THE EFFECT OF SUPPRESSION AGENTS TOWARDS LIQUEFIED PETROLEUM GAS (LPG) & NATURAL GAS (NG) EXPLOSION LIMIT

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ABSTRAK

Projek ini adalah untuk mengenalpasti kesan agen penindasan terhadap letupan yang dihasilkan oleh gas petroleum cecair (LPG).dan gas asli (NG). Tujuan kajian ini dijalankan adalah untuk mengenalpasti agen penindasan yang lebih baik untuk menghentikan impak letupan dari peringkat awal. Dalam ujian yang dijalankan, beberapa jenis agen penindasan digunakan iaitu ammonium fosfat, gas argon dan gas karbon dioksida. LPG digunakan sebagai sumber bahan bakar disebabkan oleh sifat gas itu sendiri yang mudah terdedah kepada letupan dan boleh mengakibatkan letupan besar seperti BLEVE. Memandangkan NG juga digunakan secara meluas sebagai sumber tenaga pada masa kini, adalah amat penting untuk memastikan langkah-langkah pencegahan awal daripada berlakunya letupan dijalankan. Semakin rendah tekanan optimum yang dihasilkan, semakin berkesan agen tersebut. Ujian dijalankan dengan menggunakan unit letupan gas. Agen penindasan yang terdapat dipasaran adalah dari gas karbon dioksida dimana ianya meninggalkan kesan sampingan yang negatif kepada alam sekitar. Oleh yang demikian, data yang diperolehi daripada ujian yang dijalankan akan menunjukkan bahawa ammonium fosfat adalah lebih efektif dalam memberhentikan letupan gas sekaligus mengatasi masalah yang diakibatkan oleh agen penindasan yang terdapat dipasaran.

ABSTRACT

The objective of the research is to determine the effect of suppression agents towards liquefied petroleum gas (LPG) and natural gas (NG) explosion limit. The main target of the research is to identify the best suppression agents that can be used in the suppression system to mitigate explosion from its early stage thus preventing catastrophic. In the experiment, several types of suppression agents are used which are ammonium phosphate, argon gas and carbon dioxide gas. Liquefied petroleum gas (LPG) and natural gas (NG) is used as a fuel source. The purpose of using LPG as the fuel source is because LPG is one of the most dangerous sources of fuels that can easily involve in an explosion due to its properties that can cause boiling liquid expanding vapour explosion (BLEVE). Since natural gas is also commonly used in the industries and as well as residential area, it is best to make sure that the prevention is fully secure. The lower the maximum pressure, the more effective the suppressants are. The experiments are carried out by using the gas fire explosion unit. Conventional suppression agent that is commonly used in the industries nowadays is carbon dioxide. However, carbon dioxide can give a side effect to the environment. Therefore by the end of the experiments, the results will show that ammonium phosphate does mitigate the gas explosion more effectively thus overcoming the problem cause by the conventional suppression agent.

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CHAPTER 1

INTRODUCTION

1.1 Introduction to Explosion

An explosion phenomenon is a process whereby a pressure wave is generated in air by a rapid release of energy. This pressure wave often referred to as the blast wave that is largely responsible for the injuries and damaged. The blast wave produced by an explosion interacts with any objects in its path, imposing a mechanical load on them. This mechanical load could be very dangerous to building and structures.

People may be injured and structures could be damaged by an explosion through several mechanisms such as crater formation, ground shock and fire. Ground shock and cratering resulting from condensed phase explosion or detonations can be important considerations for buried targets such as pipelines and hence cause ‘domino’ or ‘knock-on’ effects. But for target above ground, the effects are normally small compared with those of the blast wave (Barton, 2002).

Each year the process industries handle a wide range of different materials and utilize them in many different types of chemical reaction. A significant proportion of the materials used are hazardous and many of the processes must be very carefully managed to ensure safe operation.

Failure of either equipment or operational standards could in some cases results in an explosion which could take one of many forms. It could for example be a boiling liquid expanding vapor explosion (BLEVE) and as well as vapor cloud explosion (VCE) following an ignited release of flammable gas or vapor. Nowadays, such events are rare due to the attention paid to their prevention and protection (Merrifield *et al*., 1991).

1.1.1 Explosion Protection

Explosion protection plays an important role in plant and layout decisions, particularly when hazardous materials and public safety issues are involved. The danger of an explosion is difficult to avoid in processes where combustible materials are handled. Once they dispersed in air with an effective ignition source, an explosion occurs. These explosions can cause a huge disaster and it is catastrophic (Barton, 2002).

Potential explosion hazards are to be found throughout industry handling combustible powders. As a result, most countries now have legislation and standards providing guidance for practicable precautions against potential explosion hazards and to prescribe safety measures to control their occurrence. Protection measures include containment, inerting, venting and as well as suppression in which this research will be focus on (Chamberlain, 1989).

1.1.2 Explosion Suppression

Explosion suppression provides a method for extinguishing a growing fireball and relies on early detection of an incipient explosion. This is most commonly achieved by ‘set-point’ pressure detection (Siwek, 1992). This method is often used where it is not possible to protect by containment or explosion relief venting and in particular where the pressure and flame of the explosion cannot be vented to a safe location.

Explosion suppression is particularly important in cases where loss of process containment could cause the emission of toxic dusts or other substances harmful to the people or surroundings. Suppression is considered as a basis of safety to prevent and mitigate explosion. The K_{st} value, the maximum explosion pressure (P_{max}) and the minimum ignition temperature (MIT) of a dust cloud are the relevant parameters to be measured for the design and efficacy of explosion suppression systems (Barton, 2002).

Explosion suppression is in favor when we want to lower down the operational and maintenance cost significantly, extinguishes the flame from a deflagration and mitigate the associated pressure damage to the protected area by limiting the pressure thus keeping the explosion contained and also applied if process medium is hazardous to the environment, the process equipment is too far from an outside wall or cannot be protected by other measures. Designed to detect and chemically suppress an explosion in its earliest stages-before an explosion can cause a disaster or become catastrophic.

Several conditions where venting is impractical to be applied and suppression is in favoured is when the equipment is located indoors, the explosive material has a high Kst or is a hybrid, there is not enough available area on the vessel for vents, material is toxic and can't be discharged to atmosphere, there is no safe place in which to vent and flame propagation through interconnections. That is why, suppression in explosion protection is very important as the main alternative in a condition where venting is impractical.

1.2 Background of Study

This project is mainly focuses on the suppression system as the main alternative to prevent or mitigate explosion from occur especially in industrial. According to National Fire Protection Association (NFPA), the groupings that might be considered 'industrial' are basic industry, utilities, manufacturing and many of the storage properties. NFPA statistics for 1990 (Zalosh, 2002) indicate that there were 22,000 fires and explosion in the combined categories of basic industry, utilities and manufacturing. An additional 39,500 fires and explosion in the storage properties are also recorded (Barton, 2002).

The US Occupational Safety and Health Administration (OSHA) maintain a database of workplace injuries. Their data for 1998 (Bureau of Labor Statistics, 2000) indicate that there were 4152 non-fatal workplace injuries due to fires and another 1670 occupational injuries due to explosions. In addition, there were more than 300 fatalities in 1998 due to fires and explosions worldwide. These figures neglect the numerous fires and explosions that are not reported to the public fire department because they are extinguished by plant personnel or fixed suppression systems (Zalosh, 2002).

These shows that an early detection and protection systems are very important to be consider in every industry in order to prevent fires and explosion from occur. In this project, several types of suppression agent will be applied to the explosion to test and determine their effect on the explosion limit. As the fuel source, liquefied petroleum gas (LPG) will be use due to its properties and potential in the occurrence of explosion.

1.3 Problem Statement

An early detection of an explosion is very important especially in the process industries as a prevention and explosion protection. A disadvantage of this method is the potential of the suppression agent to mitigate the explosion limit especially when dealing with liquefied petroleum gas (LPG) and natural gas (NG) as a fuel source. This problem can be solved by replacing the failure suppression agents with the one which are more effectives and can be rely on.

1.4 Objectives

The main objectives of this project are to determine the effect of suppression agents towards liquefied petroleum gas (LPG) and natural gas (NG) explosion limit hence determining the best suppression agent to be use in the suppression systems.

1.5 Expected Outcome

As stated above, the objectives of the project are to determine the effect of the suppressants to the liquefied petroleum gas (LPG) and natural gas (NG) explosion limit. Therefore, as the expected outcome, it is hope that the suppressant's efficiency and the best suppression agent can be determined to be use in the suppression system.

1.6 Scope of Research

To determine the effect of suppression agents towards liquefied petroleum gas (LPG) and natural gas (NG) explosion limit hence identified the best suppression agent. Several parameters will be considered in the experiment such as the minimum pressure (P_{min}), maximum pressure (P_{max}) and the types of suppression agents used. Three types of suppression agents will be test in the experiment which is Ammonium Phosphate, Carbon Dioxide, and Argon, Ar, 18. Liquefied petroleum gas (LPG) and natural gas (NG) will be use as a fuel sources due to its tendency to create an explosion and its potential in the occurrence of boiling liquid expanding vapor explosion (BLEVE).

In overall, there are three tasks that must be run and complete in order to get the best result. First task is to run the basic explosion of LPG and NG without applying the suppression agent. This task will be run by using the explosion unit. This step is very important to determine the basic explosion limit of LPG and NG.

Second task is to run the explosion with the presence of suppression agents. As stated above, three types of suppression agents will be use in the experiment which is Ammonium Phosphate, Carbon Dioxide and Argon, Ar, 18. Experiments will be carried out in the explosion unit. This step is very important to determine the effect of suppression agents towards the LPG and NG explosion limit hence identify the best suppression agent to be applied in the suppression system.

Last task is to make a comparisons based on the results obtained from the suppression's efficiency hence improving the ability of the suppression agents to mitigate the LPG and NG explosion by identifying and adjusting the parameter. Several parameters will be considered such as the minimum pressure (P_{min}), maximum pressure (P_{max}) and the types of suppression agents used. This step is important to gain the best result and to understand more about the explosion limit and suppression in explosion.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The technique of explosion suppression involves the detection of a developing explosion at an early stage and extinguishing it before a destructive pressure is reached and become catastrophic. Suppression in explosion is applied at condition where venting is impractical to be applied and suppression is in favoured. The suppression in explosion works in two ways which are through chemically (interfering with the explosion's reaction) and thermally (removing heat from the deflagration's flame front and thereby lowering its temperature below that needed to support combustion). The explosion suppressant also creates a barrier between the combustible particles to prevent the further transfer of heat (Barton, 2002).

Potential explosion hazards are to be found throughout industry handling combustible powders/ dust. As a result, most countries now have legislation and standards providing guidance for practicable precautions against potential dust explosion hazards and to prescribe safety measures to control their occurrence. Protection measures include containment, inerting, venting and suppression).

For explosion containment, the plant must be designed to contain the maximum pressure generated by an explosion (Harry, 2003). This is normally combined with a system of isolation to prevent explosion transmission from one vessel to another via connecting pipework. The basis behind the application of inerting as a method of explosion protection is the ability to reduce the oxygen concentration of a dust/air cloud below the minimum required for ignition and so render it inert. Nitrogen, carbon dioxide and flue gases are examples of inert gases used for this method. Inerting is facilitated by a relatively closed process and accurate monitoring of the process oxygen concentration (Cate, 1999).

Most published research has been carried out on venting technology, as traditionally there has been a greater demand for this cheaper type of protection. Explosion venting relies on the relief of overpressure through the opening of appropriately sized and pressure-rated apertures. There is no attempt to control the rate of burning and it is therefore based on the complete burning of the dust cloud and the full growth of the fireball with associated maximum burning rate. The advantage to the application of venting includes the ability to discharge vented material in the form of a burning dust cloud to a safe location.

Plants processing toxic dusts which cannot be released to the atmosphere are not suitable for explosion venting. This is where explosion suppression is favored. Explosion suppression involves an early detection of the explosion and the rapid discharge of suppressant into the protected volume. Typical suppressants include dry powders, water and fluorinated hydrocarbons. The efficacy of the suppression system depends on a number of parameters including the time period between mixture ignition and suppressant interaction with the expanding flame front (time for detection, control, actuation and suppressant delivery), the location and number of suppressant containers and mass of suppressant delivered. Guidance for the design of explosion suppression systems is limited and usually proprietary information.

The propagation mechanism of an explosion may be physically or chemically controlled. Heat transfer between dust particles is usually considered to control the propagation rate of dust explosions. Hence in order to suppress most dust explosions it is essential to quench the combustion wave.

Discharging a spray of liquid or powder into a growing fireball results in a number of complex effects including quenching (heat abstraction from the combustion zone by energy transfer), free radical scavenging (active species in the suppressant compete with chain-branching reaction necessary for flame propagation), wetting (unburned dust particles are rendered non-flammable by absorption of liquid suppressant) and inerting (concentration of suppressant in suspension renders the unburned mixture inflammable). This latter effect is important for protection against the recognized problem of re-ignition of a post-suppression dust/air atmosphere (Barton, 2002).

2.2 Historical background

At the end of the 19th century it was hoped that the replacement of the black powder by the recently invented dynamites with their very short reaction times would help to prevent from the frequent firedamp explosions in underground coal mining caused by blasting works. But soon experience showed that this was not the case. The explosion temperature and the overall explosion energy had to be markedly reduced to reach a certain degree of safety against firedamp and even coal dust explosions. At that time the first testing stations were founded. The explosives to be permitted for use in underground coalmines were tested in galleries under borehole conditions in steel cannons and in the presence of methane or cold dust.

Different ways to reduce the energy of the explosives were founded successful such as shifting the oxygen balance to markedly negative or positive values and addition of inert components like salts with high crystal water content. The invention and use of delay detonators offers new possibilities of causing firedamp explosions. The prolonging of the blasting process results in a rising methane content and furthermore in opening the confinement of a not yet detonated borehole charge. Therefore explosives with enhanced safety even in unconfined conditions were needed.

After World War II the replacement of natrium chloride (NaCl) by a mixture of ammonium chloride and alkali nitrate proved to be good solution with respect to safety and energy. These powder form explosives are based upon the so called inverse salt pair (NH_4Cl/ $NaNO_3$). The ions of this salt pair are identical with those of the formerly used salt pair NH_4NO_3/ NaCl.

These explosives show a selective detonation. That means, the shock wave in the explosive is stabilized only by the detonation of about 10% nitroglycerine, whereas the extent of the reaction of the salt pair depends on the confinement of the charge as well as on the grain size of the salts and the exact content of nitroglycerine. As the invention improved, the scientist came up with a very good solution of creating and as well as preventing explosion. In terms of prevention and mitigation, they came up with few solutions such as venting, suppression and isolation (Bartknecht, 1989).

As early as 1860, liquefied petroleum gas (LPG) was used for a portable fuel source, and its use has expanded dramatically ever since. The extensive use of LPG did not develop until the 1940’s through the 1960’s. Liquefied petroleum gas is primarily and widely used in rural areas where piped natural gas is not available.

Propane and butane, which are the primary gases in LPG, are heavier and contain more heat per cubic foot than natural gas. LPG contains 2,500 BTU per cubic foot, and is sold by the gallon. One gallon of LPG contains approximately. 90,000 BTU. Liquefied petroleum gas is a safe fuel if installed and handles correctly. However, improper use, installation and maintenance of LPG appliances can cause fire, explosion or asphyxiation (Zalosh, 2002).

2.3 Explosion

An explosion is defined as a process whereby a pressure wave is generated in air by a rapid release of energy. This definition encompasses widely differing events ranging from the trivial example of a spark discharge through sudden release of stored energy in a compressed gas to the extreme of chemical detonations and nuclear explosions. Explosion can be measured by the explosion limits (Zalosh, 2002).

Figure 2.3.0 (a) shows the explosion pressure curve in order for the explosion to occur. The figure shows that at normal process pressure, explosion started to develop in the centre of ignition. By the end of the process which was estimated around pressure of 8 bar, the explosion is already at the final stage and it started to expand rapidly causes a blasting effect. Figure 2.3.0 (b) shows the characteristics of explosion event where in the presence of flammable substances, oxidizer and ignition sources, an explosion can occur.

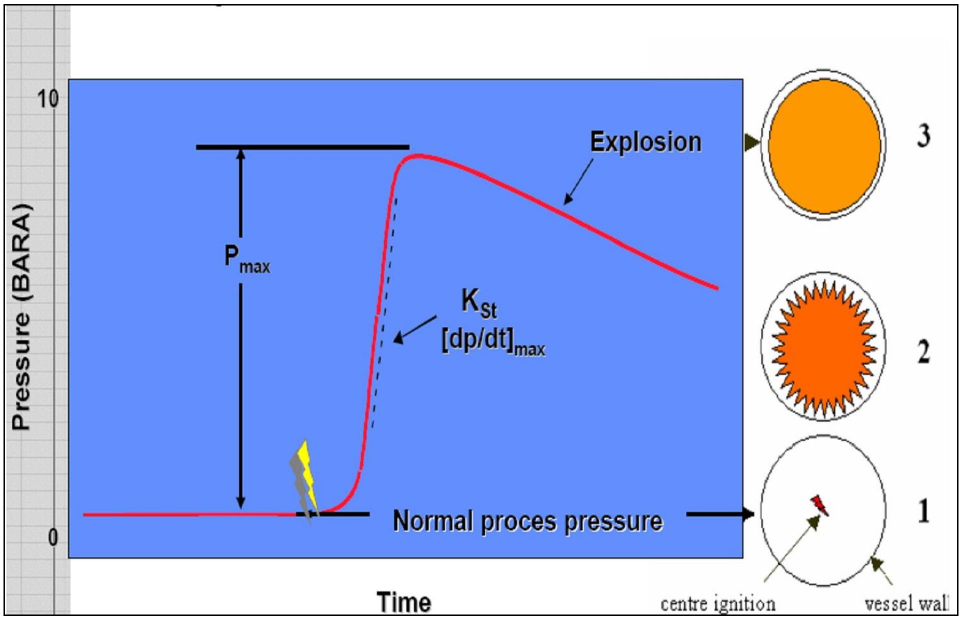

Figure 2.3.0 (a): Explosion Pressure Curve

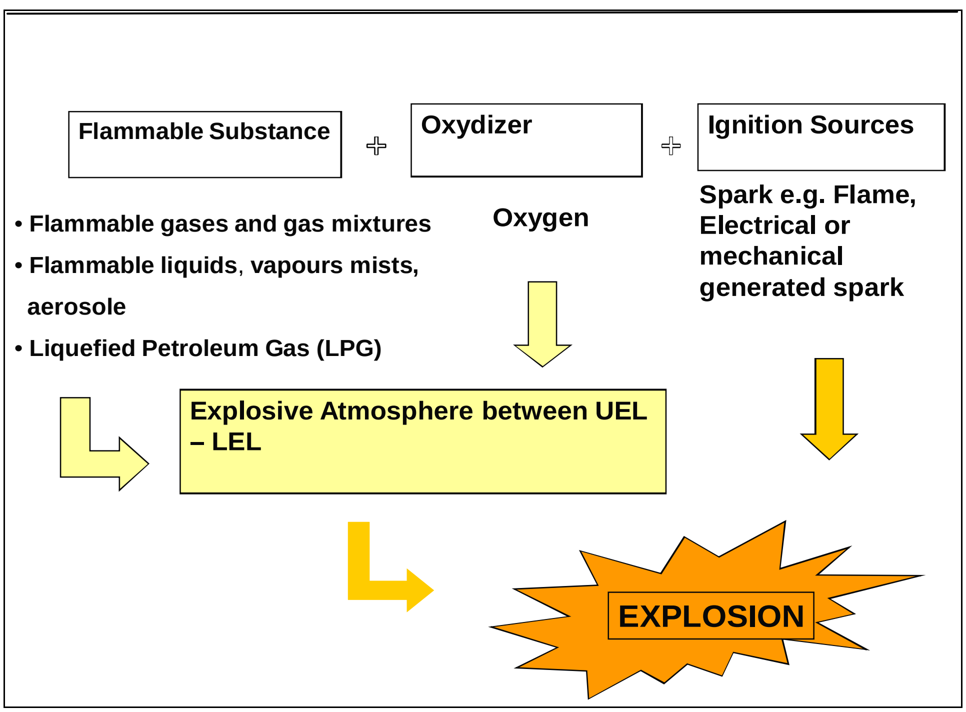

Figure 2.3.0 (b): Characteristics of Explosion Event

2.3.1 Explosion Limits

Explosion limits describe the concentration range of dust and air mixtures in which explosions are possible. Usually, only the lower explosion limit (LEL) is determined. These measurements are important if the avoidance of an explosible dust cloud forms part of the basis for safety. Combustion may only be sustained if the heat released due to combustion is greater than that absorbed by the surroundings. Flammable gases will burn over a range of compositions either side of the stoichiometric.

However it has been found experimentally that there are lower (lean) and upper (rich) values of the flammable gas concentration beyond which a flame will not propagate. Lean limit is required critical flame temperature for the flame chemistry to proceed and it is approximately 1500 K – 1573 K. Lower explosive limit (LEL) is the smallest quantity of combustible when mixed with air (or other oxidant) which will support a self propagating flame. Upper explosive limit (UEL) is the highest quantity of combustible when mixed with air (or other oxidant) which will support a self propagating flame

Essentially the concentration of an explosible dust is systematically reduced in a series of tests until the dust suspension can no longer be ignited. The highest dust concentration at which the dust/ air mixture can no longer be ignited in the tests is specified as the LEL (Barton, 2002). Figure 2.3.1 (a) shows the effect of temperature on the lower explosive limits (LEL). In this figure, propane and butane has a lower explosive limit (LEL) about 2%.

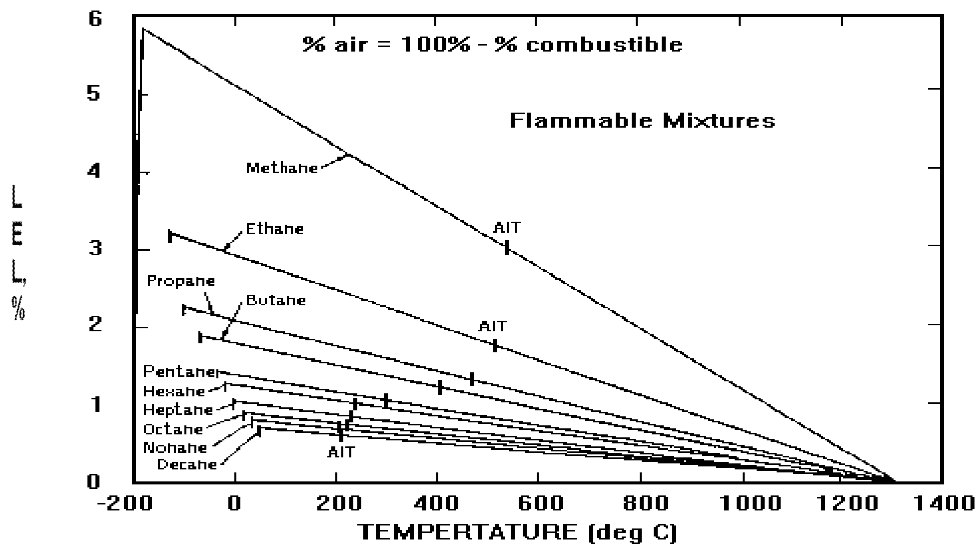

Figure 2.3.1 (a): The Effect of Temperature on Lower Limits Flammability

Table 2.3.1 (b) shows the typical flammable range in air for methane, ethane, propane, butane, pentane, hexane, heptanes and heavier hydrocarbon as shown. In this table, lower explosive limit (LEL) and upper explosive limit (UEL) are given.