PENGESAHAN PENYELIA

" Saya akui bahawa saya telah membaca
karya ini dan pada pandangan saya karya ini
adalah memadai dari segi skop dan kualiti untuk tujuan penganugerahan
Ijazah Sarjana Muda Kejuruteraan Mekanikal (Termal Bendalir)"

Tandatangan : ……………………………

Nama Penyelia I : EN. MOHD. ZAID BIN AKOP

Tarikh : APRIL 2010

Tandatangan : …………………………………..

Nama Penyelia II : EN. SUHAIMI BIN MISHA

Tarikh : APRIL 2010

THE STUDY OF HEAT RADIATION IN FLARE SYSTEMS APPLICATION IN THE OIL, GAS AND PETROCHEMICAL INDUSTRY

ALWANI @ RAFEQAH BINTI ABD. GHANI

Laporan ini dikemukakan sebagai

memenuhi syarat sebahagian daripada syarat penganugerahan

Ijazah Sarjana Muda Kejuruteraan Mekanikal (Termal Bendalir)

Fakulti Kejuruteraan Mekanikal
Universiti Teknikal Malaysia Melaka

APRIL 2010

"I hereby to declare that this project report entitled THE STUDY OF HEAT RADIATION IN FLARE SYSTEMS APPLICATION IN THE OIL, GAS AND PETROCHEMICAL INDUSTRY is written by me and is my own effort except the ideas and summaries which I have clarified sources"

Signature : ………………..………………

Author : ALWANI @ RAFEQAH BINTI ABD. GHANI

Date : APRIL 2010

"Dedicated with love to my beautiful family, best friends and supportive lecturers who has been supportive and give encouragement throughout my whole life"

ACKNOWLEDGEMENTS

First of all, I would like to express my thankfulness to Allah Almighty for blessing: I managed to complete this project on time and could submit it to Mechanical Engineering Faculty of University Technical Malaysia Malacca (UTeM) to fulfill the requirements of my Bachelor's Degree in Mechanical of Thermal Fluids.

My appreciation is extended to all who provided helpful suggestion to improve this project. I want to thank to most honored project supervisor, En. Mohd. Zaid bin Akop for his guidance during this project and lecturer, Pn. Mahanum binti Mohd Zamberi. Besides, I also would like to thank him for willing to spend his convenience times for giving advices along project was conducted. Also, for his support and encouraged, my Project Sarjana Muda entitled THE STUDY OF HEAT RADIATION IN FLARE SYSTEMS APPLICATION IN THE OIL, GAS AND PETROCHEMICAL INDUSTRY be a part of among finalist to the Shell Inter Varsity Student Paper Contest 2010 that was held at UTM, Skudai.

I also would like to send my deep appreciation toward my course mates, 4BMCT and housemates, Suhaila binti Mat Said and all who had contributed some comments and suggestion in this project. Last but not least, to my beloved mother, Asmah binti Parto, my beautiful family and love, Muhd Syafiq for unlimited support and tolerance in completing my project. Without all the helps provided, this project might not proceed smoothly. Lastly, thank you to all.

ABSTRACT

Heat released from flaring activity can gave a big impact to our skin even the flare tip commonly located at a high level. Flaring is high-temperature oxidation process used to burn volatile organic compound (VOC). This reaction produces heat, noise, light as well as pollutant. The heat released caused heat radiation and emitted by matter in the form of electromagnetic ways. Hence, when designing the flare system, heat radiation is one of another factor that has to be considered. The proper design of flare is a vital in oil and gas industry as weak design may cause damage in property as well as effect to human being. The study has indicated that an intensity of 7500 Btu/hr/ft^2 caused burns on bare skin of white rats in approximately 6 seconds. However, human with appropriate clothing can endure radiant heat intensity approximately 1500 Btu/hr/ft^2 for several minutes which they can do some quick work at flare area. In this study, the design of flare system has been conducted by referring to American Petroleum Institute Recommended Practice 521 (API RP 521). An analysis has been done in order to ensure the current design of flare system meet the API standard. The analysis takes place on both high pressure and low pressure flare. As for high pressure, the standard is 1 Mach, while for low pressure is below 0.5 Mach. In analysis, the radiant heat intensity and the maximum distance from flare stack to the exposure object are taken from API RP 521 Standard while the opening diameter, the height of flare stack and tip were taken from current design. After all, the important of determining suitable flare radius are to keep worker safely as well as equipment.

ABSTRAK

Haba yang terhasil daripada aktiviti menyahkan gas melalui pembakaran boleh memberikan kesan yang teruk pada kulit kita walaupun nyalaan apinya berada pada aras yang tinggi. Pembakaran ini adalah satu proses oksidasi bersuhu tinggi yang digunakan untuk membakar sebatian organik meruap. Reaksi ini juga menghasilkan haba, kebisingan, cahaya dan juga pencemaran. Haba yang terhasil menyebabkan radiasi haba dan dikeluarkan oleh jisim dalam bentuk gelombang elektromagnetik. Maka, apabila mereka cipta sistem pembakaran ini, radiasi haba adalah salah satu faktor yang perlu dipertimbangkan. Rekabentuk sistem pembakaran yang betul adalah penting dalam industri gas dan petrokimia pabila rekabentuk yang lemah menyebabkan kerosakkan pada harta dan juga memberi kesan pada manusia. Kajian telah menunjukkan pada satu keamatan 7500 Btu/hr/ft^2 menyebabkan kesan terbakar pada kulit tikus putih yang terdedah pada jangka masa 6 saat. Bagaimanapun, manusia (pekerja) dengan pakaian yang sesuai boleh menahan keamatan radiasi haba sehingga 1500 Btu/hr/ft^2 untuk beberapa minit dimana mereka masih mampu (boleh) melakukan kerja dengan cepat pada kawasan tersebut. Dalam kajian ini, rekabentuk sistem pembakaran ini telah dilakukan dengan merujuk kepada American Petroleum Institute Recommended Practice 521 (API RP 521). Satu analisis telah diadakan bagi memastikan rekabentuk sistem pembakaran terbaru mematuhi taraf API. Analisis ini diadakan pada kedua-dua tekanan tinggi dan rendah sistem pembakran. Bagi tekanan tinggi, tarafnya ialah 1 Mach, manakala untuk tekanan rendah ialah di bawah 0.5 Mach. Dalam analisis, nilai keamatan haba sinaran dan jarak maksimum daripada nyalaan api kepada objek yang terdedah diambil daripada API RP 521 Standard manakala garis pusat pembukaan, ketinggian batang corong dan corong nyala telah diambil daripada reka bentuk semasa. Lagipula , adalah penting menentukan jejari nyalaan yang sesuai untuk memastikan keselamatan pekerja serta peralatan.

CONTENT

CHAPTER	CONTENTS		PAGES

LIST OF TABLE

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATION

API	American Petroleum Institute
API-RP	American Petroleum Institite Recommended Practise
B & S	Brzustowski & Sommer
FFG	Flame Front Generation
GPSA	Gas Processor Suppliers Association
HP	High Pressure
ICP	Ignitor Control Panel
ICE	Ignition Device Enclosure
LP	Low Pressure
NAO	National Airoil Burner
S.I	International System units
VOC	Volatile Organic Compound

CHAPTER I

INTRODUCTION

1.1 Introduction into General Topic

In heat transfer, heat is form of energy that flows from high temperature to low temperature. There are three modes of heat transfer; conduction, convection and radiation. Conduction is the transfer of energy from the more energetic particles of a substance to the adjacent less energetic ones as a result of interactions between the particles. Normally, it occurs in solids, liquids and gases. Convection is the flow of heat through a bulk, microscopic movement of matter from a hot region to a cool region. However, convection occurs on solid surface and it involves the combine effects of conduction and fluid motion. Unlike conduction and convection, heat transfer by radiation can occur between two bodies, even when they are separated by a medium colder than both of them. Radiation is the energy emitted by matter in the form of electromagnetic waves.

As offshore oil gas exploration realms begin to engulf new and increasingly challenging environments the problem associated with the disposal of volatile organic compound (VOC). Flaring is widely use at plan to dispose unwanted gases or relief gases by burned those gases. Combustion is complete if all VOCs are converted to carbon dioxide and water. However, incomplete combustion promotes VOCs unaltered or converted to other organic compounds such as acids or aldehydes. As a result, some undesirable by-products including noise, smoke, heat radiation, light, SO_x, NO_x, CO_x, and an additional source of ignition where not desired. Though, a proper design will help to minimize these problems.

1.2 Flare System Application

The application of flare widely use in the oil, gas and petrochemical industry. Flare means gas is disposed and consume as fire in an atmospheric area. Petrochemical industry such as refinery plant, used flare to burned wasted gas or over-pressuring gas. Either onshore or offshore, the wasted gas is burned out using flare that may cause effect of the emission. Figure 1 below showed the application of flare on offshore platform.

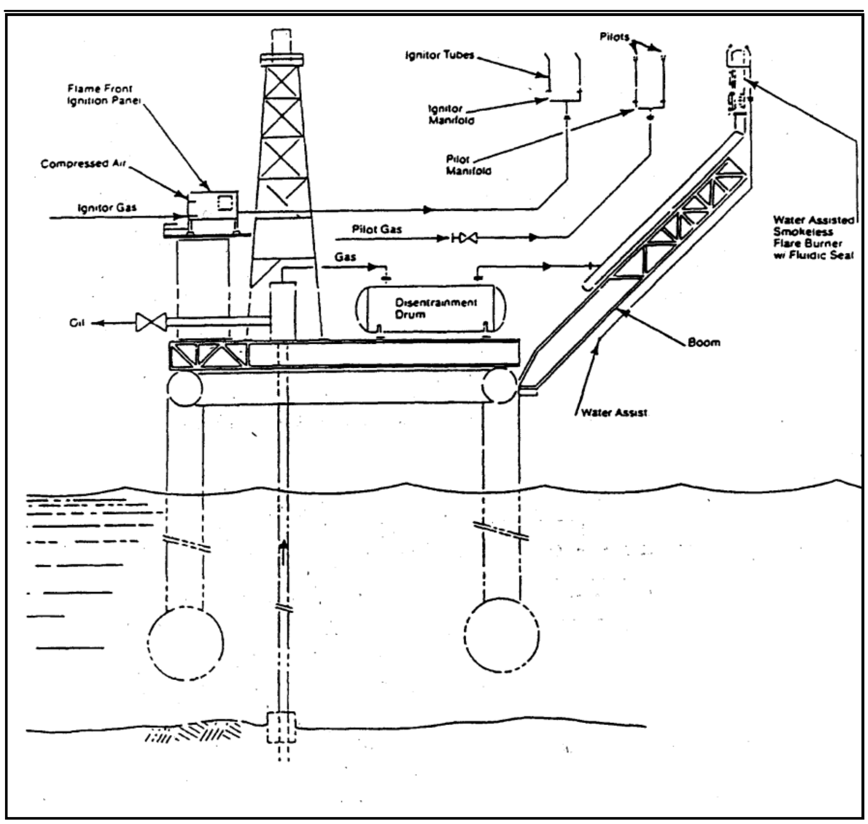

Figure 1: Offshore platform (Source: Gas Disposal, and Flare and Vent System handbook)

1.3 Flare System Technology

Flare system technology nowadays becoming more challenging as petrochemical industry are in races to design the best system with considering some risks. The consideration probably will be on the normal exit of waste gas or emergency exit, means the over-pressuring gas. In the other hand, technology of design flare become more widely as they consider the emission or heat radiated from the flaring activity instead of soot or smoke.

High Pressure/Low Pressure Flare Package is an example for flare technology. This example was referring to the Flareon Sdn.Bhd previous project. The system consists of two different stacks. The stack is for high pressure flow and another one is for low pressure flow.

1.3.1 Sonic High Pressure Flare

Sonic flares utilize multi-point exit nozzles to dispose of high pressure waste gas streams. The MACH-1 Sonic Flare Tip utilizes the pressure of the waste stream (creating sonic exit velocities) to create turbulent mixing and induce excess quantities of air for more complete combustion.

The minimum HP purge rate of oxygen free hydrocarbon gas required to prevent air entertainment thus any possible flashback within the Flare System is 314 SCFH (8.9sm^3/hr) for a 20mph(10m/s) wind.

1.3.2 Low Pressure Flare

The minimum LP purge rate of oxygen free hydrocarbon gas required to prevent air entertainment thus any possible flashback within the Flare System is 79 SCFH (2.2sm^3/hr) for a 20mph (10m/s) wind.

1.3.3 Flame Front Generation (FFG)

FFG is the simple backup system in case of the igniter (spark plug) failure. So, flows of both Fuel Gas and Air are mixed together in a flammable ratio at a location which is easily accessible to operating personnel, usually fairly close to the bottom of an elevated flare. Then, the result is as though there is a “ball” of flame rolling along the line at something between 10 – 70 fps (usually).

1.3.4 Ignition Control Panel (ICP) and Skid

Ignition control panel is a medium to control ignition at pilot. ICP contains push button, pilot’s lamp to received signal from IDE either the pilot is ready to use or not. Ignition Device Enclosure is a medium to transfer signal from thermocouple to ICP at the bottom. Thermocouple which is use in this project is Single Element Type K Thermocouple with Swage Connections (SS) for pilot. When the pilot is burning, thermocouples will detected the heat of the flame and give a feedback to the control panel. If failed, the control panel will be lighted red, but if success the control panel will be lighted green.

Skid is structural steel frame to hold three bottle of propane gas, ICP box, FFG transformer box and all instruments, tubing and fitting on it.

1.4 Problem Statement

As working at the most hazardous area, the design of flare system must be correct to avoid any accident. When flaring, instead of expose to smoke, workers also expose to heat radiation. The height of stack, opening diameter, and sizing should be calculated to avoid workers from expose to heat radiation.

1.5 Objective

- To determine the minimum distance from a flare to exposure object.
- To study the effect of heat radiation towards equipment and life being.
- To achieve optimum level of operation.
- To define sizing of flare (diameter, height, opening)

1.6 Scope

The scope of study includes:

- Collecting information about heat radiation or flare.
- Review collected information.
- Analysis the heat radiation, the minimum distance from flare to exposure object, the heat radiation of flare system towards personnel and equipment and analysis of the sizing of flare.
- Analysis the current design of flare.
- The analysis will use NAO method and API Simple Approach
- Conclusion

1.7 Expected Result

After analysis, the minimum distance from a flare to exposure object could be determined. Beside that, the sizing of flame length, diameter and percentage of different can be defined. The minimum distance shall meet API Standard as well as the flame length. Hence, the current design is followed the API Standard.

1.8 Thesis Content

This project is divided into six chapters. Each chapter contains appropriate information as it should have. Chapter I is an Introduction. In this chapter, there were content of introduction into general topic, flare system application and technology, the problem statement, objective, scope, expected result and thesis content.

A basic explanation of heat transfer consists in this chapter along with the application and technology in flare system. A problem statement shall be clearly understood before proceed to the next stage. The objectives are the main element in this thesis is clearly clarified. Scope section included the task that shall do in purpose to accomplish the objective of this thesis. Expected result as well as hypothesis is the predicted result from this thesis. It is important to give an expected result as the final result shall be compared with it. Last section in this topic is thesis content. Thesis content is important as they shall summarize each chapter in one section.

Next chapter is Chapter II which is Literature Review. In this chapter, the deeply elaboration of thesis is stated. It consists of the principle of flare, the previous research summary, the fundamental of heat radiation and a hazard and operability (HAZOP). In this chapter, the understanding of thesis topic is more to be understood. Referring to the previous research, the methods used are different.

Chapter III is the Methodology. As it named as methodology, it is defined method use in order to achieve objective line. The method use is the latest method by American Petroleum Institute (API). The method is API Recommended Practice 521 a Guide for Pressure Relieving and Depressuring System 4th Edition. The minimum distance from exposure objects is determined by this method.

Chapter IV is the Data Analysis. The data is analyzed using two methods. There were NAO method and API Simple Approach method. Both methods gave the different result for the flame length and the minimum distance from flare stack to exposure object. The analysis took an account for stagnant air (still air) and windy condition. However, for stagnant air, there was only one method can be used. Some parameters are set to be fixed as to standardize the data obtained.

The next chapter is Chapter V, where all result is stated here. The results are for both methods and air conditions were stated in a table as the different easier to see. The minimum distance from flare stack to exposure object is stated at the last part of this chapter. While in the next chapter, Chapter VI is a Discussion. In discussion section, the result obtained is discussed. Finally is Chapter VII. The last chapter definitely shall be the Conclusion. The overall project will be presented in the conclusion along with result obtained.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Prior to 1947 in the United State of America, the process of vent streams were directly exhausted to the atmosphere. Late 1947, regulations required that hydrocarbon vent streams be safely burned or flared. Flares are designed to safely and efficiently combust vent streams of combustible gases from the plant. They also must operate over a wide range of conditions, from small purge rate flow to large emergency relief flow, with vent gas compositions that are often highly variable. Large relief gas flow will produce large flames. Thermal radiation, noise and visible smoke are all important emissions that need to be minimized.

Flaring is high-temperature oxidation processes used to burn VOC. Commonly are hydrocarbons, waste gases from industrial operations. Natural gas, propane, ethylene, propylene, butadiene and butane constitute over 95 percent of the waste gases flared. In combustion, gaseous hydrocarbons react with atmospheric oxygen to form carbon dioxide (CO2) and water. In some waste gases, carbon monoxide (CO) is the major combustible component. Presented below, as an example, is the combustion reaction of propane.

$$C3H8 + 5\ O2 > 3\ CO_2 + 4\ H2O \quad (1)$$

During a combustion reaction, several intermediate products are formed, and eventually, most are converted to CO_2 and water. Some quantities of stable intermediate products such as carbon monoxide, hydrogen, and hydrocarbons will escape as emissions.

2.2 Flare System

A flare system provides a method of protecting equipment from overpressure or in the other sentences is the safe disposal method of the released fluids. Usually, there is another method of disposal system instead of flare. It is call a vent system. Roughly, both of those methods have the same purpose. However, when flaring, it means the gas is burned but when venting, it means the gas is discharged directly to atmosphere or water.

Flaring is a combustion process which volatile organic compound are piped to a remote, usually elevated and burned in an open flame in the open air using a specially designed burner tip, auxiliary fuel, and steam or air to promote mixing for nearly complete volatile organic compound destruction. Combustion is the rapid oxidation fuel. This reaction produces heat, noise and light as well as pollutant such as NO_x, CO_x and H_2O.

Basically, flare consists of flare stack, flare tip and pilot. As an electronic device is located in control panel box, it is excepting to discuss instead of the report is about mechanical part. Generally, flare stack is a tall vertical vent pipe use in petroleum refineries, chemical plants and petrochemical plants oil and gas drilling sites, natural gas processing plants, and landfills for burning off unusable waste gas or flammable gas released by pressure relief valves during unplanned over-pressuring of plant equipment.

Flare tip is located at the top of flare stack. The functions of flare tip are to burned or vent all of wasted gas to the air. As flare stack acts such a medium to transport wasted gas to the flare tip. There are pilots at flare tip to ignite combustion of the wasted gases. The material usually use for flare tip is stainless steel (SS316). Pilot is controlled by a system in a control panel box that is located in ICP Skid.

2.3 Types of Flare

Generally, flare can be categorized by two characteristic, first by the height of the flare tip and second by the method of enhancing mixture at flare tip. For example ground or elevated can be categorized as the first characteristic while steam-assisted, air assisted, pressure-assisted and non-assisted can be put in the second group of characteristic. Elevating the flare can reduce the risk of dangerous conditions at ground level where the ignition is near the process unit. Furthermore, the product of combustion can be dispersed above working areas to reduce the effect of noise, heat, smoke, and objectionable odors.

Failure to destroy waste gases correctly is not a new issue although the problem is increasing in profile due to legislation and corporate environmental focus over recent years. In most flares, combustion occurs by means of a diffusion flame. A diffusion flame is one in which air diffuses across the boundary of the combustion product stream toward the center of mixture flow, forming the envelope of combustible gas mixture around a core of fuel gas. This mixture, on ignition, establishes a stable flame zone around the gas core above the burner tip. This inner gas core is heated by diffusion of hot combustion products from the flame zone.

When the formations of small hot particles of carbon give the flame characteristic luminosity it can occur cracking on flare stack. However, if there is an oxygen deficiency and if the carbon particles are cooled to below their ignition temperature, smoking occurs. Hence, an adequate air supply and good mixing are required to complete combustion and minimize smoke to overcome this problem.

Consequently, the various design of flare takes part to overcome this problem. As an example, to create smokeless operation, steam-assisted flare will be selected. It burned vent gas in essentially a diffusion flame. To ensure an adequate air supply and good mixing, this type of flare system injects steam into the combustion zone to promote