Simulation Analysis of Propylene Storage Tank leakage Based on ALOHA Software

Rili Yang, Ke Gai, Fengfeng Yang, Guangsheng Zhang, Ning Sun, Biyang Feng, Xiulan Zhu

School of Energy Engineering, Long-Dong University, Qing’yang, Gan’Su, 745000,
Corresponding author’s e-mail address: 446048772@qq.com

Abstract: Hazardous chemical leakage accidents occur frequently, and once it appears, it will create a great effect. If a more accurate risk assessment impact area can be made in advance, the preventions and controls will play an invaluable role. A propylene storage tank in an industrial park was taken to identify the lying accidents and the risk ranks with the method of Preliminary Risk Analysis. It was found that the propylene poisoning accident and the steam cloud explosion accident have a great threat to the surrounding. With the inputs of relevant parameters, ALOHA software was used to simulate each accident, and the propylene poisoning accident and the vapour cloud explosion accident threat areas were obtained. The simulation provides effective information for the prevention and control of leakage accidents in the propylene storage tank leaking, and provides a scientific guideline for its ordinary safety management.

1. Introductions
In recent years, with the rapid development of the production scale of chemical companies, the number of hazardous chemicals varieties and the demands has increased sharply. Most of chemicals are often inflammable, explosive, and toxic. If during the process of production, usage and storage, with improper management or disoperation, large-scale leakage of hazardous chemicals may result in catastrophic consequences [1].

Up to now, some scholars at home and abroad have studied the hazardous chemicals leakage diffusion models, which mainly include theoretical analysis, experimental research and practical application. Hundreds of typical accident consequence models have been put forward, such as Gaussian model, BM model, Sutton model, FEM3 model and P-G model [2-7]. Combined with different leakage consequences models, some related softwares have been developed, such as PHAST, SAFETI, ALOHA etc., some of which have been implemented to simulate different types of hazardous chemicals.

This paper takes a single propylene tank with the most specifications in the industrial park as an example, uses ALOHA software to simulate the possible consequences of the leakage accident, and calculate the scope of quantitative hazard and proposes some reasonable risk control measures, which are greatly benefit to improve the risk forecasting and overall prevention capabilities, and provide a guideline for future propylene leak rescue decision-making.

2. Analysis on propylenephysicochemical properties and accident consequences

2.1 physicochemical properties
Propylene, C\textsubscript{3}H\textsubscript{6}, molecular weight of about 42, heavier than air, a colorless and slightly sweet gas at room temperature, which is a simple asphyxiated mild anesthetic, carcinogenic; undissolved in water, soluble in organic solvents. Freezing point -185.3\degree C, boiling point -47.4\degree C, flammable, explosion limit of 2\% to 11\%, according to the risk of fire, it belongs to a Class A dangerous substance. Propylene is the basic raw material of three major synthetic materials, mainly used in the production of polypropylene, acetone and propylene oxide, which is the main material for a variety of synthetic chemical raw materials.

2.2 Analysis on the leakage consequences

Table 1 shows the types of accident consequences and the level of hazard that may occur after propylene storage tank leaks. Among these accidents, the main focus on the damage caused by the explosion pressure, poisoning, heat radiation and steam cloud explosion, which have a impact on the personnel and equipment in the area around the tank.

| Cause of accident         | Consequences                                                                 | Risk level | Recommended safety measures                           |
|---------------------------|------------------------------------------------------------------------------|------------|--------------------------------------------------------|
| Propylene tank leakage    | Partial accumulation of propylene, causing poisoning and suffocation         | III        | Periodic detection using a leak alarm system           |
|                           | Under certain conditions of meteorological conditions, a vapor cloud is formed to reach the explosion limit, and a steam cloud explosion occurs in case of fire. | IV         | Avoid any form of fire, fire or spark                  |

3. Software overview and leak simulation

Combined with the analysis in Table 1, the poisoning and steam cloud explosion accidents were selected to respectively simulated after the propylene storage tank leakage occurred.

3.1 Software Introduction and Features

ALOHA (Areal Locations of Hazardous Atmospheres), the hazardous environment regional positioning software was developed jointly by the Office of Response and Recovery of the National Oceanic and Atmospheric Administration and the Emergency Management Office of the Environmental Protection Agency. The software is designed for people who handle chemical spills, prepare emergency solutions and related training, and can achieve toxicity, flammability, heat of toxic gas diffusion, fire and explosion after the explosion of important hazardous chemicals. Simulations such as radiation (heat or helium), over pressure (explosive blasting force), and accurate estimation of threat areas associated with the release of hazardous chemicals. And combined with MARPLOT, make judgments on threat area warnings, and better provide a basis for the preparation of emergency plans.

3.2 Parameter setting

The parameter conditions selected for the simulation are: propylene bedroom storage tank with a volume of 50m\textsuperscript{3}, the design pressure of the storage tank is 2.16MPa, the filling factor 0.9, the altitude of the industrial area 1398meters, the geographical coordinates 35\degree 43′north latitude, and the longitude 107\degree 38′east longitude. The annual maximum frequency wind speed is 2.4m/s, the wind direction SE, the measuring height 3meters, the sky 25\% with clouds, the temperature 8.7\degree C, the relative humidity 62\%, the cloudy level 5 and the leakage caliber about 0.05meters. The specific values are set in the ALOHA software, as shown in Figure 1.
3.3 Leakage simulation

3.3.1 Poisoning accident simulation. When a propylene storage tank instantaneously or slowly leaks, a large area of liquid pool is formed, and the leaked gas rapidly turns into steam and diffuses in the air. When the weather conditions are stable, a certain gas concentration area is formed. If the concentration reaches a certain threshold (that is, in the threat zone), it will cause certain toxicity and suffocation to the workers in the gas zone.

3.3.2 Simulation of steam cloud explosion accident. Analysis on the fire and explosion accidents consequences in propylene storage tanks shows that when a propylene fire accident occurs, the BLEVE (boiling liquid extended steam explosion) generated by fireball has the largest impact.

4. Simulation results and conclusions

As Figure 2 shows: with the influence of wind direction, the concentration of propylene in the range of 199m is as high as 170,000ppm. The long-term retention will pose a threat to human life; in the range of 199-503m in the lower air outlet, it will hurt human body and cause irreparable harm; in the yellow areas, there is no any health effect other than nasty smell.

It can be read from Figure 3: the range fireball influence is up to 243m. the region that more than 243m is a safe area, 132-243m is a light injury area (yellow area), outer of 132m is a serious injury area (orange area), and there is no red area in the picture (destruction of building collapse).
Figure 3 Simulations of Vapor Cloud Explosion Accident and MARPLOT Area Display

5. Suggestion
With the analysis on the propylene leakage consequences, the ALOHA simulation software was used to simulate the accident-affected area, and the propylene poisoning area and the explosion-affected area were obtained.

(1) According to the simulation range of the area affected by propylene diffusion, the range of influence of different accidents can be obtained. Therefore, in the evacuation process, the maximum accident impact range should be used as the reference standard for group evacuation.

(2) According to the simulation results, it is suggested to strengthen the daily safety management supervision focus and set emergency disposal cards in different hazard level areas. And it is beneficial to paste some monitoring words in the storage tank area as much as possible, and eliminate the occurrence of any fire and static sparks.

Acknowledgement
This research paper was supported by Safety Production Technology Key Project (GAJ00004).

Reference
[1] Li Sun, Ying Zhao, Fei Gao, Ming Ye. Comparison and Analysis on Research Situation of Release and Dispersion Models of Hazardous Chemicals at Home and Abroad[J]. China Safety Science Journal, 2011,21(01):37-42.

[2] Xinwei Ding, Shulan Wang, Guoqing Xu. A Review of Study on the Discharging Dispersion of Flammable and Toxic Gases[J]. Chemical industry and engineering, 1999(02):58-62.

[3] Xuhai Pan, Juncheng Jiang. Zhirong Wang. Numerical analysis of diffusion process of flammable and toxic gases discharging accident. Progress in Safety Science and Technology [M]. Beijing: Chemical Industry Press, 2000. 297-301.

[4] Bincai Zhang, Jun Zhao. Application of Gaussian Plume Model of Atmosphere Diffusion Integrated with GIS [J]. The Administration and Technique of Environmental Monitoring, 2008(05):17-19+55.

[5] Bo Zhou, Guoshu Zhang. Numerical simulation for the leakage diffusion of harmful materials [J]. Industrial Safety and Dust Control, 2005(10):42-44.

[6] Liu Zhao, Kun Ouyang, Yingli Xie, Xinlei Xu, Zheng Fang. The Applied Research of Gaussian Putt Model on 3D GIS and TGIS[J]. Bulletin of Surveying and Mapping, 2011(05):80-82+88.

[7] Shiwei Li, Jianqiang Wang, junwei Zeng. Improved Gaussian Estimate Model Algorithm for Radioactive Gas Diffusion [J]. Application Research of Computers, 2012,29(01):123-126.