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ALOHA Simulation on the Leakage Accident of CO_2 in Gas Welding Process

Pakkarada Sansuksom[1]*

[1] Faculty of Engineering, Suvarnabhumi Institute of Technology, Bangphli, Samut Prakan 10540

* Corresponding author.

E-mail: pakkarada.sam@svit.ac.th; Telephone: 08 9183 7568

Abstract

Chemical accident is a major problem in environmental pollution. It could occur from chemical leakage which leads to people illness, injury, or death. The automotive industry in Thailand has dramatically grown in recent years and gas welding plays a major role in it. The process uses gas and oxygen to weld metals together. Comparing to other gases, CO_2 is the least expensive and can be used without any inert gas. However, the exposure of highly concentrated CO_2 can be fatal since it is the cause of asphyxia and suffocation. In this research, the Area Location of Hazardous Atmosphere (ALOHA) model has been chosen to simulate the release of CO_2 in storage tank with an objection to predict the most serious incident and the area of threat zones. Assuming the case with a complete rupture of the storage tank, all CO_2 will be released. The thread zones, depend on wind speed and temperature, are between 55 and 126 meters. The results indicate an immediately dangerous to life or health (IDLH) value and can be used as a guidance to help deciding and responding in emergency incident in the future.

Keywords

ALOHA; risk assessment; CO_2 leakage; IDLH

1. Introduction

The automotive industry in Thailand has dramatically grown and is a major driver of Thai economy. Gas welding is the most applicable type of welding process used in automotive industry. The process uses gas and oxygen to weld metals together. Carbon dioxide (CO_2) is the most common gas to be used in this process due to its properties. Comparing to other gases, CO_2 is the least expensive and it can be used without any inert gas. Another advantage is the elimination of plasma plume, which protects the surface of the metal from the exposure to oxygen in the air. Therefore, rust is prevented and the corrosion is decreased [1]. A plant with a welding process uses a large amount of liquid CO_2 stored in the storage tanks. Assuming the case with a complete rupture of the storage tank, liquid CO_2 will be released into the air and turns into gaseous state. In this case, highly concentrated CO_2 can cause a fatal damage to human body as the CO_2 will replace the O_2 in the air which leads to the vascular expansion and stimulated respiratory system, called Hypercapnia (high level of carbon dioxide in the blood) [2].

The probability of death due to CO_2 exposure depends on the concentration of CO_2 and the duration of exposure, a high concentration of CO_2 can be the cause of death in a few minutes, shown in Fig.1. [3]

Chemical accident is a leakage of one or more hazardous substances that can cause people illness, injury, or death. For example, Bhopal reacted with methyl isocyanate leakage in 2^{th} December 1984, approximately 15,000 people were killed. 30 years later, with toxic materials still contaminated the area, many of those who encountered the incident had given birth to physically and mentally disabled children. The worst chlorine gas accident happened at Graniteville, United States in 2005, 120,000 pounds of gas released and killed 9 people and more than 550 people were left with lung injuries. The accident which occurred during August 2008 in Germany from CO_2 extinguishing systems, CO_2 leaked on an automatic fire extinguishing system hospitalized 16 people. Therefore, it is important to study the risk assessment of the chemical leakage to help with the decision-making process and the procedure to handle fatal emergencies.

In this research, the Area Location of Hazardous Atmosphere (ALOHA) model has been chosen to simulate the release of CO_2 from storage tank with an objection to predict the most serious incident and the scales of impact (threat zones). Using the ALOHA

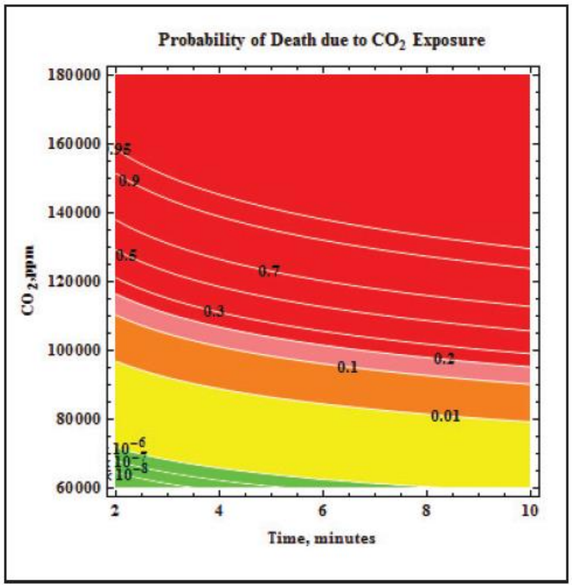

Fig. 1 Iso-probability contours of fatality due to exposure to CO_2 for combination of concentration (ppm) and time of exposure.

model requires knowing the nature of leakage event such as source of leakage, type of substance, wind speed and direction, in order to calculate the spread of substance [4–6]. This research was carried out at an anonymous welding process plant located is Thepharak Industrial Estate, Thailand. However, it was difficult to predict the size of the leak, internal pressure tank or pipe and the amount of leakage. Therefore, the prediction should be studied from a variety of situations that can possibly occur [7].

2. Research Method

2.1 ALOHA model

The model of gas dispersion used in this research is the ALOHA model, which is the air hazard modeling program. The model was developed jointly with United States Environmental Protection Agency (EPA) and National Oceanic and Atmospheric Administration

Table 1 Hypothetical scenario

Fixed parameters			
Total amount released	1,860 kilograms		
Source height	1 feet		
Model of release	Direct source (Instantaneous source)		
Relative humidity	74%		
Cloud cover	10 tenths		
Stability Class	D		
Elevation of wind speed measurement	10 meters		
Vary parameters			
Wind velocity	2.6 m/s, 12 m/s		
Temperature	16°C	26.3°C	37.5°C
Wind direction	NNE (16°C)	WSW (26.3°C)	S (37.5°C)

(NOAA). The latest version 5.4.7 of ALOHA model was announced in September 2016. ALOHA can simulate threat zones for many types of hazard such as toxic gas cloud and flammable gas cloud. The model can simulate up to 1,000 substances, because of the collected database of about 1000 physical and chemical properties of hazardous substances. ALOHA is designed to use in high-pressure situations. The scenario information can be input in the program (e.g., type of chemical, wind speed, temperature, the model of release) and, after the calculation, results are summarized in graphical outputs.

2.2 Assumption of accident scenarios in welding process plant

The CO_2 leakage can lead to people illness, injury, or death.This research was carried out at an anonymous welding process plant located is

Fig. 2 Layout of welding process plant

Thepharak Industrial Estate, the layout is as shown in Fig.2. The worst case was a storage tank, which is filled to maximum capacity, rapture and all CO_2 were instantaneously released. Six hypothetical situations with varied temperature, wind velocity and wind direction are shown in Table 1.

3. Results and Discussion

ALOHA model simulates the release of CO_2 and predicts threat zones. Table 2 shows the results of toxic CO_2 release that was simulated in ALOHA model in different six hypothetical scenarios. Immediately Dangerous to Life or Health Concentrations (IDLH) values of CO_2 is 40,000ppm based on acute inhalation toxicity data in humans. In this welding process plant uses CO_2 about 1860 kg kept in storage tank. Scenario1–6 should be simulated with similar

Table 2 Threat zones of toxic CO_2 in the ALOHA simulation

Scenario	Threat zone IDLH (40,000ppm)
Scenario1 (2.6m/s, 16°c)	121 meters
Scenario2 (2.6m/s, 26.3°c)	123 meters
Scenario3 (2.6m/s, 37.5°c)	126 meters
Scenario4 (12m/s, 16°c)	55 meters
Scenario5 (12m/s, 26.3°c)	56 meters
Scenario6 (12m/s, 37.5°c)	57 meters

Fig. 3 Scenario1 , wind speed: 2.6 m/s, temperature: 16 °C, wind direction: North-northeast.

Fig. 4 Scenario2, wind speed: 2.6m/s, temperature: 26.3 °C, wind direction: West-southwest.

Fig. 5 Scenario3, wind speed: 2.6m/s, temperature: 37.5 °C, wind direction: South

Fig. 6 Scenario4, wind speed: 12m/s, temperature: 16 °C, wind direction: North-northeast.

Fig. 7 Scenario5, wind speed: 12m/s, temperature: 26.3 °C, wind direction: West-southwest.

Fig. 8 Scenario6, wind speed: 12m/s, temperature: 37.5 °C, wind direction: South

conditions, there are fixed conditions such as height of storage tank at 1 feet, relative humidity at 74% cloud cover at 10 tents, stability class at D, elevation of wind speed measurement at 10m, model of release is the Gaussian model and varied conditions which are wind speed (2.6m/s, 12m/s), temperature (16°C, 26.3°C, 37.5°C) and wind direction, which depends on temperature.

Fig. 3–5 shows the results of threat zones at low wind speed (2.6 m/s) that vary with temperature, IDLH area of 121–126 meters is also shown in the figure. Fig. 6–8 shows IDLH area of 55–57 meters at high wind speed (12 m/s). The results show that wind speed has an enormous impact on IDLH area. At lower wind speed the IDLH area increased about 1.2 times. At constant wind speed, the IDLH area slightly change with varied temperature. Fig. 3–8 shows increased temperature, threat zone dispersion increased about 0.04 times. Fig.5. is the worst case amongst the six hypothetical scenarios that shows IDLH area of 126 meters at low wind speed (2.6 m/s) and high temperature (37.5 °C). The results show IDLH area in the range of 55–126 meters that the threat zone affect the surrounding facilities and plants. If nearby plant have some chemical substances that can be react with CO_2, the damage can be increased.

4. Conclusions

From the simulations of ALOHA model, wind speed and temperature are vary conditions of dispersion of toxic CO_2 in scenario 1–6. The wind speed has a large impact comparing to temperature. The wind direction affects the surrounding area that CO_2 was released. The dispersion of CO_2 is simulated by using ALOHA model which can predict the area of threat zones under various circumstances. The results from simulation can be used as the base of risk assessment and decision making of the plant. If operators are able to collect and survey environmental data, the simulation of the pattern of dispersion in various conditions with the ALOHA model can be conducted. The data from simulation can be helpful to the operators and residents in surrounding area. The results can also raise situation awareness and help manage the effects and further reduce the damage of lives and properties.

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