



**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**THE EFFECT OF CRUDE OIL TO THE CORROSION  
PROPERTIES OF PETROLEUM PIPELINE**

This report submitted in accordance with requirement of the Universiti Teknikal  
Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering  
(Engineering Materials) (Hons.)

by

**HAZWAN HASIF BIN HAMDAN**

**B050910081**

**891108-01-5071**

**FACULTY OF MANUFACTURING ENGINEERING**

**2013**



# UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **The Effect of Crude Oil to the Corrosion Properties of Petroleum Pipeline**

SESI PENGAJIAN: 2012/13 Semester 2

Saya **HAZWAN HASIF BIN HAMDAN**

mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.



SULIT

(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysiasebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)



TERHAD

(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)



TIDAK TERHAD

Disahkan oleh:

\_\_\_\_\_  
Alamat Tetap:

\_\_\_\_\_  
Cop Rasmi:

No. 24, JALAN OREN,

\_\_\_\_\_  
TAMAN BUKIT PASIR,

\_\_\_\_\_  
83000 BATU PAHAT, JOHOR

Tarikh: \_\_\_\_\_

Tarikh: \_\_\_\_\_

\*\* Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

## DECLARATION

I hereby, declared this report entitled “The Effect of Crude Oil to the Corrosion Properties of Petroleum Pipeline” is the results of my own research except as cited in references.

Signature : .....

Author's Name : HAZWAN HASIF BIN HAMDAN

Date :

## **APPROVAL**

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Engineering Materials) (Hons.). The members of the supervisory committee are as follow:

.....

(DR. MOHD. ASYADI 'AZAM BIN MOHD. ABID)

## ABSTRACT

This project is about the pipeline corrosion caused by the composition of petroleum product in particular crude oil to the internal surface of carbon steel pipeline. Internal and external pipeline corrosion has been the main causes of pipeline failure in oil and gas industry not only in Malaysia but all over the world. However, the internal corrosion is preferred to be concerned in this project because it involved one of the corrosive media in crude oil such as sulfur content. The first objective in this project is to study the sulfur concentration in crude oil by using Fourier Transform Infrared (FTIR) spectroscopy and Atomic Absorption Spectroscopy (AAS). The corrosion rate, corrosion current ( $E_{corr}$ ) and corrosion potential ( $I_{corr}$ ) of API X65 grade carbon steel pipeline in different concentration of simulated  $H_2SO_4$  solution were analyzed using Tafel extrapolation method. The corrosion properties on the sample were measured using Optical Microscope (OM), Scanning Electron Microscope (SEM) and Energy Dispersive X-ray (EDX).

The results showed that the corrosion rate of carbon steel increased significantly with the increase of  $H_2SO_4$  concentration. The corrosion products formed on carbon steel surfaces were mainly composed of iron sulfate ( $FeSO_4$ ), iron sulfide (FeS) and iron oxide (FeO). These findings is important to understand the crude oil corrosivity behavior and should be further investigated the other probability influence factor such as temperature.

## ABSTRAK

Projek ini adalah mengenai pengurangan saluran paip yang disebabkan oleh komposisi produk petroleum khususnya minyak mentah ke atas permukaan dalaman paip keluli karbon. Pengurangan luaran dan dalaman adalah punca utama kegagalan saluran paip dalam industri minyak dan gas bukan hanya di Malaysia sahaja tapi di seluruh dunia. Walau bagaimanapun, pengurangan dalaman adalah menjadi pilihan dalam projek ini kerana ia melibatkan salah satu media pengurangan dalam minyak mentah contohnya sulfur. Objektif pertama projek ini adalah untuk mempelajari kepekatan sulfur dalam minyak mentah dengan menggunakan Fourier Transform Infrared (FTIR) spektroskopi dan Spektroskopi Penyerapan Atom (AAS). Kadar pengurangan, potensi pengurangan ( $E_{corr}$ ) dan arus pengurangan ( $I_{corr}$ ) paip keluli karbon gred API X65 dalam simulasi larutan berasid  $H_2SO_4$  dengan kepekatan berbeza telah dianalisis menggunakan kaedah ekstrapolasi Tafel. Ciri-ciri pengurangan pada sampel diuji dengan menggunakan Mikroskop Optik (OM), Mikroskop Imbasan Elektron (SEM) dan Sebaran Tenaga Sinar-X (EDX).

Hasil kajian menunjukkan bahawa kadar pengurangan keluli karbon meningkat dengan ketara dengan peningkatan kepekatan  $H_2SO_4$ . Produk-produk pengurangan terbentuk pada permukaan keluli karbon terutamanya terdiri daripada sulfat besi ( $FeSO_4$ ), sulfida besi ( $FeS$ ) dan oksida besi ( $FeO$ ). Penemuan ini penting untuk memahami tingkah laku pengurangan oleh minyak mentah dan juga perlu disiasat faktor pengaruh lain contohnya suhu yang mungkin menyebabkan peningkatan mekanisme pengurangan.

## **DEDICATION**

I would like to express my gratitude to my supervisor, Dr. Mohd. Asyadi 'Azam bin Mohd. Abid for his guidance, support and push during this Final Year Project. His expertise and contribution have been invaluable for my bachelor studies. I truly appreciate Dr. Asyadi for his deep theoretical and practical knowledge in corrosion and his organizational abilities.

And also my sincere love to my beloved parents for their love and support. I will try my best to make you guys proud.

## ACKNOWLEDGEMENT

*Bismillahirrahmanirrahim...*

Firstly, I would like to convey my gratitude towards the Al-Mighty for giving me the strength and willingness during this Final Year Project. Then I would like to express my sincere gratitude and appreciation to my supervisor, Dr. Mohd. Asyadi 'Azam bin Mohd. Abid who guided me during this project. I deeply appreciate for the countless hours spent by him on this project.

Special thanks and appreciation to my parent, Mr. Hamdan bin Ogok and Mrs. Samporna binti Tosin for their sacrifice and encouragement in the dissertation efforts. Acknowledgement of appreciation also goes to my friends for their patience and support. Thank you again.

*Wassalam...*

*Hazwan Hasif bin Hamdan*



Abstract	i
Abstrak	ii
Dedication	iii
Acknowledgement	iv
Table of Content	v
List of Figures	ix
List of Tables	xii
List of Abbreviations, Symbols and Nomenclatures	xiii
<b>CHAPTER 1: INTRODUCTION</b>	<b>1</b>
1.1 Background	1
1.2 Problem statement of the project	2
1.3 Objectives	3
1.4 Scope	3
<b>CHAPTER 2: LITERATURE REVIEW</b>	<b>4</b>
2.1 Oil and gas industry in Malaysia	4
2.1.1 History	4
2.1.2 Activities in oil and gas industry	6
2.1.2.1 Exploration and production	7
2.1.2.2 Refining	7
2.1.2.3 Development	7
2.1.2.4 Trading and marketing	7
2.1.2.5 Distribution, transport and storage	8
2.1.3 Contribution of this industry to the country	8

2.2	Petroleum products	10
2.2.1	Crude oil	10
2.2.2	The hydrocarbons in crude oil	11
2.2.3	Crude oil distillation process	12
2.3	Petroleum pipeline	13
2.3.1	Carbon steel pipeline	13
2.3.2	Grades of pipeline	13
2.3.3	Coating of pipeline	15
2.4	Overview of corrosion	17
2.4.1	Definition of corrosion	17
2.4.2	Corrosion in oil and gas industry	17
2.4.3	Types of corrosion in oil and gas industry	19
2.4.3.1	External corrosion	19
2.4.3.2	Types of internal corrosion	20
2.4.4	Importance to understand corrosion	24
2.4.5	Effect of corrosion to economy	24
2.4.6	Mechanism of corrosion	25
2.4.7	Calculation of corrosion rate from the corrosion current	28
2.5	Characterization of crude oil and pipeline	29
2.5.1	FTIR spectroscopy	29
2.5.2	AAS	29
2.5.3	OM	30
2.5.4	Electrochemical corrosion testing	30
2.5.5	Metallographic study	31
2.5.5.1	SEM	32
2.5.5.2	EDS or EDX	35

<b>CHAPTER 3: METHODOLOGY</b>	<b>37</b>
3.1 Flow of methodology process	38
3.2 FTIR spectroscopy	39
3.2.1 Checking the crude oil composition	39
3.2.2 Conversion from FTIR spectra to solution concentration	40
3.3 Sample preparation for corrosion test	41
3.3.1 Sample cutting and copper wire attached	42
3.3.2 Cold mounting	44
3.3.3 Grinding and polishing	45
3.3.4 Etching	47
3.3.5 Electrolyte for corrosion rate measurement	47
3.3.6 Dilution of H <sub>2</sub> SO <sub>4</sub> solution	47
3.4 Experimental setup for corrosion test	48
3.5 Surface characterization and elemental analysis: OM, SEM, EDX	50
3.6 Corrosion rate measurement from Tafel extrapolation analysis	51
<b>CHAPTER 4: RESULTS AND DISCUSSION</b>	<b>53</b>
4.1 Observation and presentation of the collected data	53
4.2 FTIR analysis of sulfur in crude oil	54
4.3 AAS analysis of sulfur concentration in crude oil	56
4.4 Molarity determination for H <sub>2</sub> SO <sub>4</sub> solution from the concentration of SO <sub>4</sub> <sup>2-</sup> in ppm (parts per million)	57
4.5 Tafel extrapolation analysis for corrosion rate determination	58
4.6 Digital image for API X65 pipeline steel	63
4.7 Optical Microscope (OM)	65
4.7.1 Microstructure observation of steel sample before corrosion testing	65
4.7.2 Microstructure observation of steel sample after corrosion testing	66
4.8 SEM analysis of corrosion product on steel samples	68
4.8.1 Surface morphology of steel samples before corrosion testing	68

4.8.2	Surface morphology and cross section of steel samples after corrosion testing	68
4.9	Corrosion product analysis by EDX	75
4.10	Suggestions of corrosion mechanism	81
<b>CHAPTER 5: CONCLUSIONS AND FUTURE WORKS</b>		<b>83</b>
5.1	Conclusions	83
5.2	Future works	84
<b>REFERENCES</b>		<b>85</b>
<b>APPENDIX</b>		

## LIST OF FIGURES

2.1	Malaysia's oil production and consumption, 1991 – 2010	5
2.2	Malaysia's Oil and Gas Reserves from 2006 until 2010	6
2.3	The way government get income from oil and gas industries	9
2.4	Crude oil distillation process	12
2.5	Installation of an exterior pipe tape wraps	16
2.6	Internal pitting corrosion in pipeline	20
2.7	Erosion corrosion at pipe elbow	21
2.8	CO <sub>2</sub> corrosion on internal pipe surface	22
2.9	H <sub>2</sub> S corrosion on internal pipe surface	23
2.10(a)	SEM surface morphologies and EDX of carbon steel after CO <sub>2</sub> corrosion	33
2.10(b)	SEM surface morphologies and EDX of carbon steel after H <sub>2</sub> S corrosion	34
2.11	Example of SEM image of carbon steel pipe with 4000 x magnification	35
3.1	Flow of methodology process	38
3.2	Crude oil	39
3.3	ATR-FTIR machine	40
3.4	Sample preparation flow chart	42
3.5	Original pipeline sample from PETRONAS	41
3.6	Sample dimensions	43
3.7	Horizontal band saw machine	43
3.8	Diamond cutter	43
3.9	Carbon steel specimens	44
3.10	Carbon steel pipe specimens attached with copper wire	44
3.11(a)	Cold mounting process	45
3.11(b)	Cold mounting specimens	45
3.12(a)	Grinding process of cold mounted specimen	46
3.12(b)	Grinding machine	46

3.13	Polishing machine	46
3.14	Electrochemical cell for corrosion test with H <sub>2</sub> SO <sub>4</sub> solution	48
3.15	OM	50
3.16	SEM and EDX	50
3.17	Example of Tafel plot	51
4.1	FTIR analysis result of sulfur in crude oil	54
4.2	Tafel curve obtained once the corrosion film is formed on API X65 in 0.05 M H <sub>2</sub> SO <sub>4</sub>	59
4.3	Tafel curve obtained once the corrosion film is formed on API X65 in 0.20 M H <sub>2</sub> SO <sub>4</sub>	60
4.4	Tafel curve obtained once the corrosion film is formed on API X65 in 0.40 M H <sub>2</sub> SO <sub>4</sub>	60
4.5	Tafel curve obtained once the corrosion film is formed on API X65 in 0.75 M H <sub>2</sub> SO <sub>4</sub>	61
4.6	Tafel curve obtained once the corrosion film is formed on API X65 in 1 M H <sub>2</sub> SO <sub>4</sub>	62
4.7	Digital image of steel sample with 1.0 x magnification	63
4.8	Digital image of pitting corrosion after corrosion test in (a) 0.05 M (b) 0.20 M (c) 0.40 M (d) 0.75 M (e) 1 M H <sub>2</sub> SO <sub>4</sub>	64
4.9	OM for microstructure of API X65 carbon steel pipe	65
4.10	Optical micrograph of pitting corrosion after corrosion test in (a) 0.05 M (b) 0.20 M (c) 0.40 M (d) 0.75 M (e) 1 M H <sub>2</sub> SO <sub>4</sub>	67
4.11	SEM morphology of API X65 carbon steel sample surface without corrosion product	68
4.12	SEM morphology image of sample in the solution of 0.05 M H <sub>2</sub> SO <sub>4</sub>	69
4.13	SEM morphology image of sample in the solution of 0.20 M H <sub>2</sub> SO <sub>4</sub>	69
4.14	Cross-section SEM image corrosion layer after corrosion test with 0.05 M H <sub>2</sub> SO <sub>4</sub>	70
4.15	Cross-section SEM image corrosion layer after corrosion test with	



0.20 M H <sub>2</sub> SO <sub>4</sub>	70
4.16 SEM morphology image of sample in the solution of 0.40 M H <sub>2</sub> SO <sub>4</sub>	71
4.17 SEM morphology image of sample in the solution of 0.75 M H <sub>2</sub> SO <sub>4</sub>	71
4.18 Cross-section SEM image corrosion layer after corrosion test with 0.40 M H <sub>2</sub> SO <sub>4</sub>	72
4.19 Cross-section SEM image corrosion layer after corrosion test with 0.75M H <sub>2</sub> SO <sub>4</sub>	72
4.20 SEM morphology image of sample in the solution of 1 M H <sub>2</sub> SO <sub>4</sub>	73
4.21 Cross-section SEM image corrosion layer after corrosion test with 1 M H <sub>2</sub> SO <sub>4</sub>	74
4.22 Analysis of corrosion product after corrosion test with 0.05 M H <sub>2</sub> SO <sub>4</sub>	75
4.23 EDX peak after corrosion test with 0.05 M H <sub>2</sub> SO <sub>4</sub>	76
4.24 Analysis of corrosion product after corrosion test with 0.20 M H <sub>2</sub> SO <sub>4</sub>	76
4.25 EDX peak after corrosion test with 0.20 M H <sub>2</sub> SO <sub>4</sub>	77
4.26 Analysis of corrosion product after corrosion test with 0.40 M H <sub>2</sub> SO <sub>4</sub>	77
4.27 EDX peak after corrosion test with 0.40 M H <sub>2</sub> SO <sub>4</sub>	78
4.28 Analysis of corrosion product after corrosion test with 0.75 M H <sub>2</sub> SO <sub>4</sub>	78
4.29 EDX peak after corrosion test with 0.75 M H <sub>2</sub> SO <sub>4</sub>	79
4.30 Analysis of corrosion product after corrosion test with 1 M H <sub>2</sub> SO <sub>4</sub>	80
4.31 EDX peak after corrosion test with 1 M H <sub>2</sub> SO <sub>4</sub>	80
4.32 Illustration of pitting corrosion mechanism at steel surface	82

## LIST OF TABLES

2.1	Example of typical composition of crude oil in United States	11
2.2	Hydrocarbon weights in United States	11
2.3	Line pipe physical properties	14
2.4	Failures in oil and gas industry average in Western Europe, Gulf of Mexico and Poland, and India	18
3.1	API X65 pipeline steel with composition specifications	42
3.2	Data for the carbon steel specimen according ASTM G 102	47
4.1	Selected functional groups in the crude oil sample	54
4.2	AAS analysis result for sulfur concentration in crude oil	56
4.3	Value of corrosion rate, $I_{corr}$ , and $E_{corr}$ for different concentrations of $H_2SO_4$	58



## LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

A	-	Ampere
$A_{\text{initial}}$	-	Exposed specimen area
Ag/AgCl	-	Silver/silver chloride
API	-	American Petroleum Institute
ASTM	-	America Society for testing and Materials
ATR	-	Attenuated Total Reflectance
AWD	-	Analytical Working Distance
BP	-	British Petroleum
Cl <sup>-</sup>	-	Chloride
CPU	-	Control Processing Unit
CO <sub>2</sub>	-	Carbon Dioxide
CECER	-	Construction Engineering Research Laboratories
cm	-	Centimeter
Cu	-	Copper
C	-	Carbon
CCK	-	Corrosion Cell Kit
CE	-	Counter electrode
CR	-	Corrosion rate
daN	-	force display (Newton)
Et al	-	et alli (and others)
$E_c$	-	Current electrochemical parameter
$E_{\text{corr}}$	-	Corrosion potential
EDS	-	Energy Dispersive X-ray Spectroscopy
EDX	-	Energy Dispersive X-ray Spectroscopy
EIA	-	Environmental Impact Assessment
Eq	-	Equation

Ep	-	Editional photographers
Ew	-	Equivalent Weight
FKP	-	Fakulti Kejuruteraan Pembuatan
Fe	-	Iron
FeCO <sub>3</sub>	-	Iron carbonate
FTIR	-	Fourier Transform Infrared
GNP	-	Gross National Products
g/l	-	gram per liter
HNO <sub>3</sub>	-	Nitric acid
H <sub>2</sub> S	-	Hydrogen Sulfide
H <sub>2</sub> CO <sub>3</sub>	-	Carbonic acid
H <sub>2</sub> SO <sub>4</sub>	-	Sulfuric acid
IR	-	Infrared
KM	-	Kilometer
K	-	Kelvin
Kw	-	Kilowatts
Kg	-	kilograms
KLCC	-	Kuala Lumpur City Centre
Ksi	-	Kilopound per square inch
L	-	Liter
LPC	-	Production Sharing Contracts
M	-	Metal
m/s	-	meter per second
max	-	Maximum
Mpa	-	Mega Pascal
Mn	-	Manganese
mm	-	Millimeters
m/min	-	meter per minute
MHz	-	Megahertz
NaCl	-	Sodium Chloride
N	-	Nitrogen

NG	-	Not Good
O	-	Oxygen
OM	-	Optical Microscope
P	-	Phosphorus
PETRONAS	-	Petroleum Nasional Berhad
PGU	-	Peninsular Gas utilization
pH	-	Potential of hydrogen
ppm	-	Parts per million
PS	-	Production Sharing
Psi	-	Pounds per Square Inch
PSL 1	-	Products Specification Level 1
PSM	-	Projek Sarjana Muda
Rp	-	Polarization resistance
S	-	Sulfur
SEM	-	Scanning Electron Microscope
Sdn. Bhd	-	Sendirian Berhad
SO <sub>4</sub> <sup>2-</sup>	-	Sulfate ion
U.S.	-	United States
UTeM	-	Universiti Teknikal Malaysia Melaka
V	-	volt
Wt %	-	Weight Percentages
XRD	-	X-ray diffraction
°C	-	Degree Celsius
%	-	Percentage
°F	-	Degrees Fahrenheit
<i>e</i>	-	Electron
Fe <sup>2+</sup>	-	Iron (II) ion
<i>I<sub>corr</sub></i>	-	Corrosion current
μm	-	micron meter
<i>ρ</i>	-	Density

# CHAPTER 1

## INTRODUCTION

### 1.1 Background

Corrosion is the leading cause of failure of the pipelines in the world. Majority of the failures were due to internal corrosion which were more frequent than those due to external corrosion. Normally, large amount of crude oil usually needs effective transportation. So, pipeline is a great transportation to solve this problem. But any failure to ensure the safety and continuous operation on crude oil pipelines can be effected to economic, environment and life-safety implications.

The title of this project is the effect of crude oil to the corrosion properties of the petroleum pipeline. However, the focus of this project is to study compositions in the crude oil such as sulfur which have an effect on the corrosion properties of petroleum pipeline. This information is necessary in order to predict the corrosion mechanism where crude oil is flowing in the pipeline. This is because before this many studies of the corrosion in petroleum pipeline are mainly focused on the corrosion caused by gas rather than crude oil. So, this study is carried out to justify the corrosion caused by crude oil content itself. In addition, the analysis of crude oil composition that relates to the corrosion properties is very important in the corrosion behavior.

The understanding about crude oil composition and corrosion mechanism is a good method to predict the corrosion properties in the pipeline surface. So this study is

important to be carried out because the corrosion caused by crude oil is severally investigated rather than corrosion caused by gas in the pipeline.

## **1.2 Problem statement of the project**

The effect of crude oil to pipelines may cause corrosion on the internal surface of pipeline. Corrosion issues in oil and gas industries have been costly, worldwide either directly or indirectly. According to Teevens et al. (2008), internal and external corrosion are leading causes of failures in petroleum pipeline operations. From these two major types of corrosion, internal corrosion which was costing the most than those due to external corrosion. The internal corrosion is preferred to be concerned in this project because the sulfur in the crude oil is one of the corrosive media that can attack the pipeline surface. Therefore, the corrosion on internal pipeline surface is usually caused by the gas and the most popular corrosion is carbon dioxide (CO<sub>2</sub>) and hydrogen sulfide (H<sub>2</sub>S) corrosion (Razmahwata, 2005). However, studies about crude oil composition especially sulfur content effect on pipeline corrosion behavior is less known. The sulfur concentration in the crude oil may affect the corrosion behavior of the pipeline. On the other hand, the corrosion rate is one of the important factor that must be take into consideration in order determine the how fast the mechanism of the corrosion.

### 1.3 Objectives

This project is therefore to study the corrosion on the internal surface of petroleum pipelines. The main aim of this project is to study the effect of the crude oil to the corrosion behavior of petroleum pipelines. Also, this project related to the corrosion properties in the internal surface of pipelines. Therefore to achieve the aim, the following objectives are in focus:

- a) To determine the sulfur concentration in crude oil by using FTIR spectroscopy and AAS.
- b) To conduct an electrochemical measurement to determine corrosion rate and morphological analysis using OM, SEM and EDX spectroscopy.
- c) To study the corrosion mechanism caused by sulfur in crude oil to the internal surface in petroleum pipeline.

### 1.4 Scope

This project focuses on the composition of the crude oil which affects the corrosion properties of petroleum pipeline. In this project, FTIR spectroscopy, electrochemical measurement, microscopy and phase analysis are main equipment to obtain the chemical composition and microstructural characterization of corrosion product. Besides that, Tafel extrapolation method will be used to determine how fast the corrosion rate mechanism between carbon steel specimen and simulated acidic of sulfate ion ( $\text{SO}_4^{2-}$ ). The sulfur content is selected in this project to determine its effect to the pipeline corrosivity by varying concentrations. After the results has shown, it will compare together to analyze the effect from lowest to highest sulfur concentrations. Though, the prediction and assumptions will be discussed between the supervisor, Dr. Mohd. Asyadi Azam Bin Mohd. Abid in order to ensure the hypothesis about the problems raised and come up with better solutions. However, this project not covers the corrosion protection method at the carbon steel pipeline.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Oil and gas industry in Malaysia**

##### **2.1.1 History**

Oil was first discovered in Malaysia in 1910 in Miri, Sarawak. Since then, two other ground breaking events has helped shape Malaysia's Oil & Gas Industry. First, Malaysia's Parliament passed the Petroleum Development Act and second, Petroliam Nasional Berhad or PETRONAS was established to manage the country's petroleum resources. It also provides support in terms of resource planning, distribution and marketing. PETRONAS was incorporated on 17 August 1974 under the Companies Act, 1965. It is wholly-owned by the Malaysian Government and is vested with the entire ownership and control of the petroleum resources in Malaysia through the Petroleum Development Act, 1974. Over the years, PETRONAS has grown to become a fully integrated oil and gas corporation and is ranked among the FORTUNE Global 500 largest corporations in the world (Halliburton, 2012).

Malaysia has approximately 615,100 square kilometers of acreages available for oil and gas exploration. Of these, 218,678 square kilometers or 36 % of the total acreages is currently covered by Production Sharing Contracts (LPC). Exploration drilling in Malaysia by the Production Sharing Contractors has resulted in the discovery of 163 oil fields and 216 gas fields. Many significant discoveries were made in shelfal shallow waters as well as in deep water environments. Increasingly, new discoveries have been

made through new play types such as fractured basements, pinnacle reefs, low CO<sub>2</sub> gas and turbidities. Application of new technologies has also greatly contributed to exploration successes, especially in deep water areas (Halliburton, 2012).

Malaysia's national oil company, Petroliaam Nasional Berhad (PETRONAS), dominate upstream and downstream activities in the country's oil sector. PETRONAS is the only remaining wholly state-owned enterprise in Malaysia, and is the single-largest contributor of Government revenues. It holds exclusive ownership rights to all exploration and production projects in Malaysia, and all foreign and private companies must operate through Production Sharing Contracts (PSCs) with the national oil company. ExxonMobil (through its local subsidiary Esso Production Malaysia Inc.) is the largest oil company by production volume, and there are numerous other foreign companies operating in Malaysia via PSCs. PETRONAS is a major player in the retail and marketing sector, but faces competition from Shell, Chevron and BP (Razmahwata, 2005). Figure 2.1 shows the Malaysia's oil production and consumption from year 1991 until 2010.

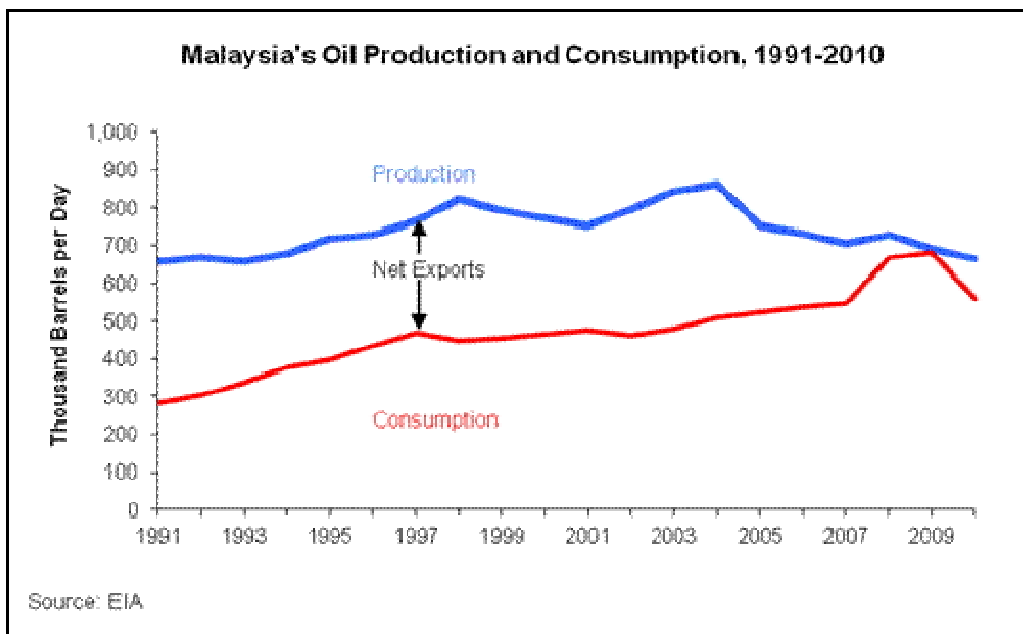


Figure 2.1: Malaysia's oil production and consumption, 1991 - 2010 (Razmahwata, 2005).