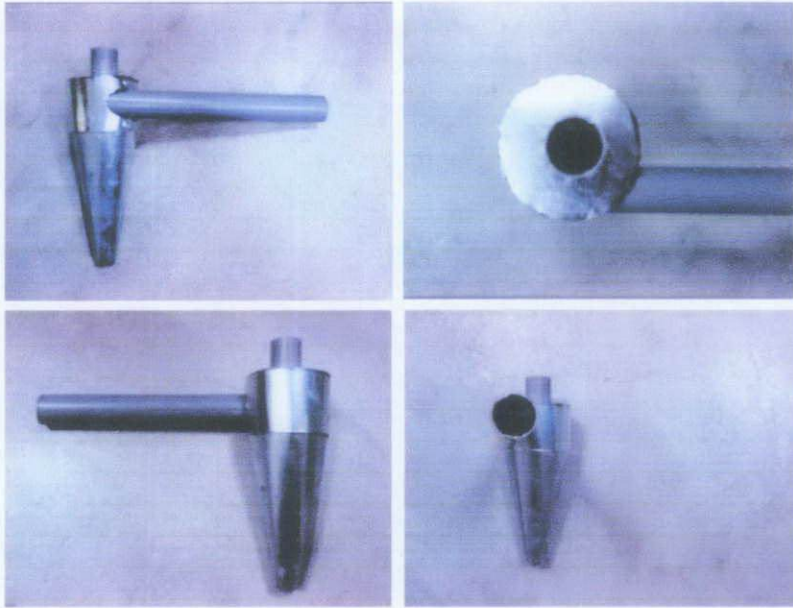


Figure 2.16 : Previous design of Hydrocyclone inlet diverter

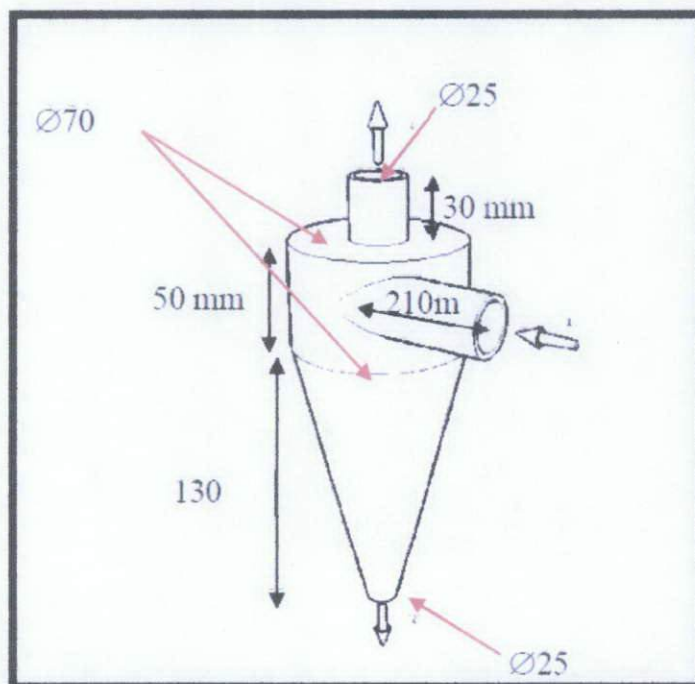


Figure 2.17: HID dimensions

CHAPTER 3

METHODOLOGY

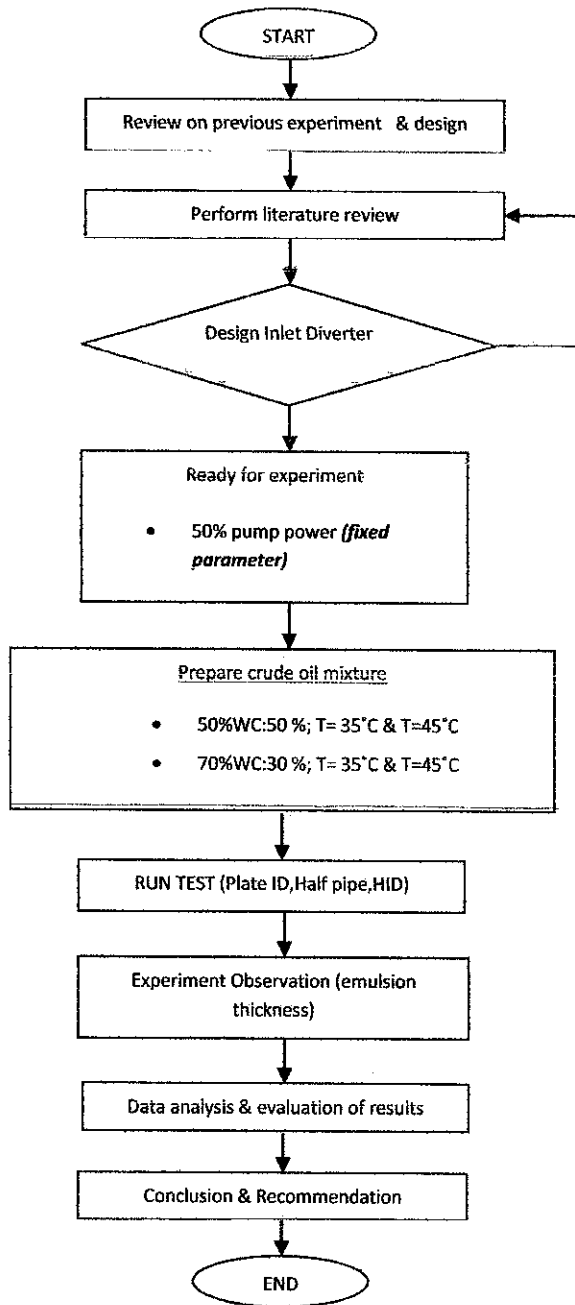
3.1 FINAL YEAR PROJECT MILESTONE

As for this FYP 1 , the focus of this project is more on the feasibility study an research on the principle of oil-water separation , types of inlet diverter and emulsion stability. An experiment toward this project will be conducted in FYP 2 using a small scale separator, crude oil and also different types of inlet diverter (Plates , Half Sphere , and HID).

| <u>FYP 1</u> | | | | | | |
|------------------------|------------------------------|------|-----|--------------------|-----|--|
| JUL | AUG | SEPT | OCT | NOV | DIS | |
| PROJECT IDENTIFICATION | | | | | | |
| PROJECT DEVELOPMENT | | | | | | |
| CONTINUOUS RESEARCH | | | | | | |
| | LITERATURE REVIEW | | | | | |
| | PRELIM REPORT | | | | | |
| | DESIGN & CONSTRUCT PROTOTYPE | | | | | |
| | PROGRESS REPORT | | | | | |
| | INTERIM REPORT | | | | | |
| | | | | FYP 1 PRESENTATION | | |

| <u>FYP 2</u> | | | | |
|---------------------|-----|-----|-------|--------------------|
| JAN | FEB | MAC | APRIL | MAY |
| PROJECT DEVELOPMENT | | | | |
| RUN EXPERIMENT | | | | |
| PROGRESS REPORT | | | | |
| FINAL REPORT | | | | |
| | | | | FINAL PRESENTATION |

3.2 PROJECT PROCEDURES AND STRATEGIES



3.3 DESIGN OF SEPARATOR

The objective of this project to investigate the design of conventional inlet diverter towards emulsion stability. Emulsion thickness will be measured as representative of emulsion stability. Greater thickness of emulsion formed indicates more stable emulsions. The design of three phase gravity separator (horizontal separator) using Level Interface Controller will be used. Dimension of this separator is scaled down to ration of 16. (ratio = 1:16). This separator can obtain 20L fluid at a time. Perspex is used as main material in constructing the vessel wall because of its cost feasibility and also can resist the oil water mixture properties at certain temperature and pressure.

Vessel dimension : $1.5 \text{ ft} \times 1 \text{ ft} \times 0.47 \text{ ft} = 0.705 \text{ ft}^3 = 20 \text{ L}$

Figure below are separator that has been used in the previous project .

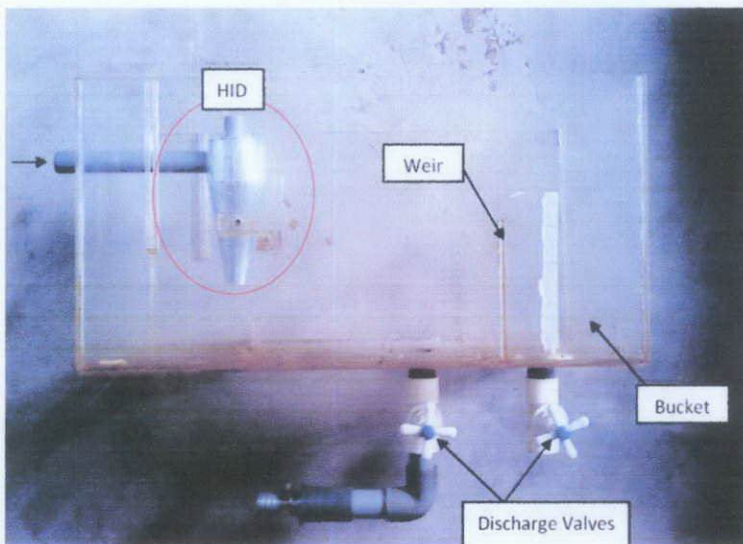


Figure 3.1 : Separator retrofited with HID design

3.3.1 "Bucket and weir" separator design

This design eliminates the need for a liquid interface controller. Both oil and water flows over weirs where level control is accomplished by a simple displacer float. The oil overflows the oil weir into an oil bucket where its level is controlled by a level controller that operates the oil dump valve. The water flows under the oil bucket and then over a water weir. The level downstream of this weir is controlled by a level controller that operates the water dump valve.

The height of the oil weir controls the liquid level. The difference in height of the oil and water weirs controls the thickness of the oil pad due to specific gravity differences. It is crucial for the operation of separation that the water weir height be below the oil weir height so that the oil pad thickness provides sufficient oil retention time.

3.4 EXPERIMENT SET UP

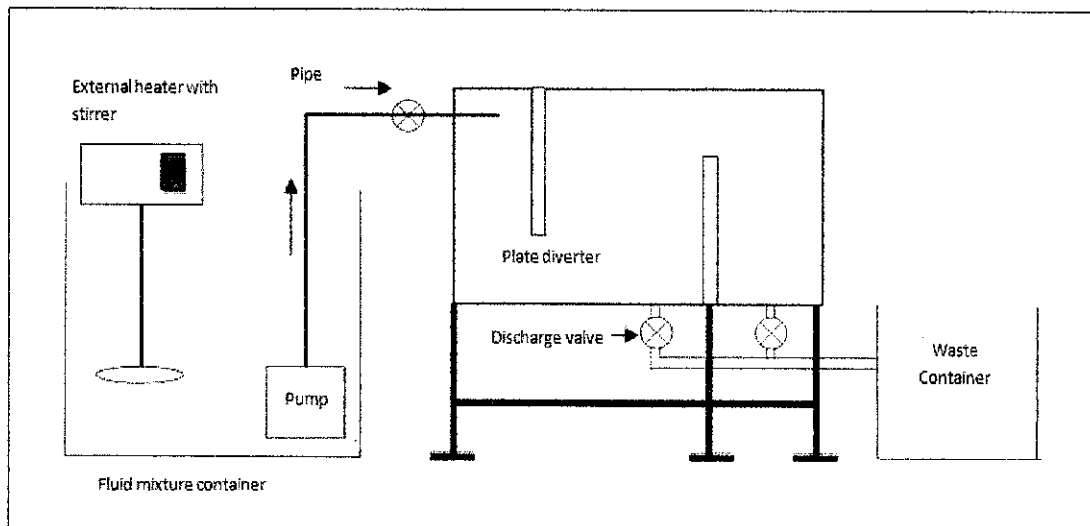


Figure 7.2 : Experiment Set Up

3.5 TOOLS REQUIRED

The main component and available substances to conduct experiment is shown in the table below : -

Chemical Substances

| | |
|-----------------|-----------------------------------------------------------------------------------------------|
| Crude oil | To be used as main fluid in this project. Act as hydrocarbon fluid that need to be separated. |
| Water | Mix with Hydrocarbon Fluid |
| Sodium Chloride | To be used as brine which contain of 1000ppm of salt in 1 liter of water |

Table 3.1 Chemical Substances

Mechanical Equipments

| | |
|-----------------------|-------------------------------------------------------------------------------|
| Pump | To pump oil-water mixture to the separator |
| Waste Container | Contain oil-water mixture waste |
| External Heater | Supply heat to mixture |
| Power Supply | Provide electric power to pump |
| Small scale separator | Main equipment to conduct project |
| Tube pipe | Act as pipeline to transport oil-mixture |
| Ruler | To measure thickness of water, emulsion and oil formed after gravity settling |
| Hand Glove | Handle crude oil as safety precaution. |

Table 3.2 : Mechanical Equipments

To ensure safety during when experiment was conducted ,some safety precaution has to be taken into consideration:-

| HAZARDS | SAFETY PRECAUTION |
|----------------------------|------------------------------------------------------------------------------------------------------------------------------------------|
| Electrical Equipment | <ul style="list-style-type: none"> • Use rubber glove as insulator • Insulate all contact surface area |
| Highly flammable crude oil | <ul style="list-style-type: none"> • Avoid any contact from heat source • Fire extinguisher that is ready to use |

| | |
|--------|--------------------------------------------------------------------------------------------|
| | <ul style="list-style-type: none"> • Avoid exposure to any electric circuit |
| Heater | <ul style="list-style-type: none"> • Avoid touching hot surface |

Table 3.3: Safety Precaution

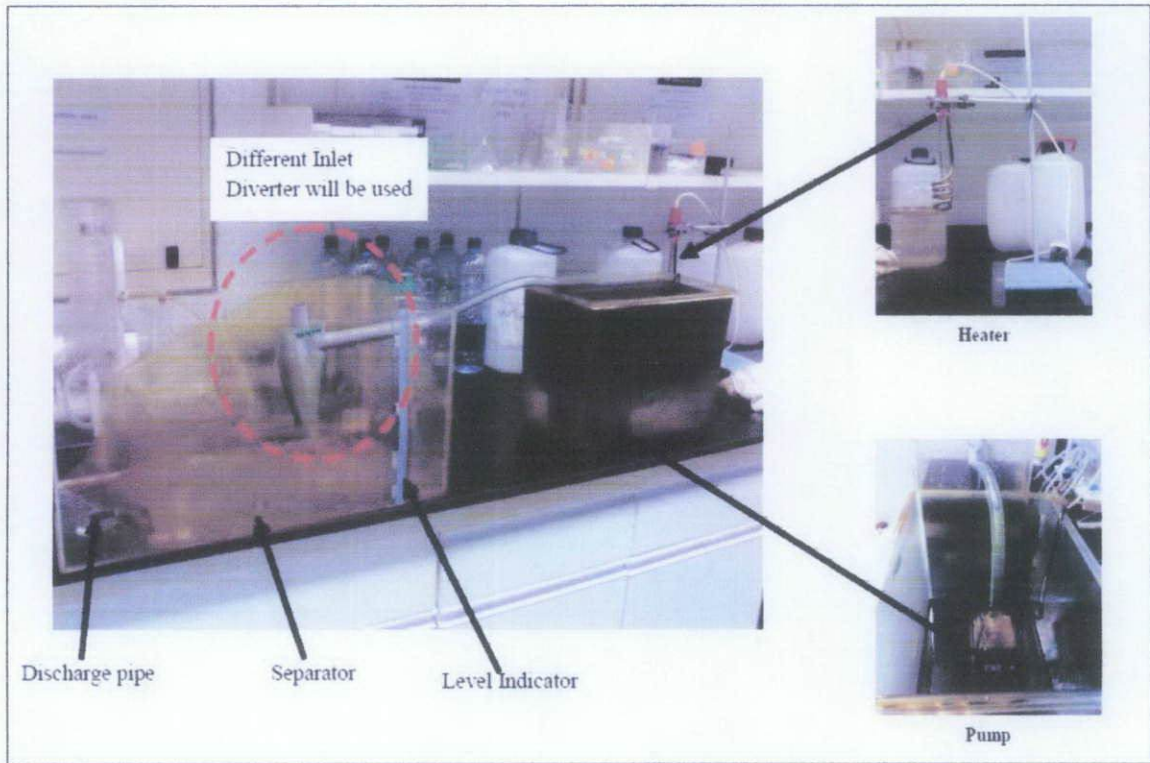


Figure 3.3 : Actual experiment set up

CHAPTER 4

RESULT & DISCUSSION

4.1 Overview

The parameters or conditions for experiment are set up differently to investigate different factors toward emulsion stability by using different inlet diverters. All cases are tabulated as follows:

Fixed parameter is : 50% pump power which flow rate is 12.9 L/min.

| CASE | WATER CUT | TEMPERATURE | INLET DIVERTER |
|------|-----------|-------------|----------------|
| 1 | 50% | 35°C | Plate |
| 2 | 50% | 35°C | Half Pipe |
| 3 | 50% | 35°C | Hydrocyclone |
| 4 | 50% | 45°C | Plate |
| 5 | 50% | 45°C | Half Pipe |
| 6 | 50% | 45°C | Hydrocyclone |
| 7 | 70% | 35°C | Plate |
| 8 | 70% | 35°C | Half Pipe |
| 9 | 70% | 35°C | Hydrocyclone |
| 10 | 70% | 45°C | Plate |
| 11 | 70% | 45°C | Half Pipe |
| 12 | 70% | 45°C | Hydrocyclone |

Table 4.1: Experiment Cases Overview

4.2 EXPERIMENT RESULT

4.2.1 Case 1

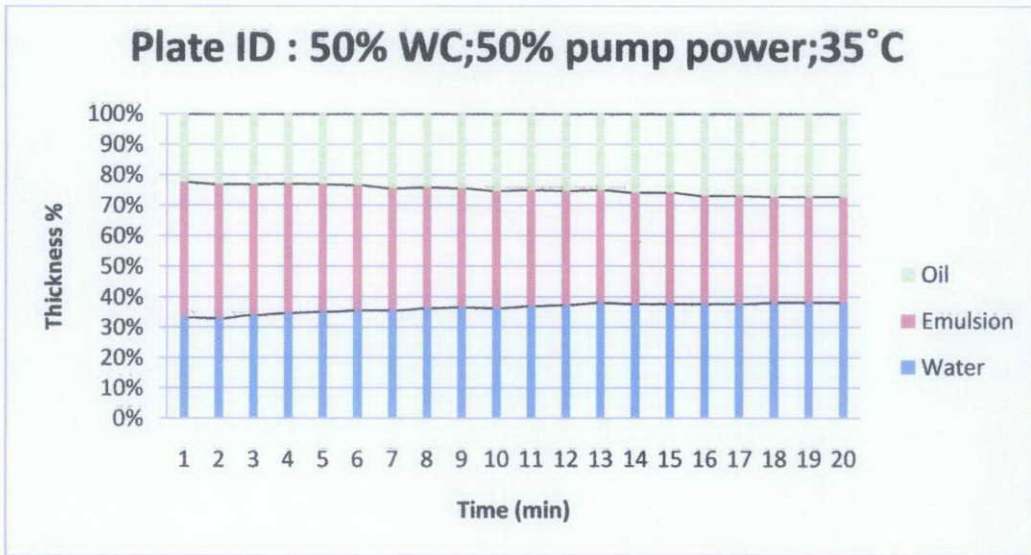


Figure 8.1: Column Chart for case 1

4.2.2 Case 2

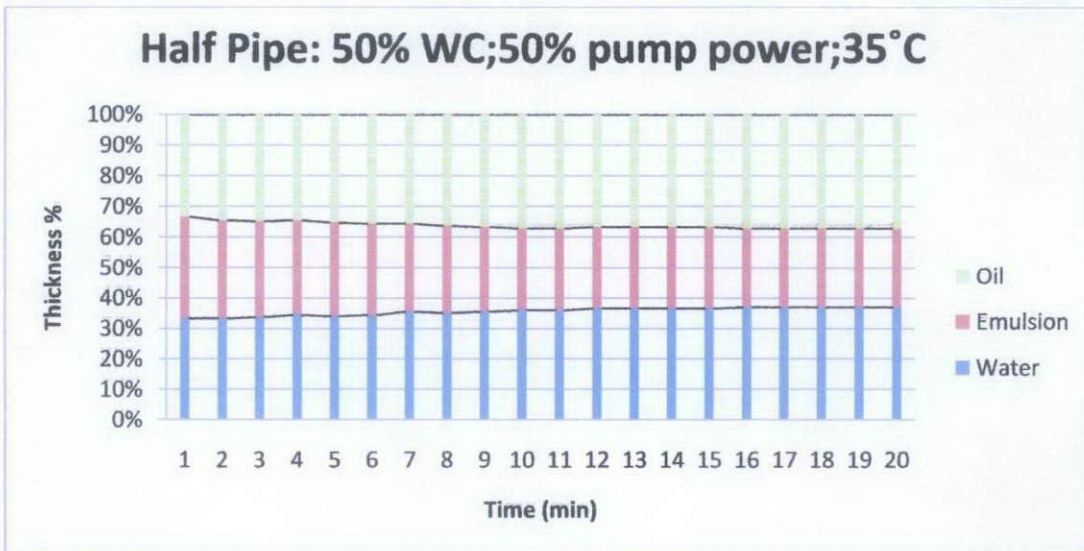


Figure 4.2: Column Chart for case 2

4.2.3 Case 3

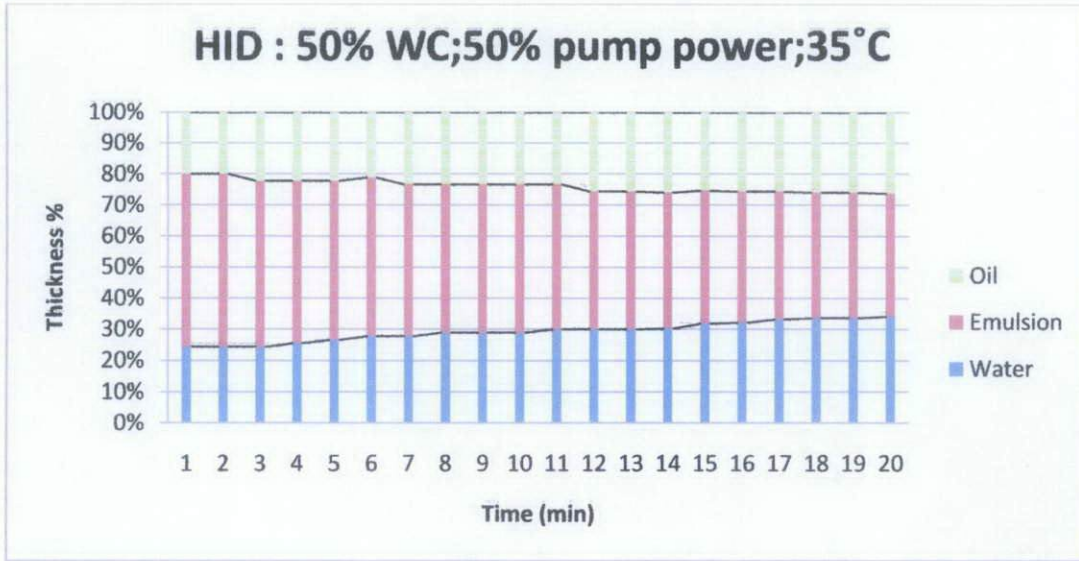


Figure 4.3: Column chart for case 3

4.2.4 Case 4

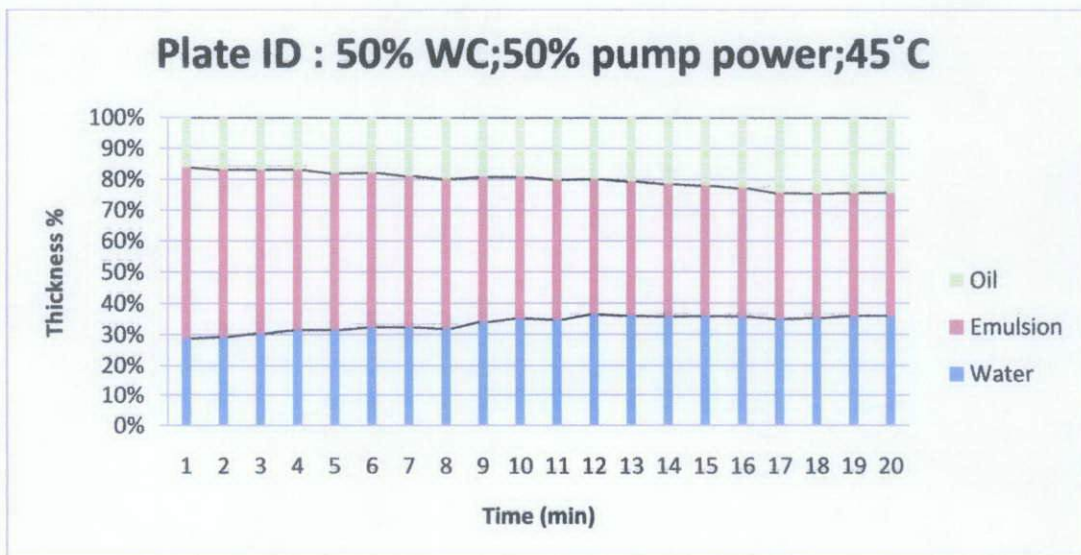


Figure 4.4: Column chart for case 4

4.2.5 Case 5

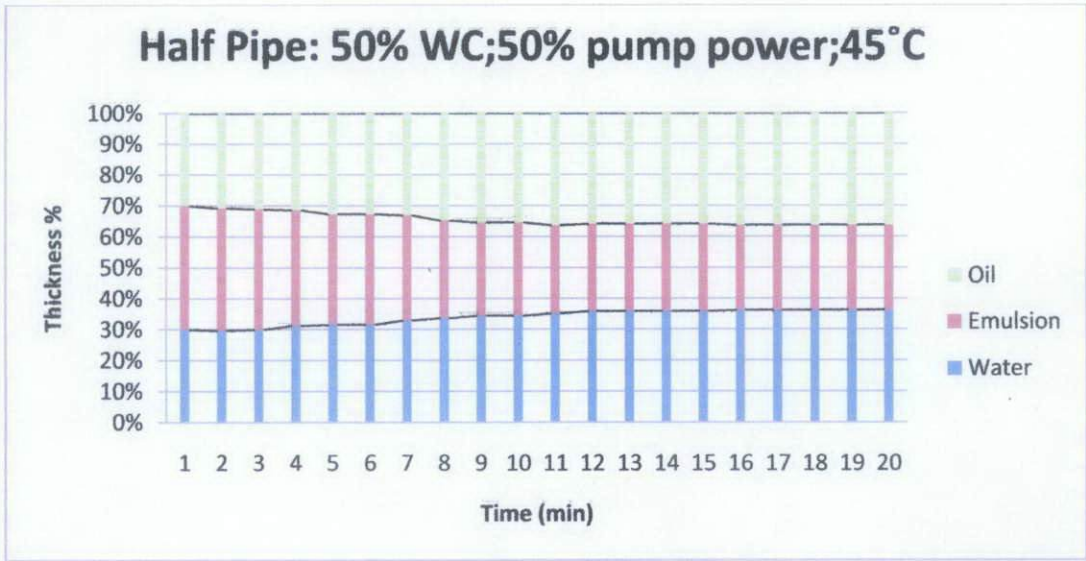


Figure 4.5: Column chart for case 5

4.2.6 Case 6

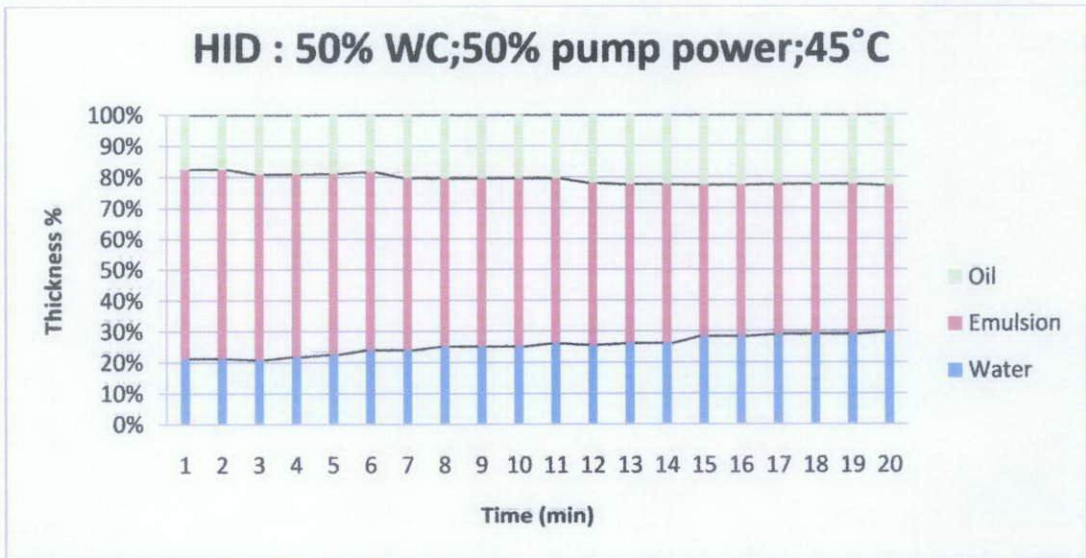


Figure 4.6: Column chart for case 6

4.2.7 Case 7

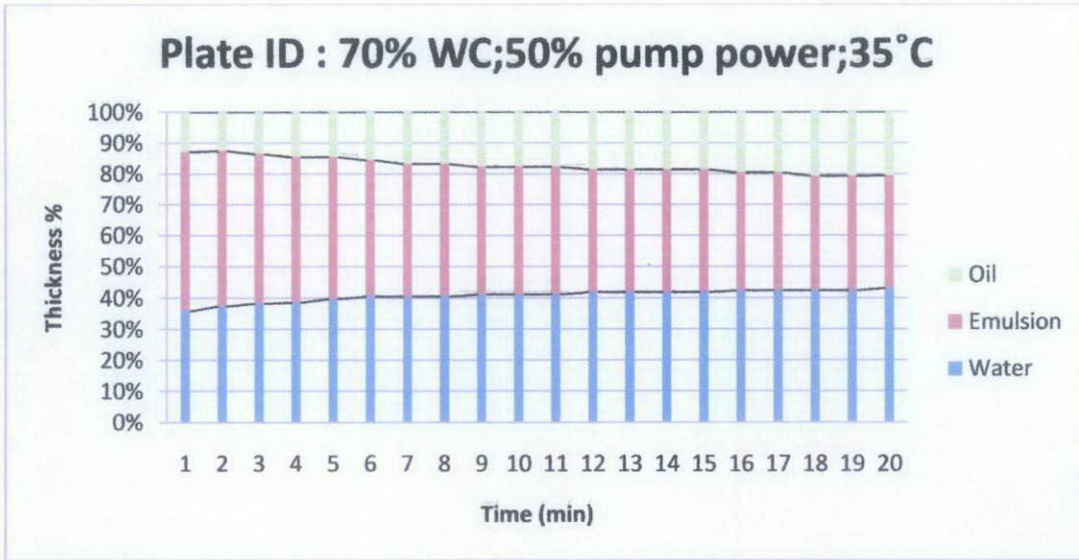


Figure 4.7: Column chart for case 7

4.2.8 Case 8

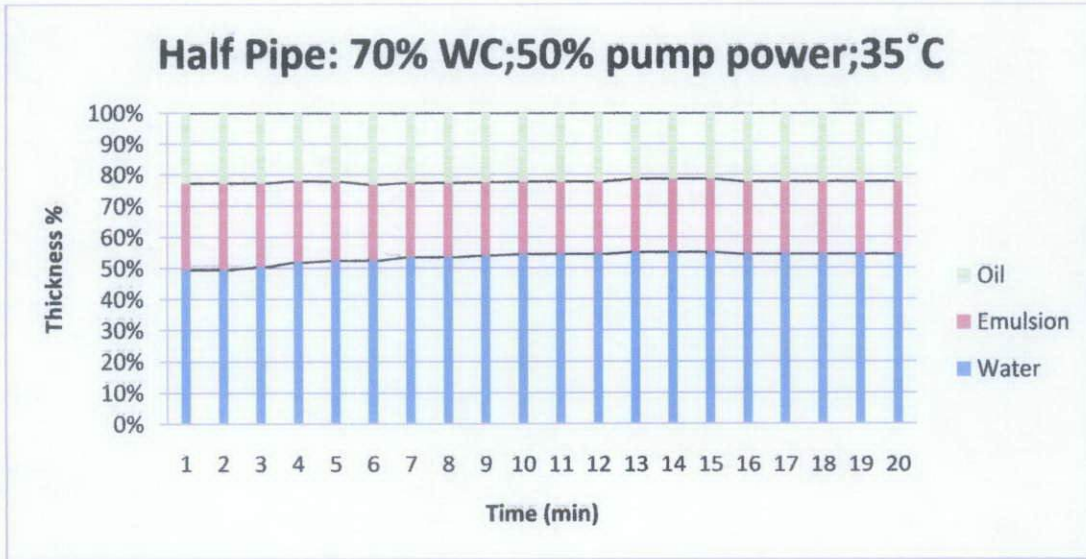


Figure 4.8: Column chart for case 8

4.2.9 Case 9

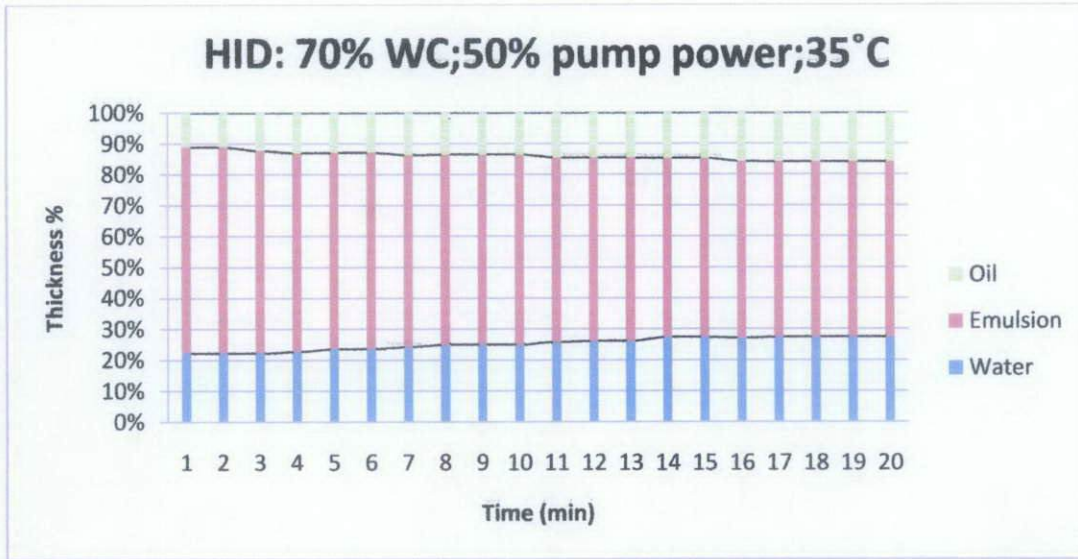


Figure 4.9: Column chart for case 9

4.2.10 Case 10

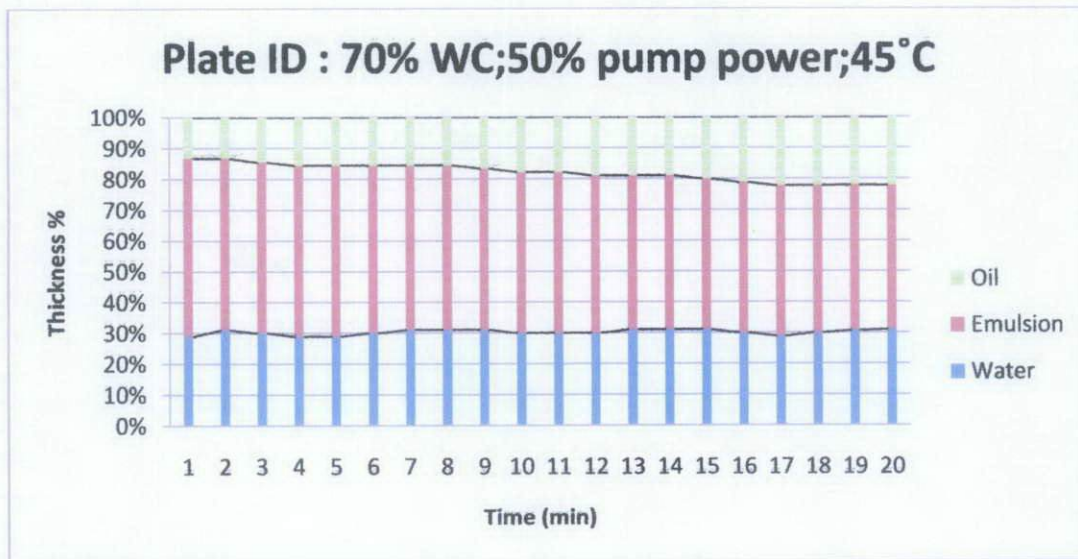


Figure 4.10: Column chart for case 10

4.2.11 Case 11

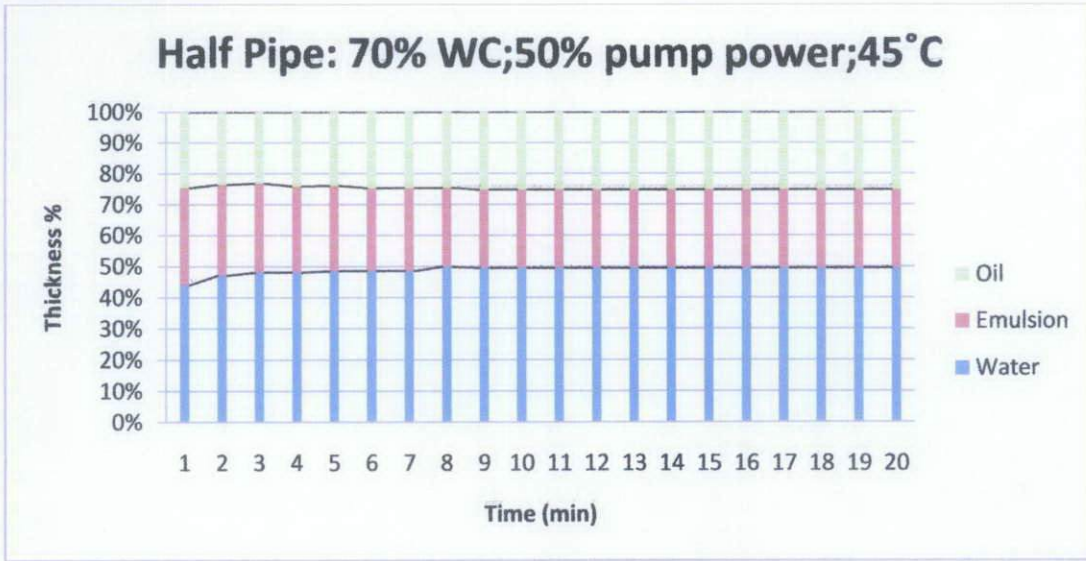


Figure 4.11: Column chart for case 11

4.2.12 Case 12

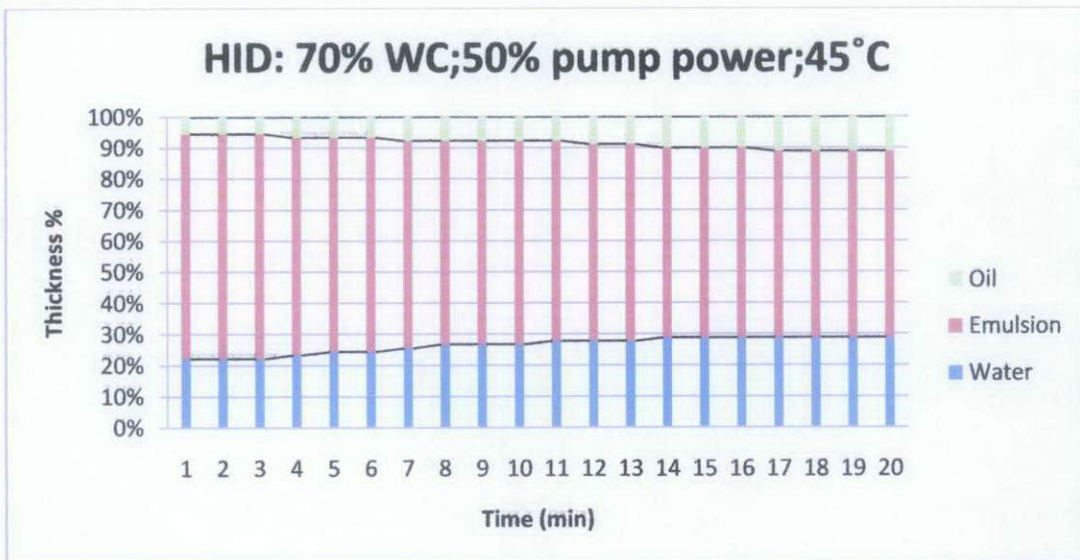


Figure 4.12: Column chart for case 12

4.3 Effect of different temperature

| | PLATE | | HALF PIPE | | HYDROCYCLONE | |
|----------|----------------|----------------|----------------|----------------|----------------|----------------|
| | 35°C Case 1 | 45°C Case 4 | 35°C Case 2 | 45°C Case 5 | 35°C Case 3 | 45°C Case 6 |
| OIL | 28% | 26% | 38% | 35% | 26% | 24% |
| EMULSION | 34% | 36% | 24% | 29% | 42% | 46% |
| WATER | 38% | 38% | 38% | 36% | 32% | 30% |

Table 4.2 : Emulsion thickness after 20 min at different temperature

Comparing case respectively will result:

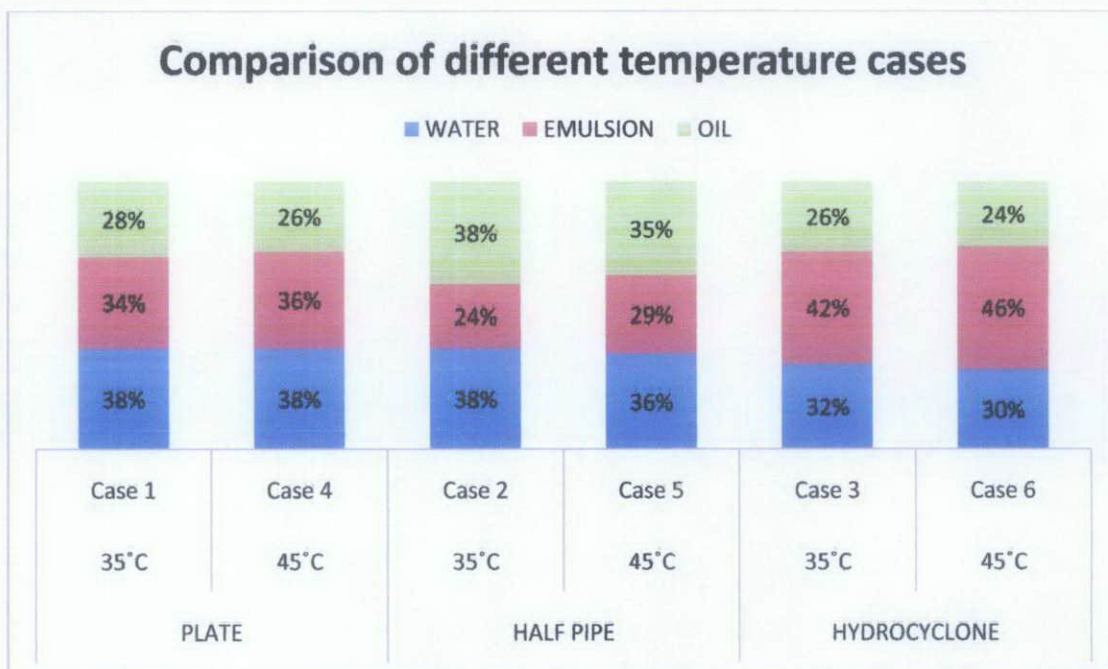


Figure 4.2: Comparison of different temperature cases

By introduce more heat energy to the crude oil mixture, intermolecular forces that bind molecules together will be reduced. Thus, this phenomenon allows oil and water easily mixed together to visible as a single phase. Even before crude oil mixture being transferred into the separator, oil and water itself forming thicker emulsion which create a major problem to separation.

As the temperature of oil mixture increased, fluid viscosity will be reduced. Sedimentation will increase and then may proceed to increase of coalescence. Small droplets in crude oil mixture

As for retention time for different inlet diverter:

| <i>ID.</i> | <i>RETENTION TIME(Min)</i> | |
|--------------|----------------------------|-----------|
| | <i>WC</i> | <i>WC</i> |
| | 50%WC | 70%WC |
| HALF PIPE | 16 | 8 |
| PLATE | 13 | 11 |
| HYDROCYCLONE | 17 | 14 |

Table 4.6: Retention time for 50% WC & 70%WC

Generally retention time reduced when there is an increase in water cut factor. Retention time is reduced from 16 min to 8 min for half pipe when water cut is increasing from 50% WC to 70% WC. This is because more portion of the water makes viscosity of the crude oil become lesser and this improve on crude oil mobility.

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1 Conclusion

From the result obtained, different Inlet Diverter performs differently towards emulsion stability. We can see that emulsion thickness is greatest by using Hydrocyclone. This is because swirling effect of hydrocyclone introduce more agitation to crude oil mixture thus forming more emulsion. As for Plate ID, it is suitable for phase difference, which means, good of oil and gas phase distribution. In this experiment, crude oil mixture is used (liquid-liquid phase) and the use of Plate ID provides ineffective separation. Half Pipe inlet diverter is most preferable for crude oil mixture. From the experiment result, its emulsion stability is the lowest one.

The effect of increasing temperature of crude oil mixture gradually over 35°C had caused a slight increase in emulsion stability (*emulsion thickness*). This phenomenon happened because of expansion of molecules and reduction of intermolecular forces, thus oil and water easier to mix together.

In increasing water to oil ratio, Hydrocyclone ID resulting more stable emulsion instead of Plate ID and Half Pipe ID. Swirling effect of Hydrocyclone ID makes size of droplets become smaller. Meanwhile, flow through Half Pipe could avoid swirling effect & reduction of droplet size.

As a conclusion, Half Pipe ID is better than Hydrocyclone ID and Plate ID in terms of emulsion stability. Some modification has to be made on Half Pipe design for better performance.

5.2 Recommendations

As this project is being conducted, there are several limitation factors that affects the results of the experiment which makes it have to be improved more because of it does not represent the actual field operation and conditions. These limitations are:

1. Equipment Limitation

Experiment was conducted using lab equipment that may not represent actual condition of the field. This is because small scale separator about 1:16 scale has been used in conducting experiment. The temperature that had been set is low as compared to actual field temperature that can reach to more than 100°C.

2. Flow rate

In this experiment, 50% pump power parameter is fixed. The flow rate for 50% pump power is about 12.9 L/min which is very low as compared to actual flow rate of separator that can achieved about 50000 bpd or 4062.5 L/min. Flow rate greatly give impact for Hydrocyclone ID. According to theory, oil supposed to exit from the top of Hydrocyclone, unfortunately during the experiment, both oil and water exit at the bottom of Hydrocyclone. Higher flow rate would provide more centrifugal force that might be enough for oil to exit from the top of Hydrocyclone.

3. Inlet Diverter Design

All three Inlet Diverter design constructed using simple tools. Thus, these prototype design of Inlet Diverter are imperfect. For example, Plate ID was constructed using simple perspex that cannot withstand high pressure impact. Looking for Hydrocyclone ID, the material used in constructing Hydrocyclone is just a simple aluminium. Leaking problem is one of the major failure of Hydrocyclone design.

4. Pressure

A pressure gauge can be installed at the conduit that transfer the crude oil from pump and separator to investigate effect of pressure towards emulsion stability.

REFERENCES

1. <http://www.wasanlab.com/pharm/emulsion.html>
2. Emulsion, Foams and Suspension- Fundamental and Application (Laurrier L. Schram)
3. Surface Production Operations- Design of oil handling systems & facilities (Ken Arnold , Maurice Steward)
4. SPE Paper 6470 : Oil & Gas separation (Theory , Application & Design) by Leon Katapodis.
5. SPE Paper77497: Crude oil emulsion: A State of the art review by Sunil Kokal, Saudi Aramco
6. Facilities & Construction Engineering.(Kenneth E. Arnorld – Volume 3 : Chapter 2 Oil and Gas Separators,Robert W.Chin,CDS Separation Technologies Inc).
7. Modeling and Control of Three-Phase Gravity Separators in Oil Production Facilities by Atalla F. Sayda and James H. Taylor
8. Gas-liquid & liquid-liquid separators by Maurice Steward & Ken Arnold.
9. <http://www.ascomsep.com> (cyclonic inlet diverter)
10. <http://www.pipingguide.net>
11. <http://www.freepatentsonline.com/4299703.pdf>
12. [http://www.wipo.int/pctdb/en/wo.jsp?WO=2004060536-small efficient separator](http://www.wipo.int/pctdb/en/wo.jsp?WO=2004060536-small%20efficient%20separator)
13. http://www.fenixchemtech.in/pdf_cat/intsep.pdf
14. Nasuha Binti Nazarudin (FINAL YEAR REPORT JULY 2009)
15. Nurizzatulshira Binti Buang (2009), Lecture Sides, "Separator : Principles and Design.
16. http://digital.library.okstate.edu/oas/oas_pdf/v111/p74_76.pdf
17. <http://www.sciencedirect.com>(Effects of temperature on water-in-oil emulsions stabilised solely by wax microparticles)
18. The effect of turbulence on efficiency of rotational phase separator (J.G.M Kuerten, B.P.M van esch , H.P Van Kemenade , J.J.H Brouwers)

APPENDICES (crude oil material data sheet)

1. IDENTIFICATION OF THE SUBSTANCE/PREPARATION

PRODUCT: CRUDE OIL
PRODUCT #: I-CRUDE
PHSD #: 90-1161000

PETRONAS Carigali Sdn.Bhd.
Level 24, Tower 1,
PETRONAS Twin Towers,
KUALA LUMPUR CITY CENTER,
50088 KUALA LUMPUR

DATE OF ISSUE: July 1, 2008

EMERGENCY CONTACT NUMBERS:
Tel: +603 20515000
Fax: +603 20265011

2. COMPOSITION/INFORMATION ON INGREDIENTS

Ingredients present at or above 0.1 wt% (classified as toxic or very toxic) or 1 wt% (classified as harmful, irritant or corrosive).

| <u>HAZARDOUS INGREDIENT</u> | <u>APPROXIMATE CONCENTRATION</u> |
|---------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
| T Xn Crude oil Contains >0.1% benzene R 45 May cause cancer R 65 Harmful: may cause lung damage if swallowed. | 100% |

NOTE: May contain small amounts of hydrogen sulphide

3. HAZARD IDENTIFICATION

R 12
Extremely flammable
R 45
May cause cancer
R 65
Harmful: may cause lung damage if swallowed.
R 52
Harmful to aquatic organisms.
R 53
May cause long-term adverse effects in the aquatic environment

High concentrations of hydrogen sulphide, a very toxic and potentially lethal gas, can sometimes develop in confined or poorly ventilated spaces associated with this product. The odour of hydrogen sulphide does not provide a

reliable indicator of the presence of hazardous levels in the atmosphere. Handling precautions must be strictly observed

3. HAZARD IDENTIFICATION (Continued)

Aspiration of liquid into the lungs directly or a result of vomiting following ingestion of the liquid, can cause severe lung damage and death.

4. FIRST AID

INHALATION:

In emergency situations use proper respiratory protection to immediately remove the affected victim from exposure. Administer artificial respiration if breathing has stopped. Keep at rest. Call for prompt medical attention.

SKIN CONTACT:

Wash thoroughly with plenty of water, using soap if available. If irritation occurs and persists, get medical attention.

EYE CONTACT:

Rinse immediately with plenty of water until irritation subsides. If irritation persists, obtain medical advice.

INGESTION:

DO NOT induce vomiting since it is important that no amount of the material should enter the lungs (aspiration). Keep at rest. Get prompt medical attention.

5. FIRE-FIGHTING MEASURES

EXTINGUISHING MEDIA:

Foam, dry chemical powder, carbon dioxide.

FIRE AND EXPLOSION HAZARDS:

Extremely flammable, high hazard. Liquid can release considerable vapour at temperatures below ambient which readily form flammable mixtures.

Vapours settle to ground level and may reach, via drains and other underground passages, ignition sources remote from the point of escape.

Static discharge; material can accumulate static charges which may cause an incendiary electrical discharge.

5. FIRE-FIGHTING MEASURES (Continued)

SPECIAL FIRE-FIGHTING PROCEDURES:

Water fog or spray, to cool fire-exposed surfaces (e.g. containers) and to protect personnel, should only be used by personnel trained in fire fighting.

Cut off "fuel"; depending on circumstances, either allow the fire to burn out under controlled conditions or use foam or dry chemical powder to extinguish the fire.

Respiratory and eye protection required for fire fighting personnel exposed to fumes or smoke.

HAZARDOUS COMBUSTION PRODUCTS:

Smoke; sulphur oxides; and carbon monoxide in the event of incomplete combustion.

6. ACCIDENTAL RELEASE MEASURES

PERSONAL PRECAUTIONS: See Section 8.

LAND SPILL:

Eliminate sources of ignition.

Shut off source taking normal safety precautions. Prevent liquid from entering sewers, water courses or low lying areas; advise the relevant authorities if it has, or if it contaminates soil/vegetation. Take measures to minimise the effects on ground water.

Recover by skimming or pumping using explosion-proof equipment, or contain spilled liquid with booms, sand, or other suitable absorbent and remove mechanically into containers.

If necessary, dispose of adsorbed residues as directed in Section 13.

WATER SPILL:

Eliminate sources of ignition and warn other shipping to stay clear. Notify port and other relevant authorities.

Do not confine in area of leakage.

Remove from the surface by skimming or with suitable absorbents. Disperse the residue in unconfined waters, if permitted by local authorities and environmental agencies.

7. HANDLING AND STORAGE

The design and operation of bulk storage and fuel systems must comply with national legislation and recognised codes of good practice.

In smaller quantities, containers such as drums should be stored in cool, well ventilated surroundings, away from all sources of ignition.

Electrical equipment and fittings must comply with local fire prevention regulations for this class of flammable product.

LOAD/UNLOAD TEMPERATURE deg. C: Ambient to 40
STORAGE TEMPERATURE deg. C: Ambient to 40

SPECIAL PRECAUTIONS:

Ensure compliance with statutory requirements for storage and handling.

Use the correct grounding procedure.

Store and handle in closed or properly vented containers.

Prevent small spills and leakages to avoid slip hazard.

8. EXPOSURE CONTROLS AND PERSONAL PROTECTION

OCCUPATIONAL EXPOSURE LIMIT:

For total hydrocarbons, ECI recommends 100 ppm (TWA, 8h-workday) (Analysis according to US NIOSH Method 1500 or UK HSE Method 60; NIOSH Manual of Analytical Methods, 3rd Ed; HSE Methods for the Determination of Hazardous Substances).

For Hydrogen Sulphide, 10 ppm (14 mg/m³) (Analysis using Draeger or similar detector tube).

For Benzene, ACGIH recommends a TWA of 0.5 ppm (1.6 mg/m³), (skin), and categorizes it as a confirmed human carcinogen (Analysis according to US NIOSH Method 1501, NIOSH Manual of Analytical Methods, 3rd Ed., or UK HSE Methods 17, 22, 50, or 60, HSE Methods for the Determination of Hazardous Substances).

PERSONAL PROTECTION:

In open systems where contact is likely, wear safety goggles, chemical-resistant overalls, and chemically impervious gloves.

Where only incidental contact is likely, wear safety glasses with side shields. No other special precautions are necessary provided skin/eye contact is avoided.

When concentrations in air may exceed the occupational exposure limit, and where engineering, work practices, or other means of exposure reduction are

8. EXPOSURE CONTROLS AND PERSONAL PROTECTION (Continued)

not adequate, approved respirators may be required.

9. PHYSICAL AND CHEMICAL PROPERTIES

APPEARANCE / ODOUR:

Typically an opaque, brown to black liquid, odour varies from mild petroleum to sour sulphurous.

DENSITY, g/ml: Data not available.

BOILING RANGE: Varies widely

VISCOSITY, mm²/S: < 7 at 40 deg. C Typically, varies widely

VAPOUR PRESSURE, kPa: at 20 deg. C Varies, typically >5 vol%

VAPOUR DENSITY AT 1 BAR (Air=1): Heavier than air

EVAPORATION RATE (n-butyl acetate=1): Varies widely

SOLUBILITY IN WATER: 20 deg. C Negligible

pH: Not Applicable.

FLASH POINT: < 35 deg. C METHOD: PMCC Typically, varies widely

FLAMMABILITY LIMITS IN AIR, % BY VOL:

LEL: 1.5 UEL: 9.0 Typically, varies widely

AUTOIGNITION TEMPERATURE: Data not available.

PARTITION COEFFICIENT n-octanol/water: Data not available.

10. STABILITY AND REACTIVITY

STABILITY (THERMAL, LIGHT, ETC): Stable

CONDITIONS TO AVOID:

Keep away from heat sources, open flames and other sources of ignition.

10. STABILITY AND REACTIVITY (Continued)

INCOMPATIBLE MATERIALS:

Avoid contact with strong oxidants such as liquid chlorine and concentrated oxygen.

HAZARDOUS DECOMPOSITION PRODUCTS:

Product does not decompose at ambient temperature.

11. TOXICOLOGICAL INFORMATION

EFFECTS OF OVER EXPOSURE:

INHALATION:

In high concentrations and/or at elevated temperatures, vapour or mist is irritating to mucous membranes, may cause headaches and dizziness, may be anesthetic and may cause other central nervous system effects.

Avoid breathing vapours, mists, or fumes.

Hydrogen sulphide may accumulate in tanks and other confined spaces that contain this material. Hydrogen sulphide may cause irritation, breathing failure, coma, and death, without necessarily any warning odour being sensed.

SKIN CONTACT:

Low order of acute toxicity.

Prolonged or repeated contact may dry and defat the skin, leading to irritation and possibly dermatitis.

Prolonged or repeated contact may also lead to more serious skin disorders, including skin cancer.

EYE CONTACT:

Slightly irritating, but does not injure eye tissue.

INGESTION:

Low order of acute/systemic toxicity.

Minute amounts aspirated into the lungs during ingestion or vomiting may cause severe pulmonary injury and death.

CHRONIC:

Contains benzene. Human health studies (epidemiology) indicate that prolonged and/or repeated overexposures to benzene may cause damage

11. TOXICOLOGICAL INFORMATION (Continued)

to the blood producing system and serious blood disorders, including leukemia. Animal tests suggest that prolonged and/or repeated overexposures to benzene may damage the embryo/fetus. The relationship of these animal studies to humans has not been fully established.

Contains polycyclic aromatic compounds (PACs). Prolonged and/or repeated skin contact with certain PACs has been shown to cause skin cancer. Prolonged and/or repeated exposures by inhalation of certain PACs may also cause cancer of the lung and of other sites of the body.

TOXICITY DATA:

ACUTE:

Based upon animal test data from similar materials and products, the acute toxicity of this product is expected to be:

Oral : LD50 > 5000 mg/kg (Rat)
Dermal : LD50 > 2000 mg/kg (Rabbit)

CHRONIC:

Data not available.

12. ECOLOGICAL INFORMATION

In the absence of specific environmental data for this crude oil product, this assessment is based on information developed with various other crude oils. Generally, crude oil immediately following a release into the environment will remain largely on the soil surface, and in water, will remain largely on the water surface. Because of the range of components which comprise crude oil, various fractions will begin to partition to varying environmental compartments (i.e. air, water, soil sediment) immediately following a release. Generally, crude oil is harmful to aquatic organisms. Indirect toxicity to shoreline species may result from physical fouling. Although crude oil is not readily biodegraded, it is inherently biodegradable. Fractions of crude oil would be expected to degrade rapidly while other fractions would be expected to persist.

13. DISPOSAL CONSIDERATIONS

This product contains hazardous ingredients listed in Section 2. Collect and

13. DISPOSAL CONSIDERATIONS (Continued)

dispose of it at an authorised disposal facility, in conformance with national and local regulations, and in accordance with EEC Directives on hazardous waste.

14. TRANSPORT INFORMATION

USUAL SHIPPING CONTAINERS:

Tankers, barges, rail cars, tank trucks, drums.

TRANSPORT TEMPERATURE deg. C: Ambient to 40

IMO CLASS: 3

ADR CLASS: 3 Item no 3(b) HIN 33

UN NUMBER: 1267

15. REGULATORY INFORMATION

DANGEROUS SUBSTANCES/PREPARATIONS CLASSIFICATION:

Extremely flammable
Carcinogenic cat. 2

HAZARD SYMBOL:

F+
T

RISK AND SAFETY ADVICE:

R 12
Extremely flammable
R 45
May cause cancer
R 65
Harmful: may cause lung damage if swallowed.
R 52
Harmful to aquatic organisms.
R 53
May cause long-term adverse effects in the aquatic environment
S 16
Keep away from sources of ignition - No Smoking
S 53
Avoid exposure - obtain special instructions before use
S 45
In case of accident or if you feel unwell, seek medical advice immediately

15. REGULATORY INFORMATION (Continued)

(show the label where possible)

S 62

If swallowed, do not induce vomiting: seek medical advice immediately and

show this container or label

S 61

Avoid release to the environment. Refer to special instructions/safety data sheet

Refer to your national legislation implementing the EC Directive 91/155/EC

16. OTHER INFORMATION

PRODUCT TYPE / USES:

Petroleum refinery feed.

SOURCE OF KEY DATA:

The recommendations presented in this Material Safety Data Sheet were

compiled from actual test data (when available), comparison with similar products, component information from suppliers and from recognised codes of good practice.

The information and recommendations contained herein are, to the best of PETRONAS Carigali knowledge and belief, accurate and reliable as of the date issued, but are offered without guarantee or warranty. They relate to the specific material designated and may not be valid for such material used in combination with any other materials or in any process. Conditions of use of the material are under the control of the user; therefore, it is the user's responsibility to satisfy himself as to the suitability and completeness of such information for his own particular use.