Journal of Fundamental and Applied Sciences

ISSN 1112-9867

Available online at http://www.jfas.info

Research Article

Special Issue

A STUDY TO DESIGN THE EMERGENCY REACTION PLAN FOR LPG TANKS IN 5TH REFINERY, SOUTH PARS GAS-CONDENSATE BY USING PHAST SOFTWARE

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Published online: 15 May 2016

ABSTRACT

Outcome Assessment is a tool applied by safety engineers in order to evaluate the risk resulting from industrial activities and determine the level of risk and damage arising from work-related accidents. After identifying and evaluating the risks, it is essential to estimate the intensity and consequences of the risks because the intensity of adverse effects and the likelihood of occurrence determine the risk. On the other hand, today, with increased density and proximity of industrial units, the adverse consequences of an accident cannot be limited to one unit.

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doi: http://dx.doi.org/10.4314/jfas.v8i3s.185

The damaging effects can spread to adjacent units or the surrounding residential area. This study aims to identify the risks in LPG storage unit, 5^{th} South Pars Gas Refinery and possible events in the process by using PHAST software. In order to enhance the modeling accuracy, Pseudo-Component Method was replaced with Multi-Component Method and it was employed to model combined hydrocarbons such as LPG. The results show that "sudden explosion of tank" is more dangerous than others, leaving irreparable financial and human damages. LPG export pipeline requires more protection due to the radiation radius as a result of fire induced by fracture.

Keywords: Outcome analysis; phast software; accident modeling; risk assessment; safety.

1. INTRODUCTION

Decision about the economical investment for safe process is one of important issues in the safety of process industries. In other words, setting criteria seems essential for making decision and prioritizing due to the large number of possible events in a process unit as well as budget limitation. Along with the possible accidents in a unit, the intensity of their effects on human, equipment, and environment is another import factor worth mentioning. Large-scale accident does not mean that it is certain because, in most cases, the scale of an accident varies inversely with the probability of occurrence. The level of risk can show the scale and probability of accident at the same time. That is why decision is made based on risk assessment and management in industrial safety. Risk assessment in chemical industry is a method for better management and more efficient safety in this industry. Risk Assessment was first used to study the electronics and nuclear safety. In the early 1980s, it was extended in the chemical industry. The risk of an accident is a measure of the damage inflicted on the humans, the environment or equipment due to the occurrence of the accident so that it follows both the likelihood of occurrence and the intensity of damages. Fig. 1 shows the schematic process of risk assessment. As it can be seen, the first stage is evaluating the possible risks in a process. These risks include equipment failure in the process which can cause some damages such as damage to other tools, or damage or release of materials in the environment.

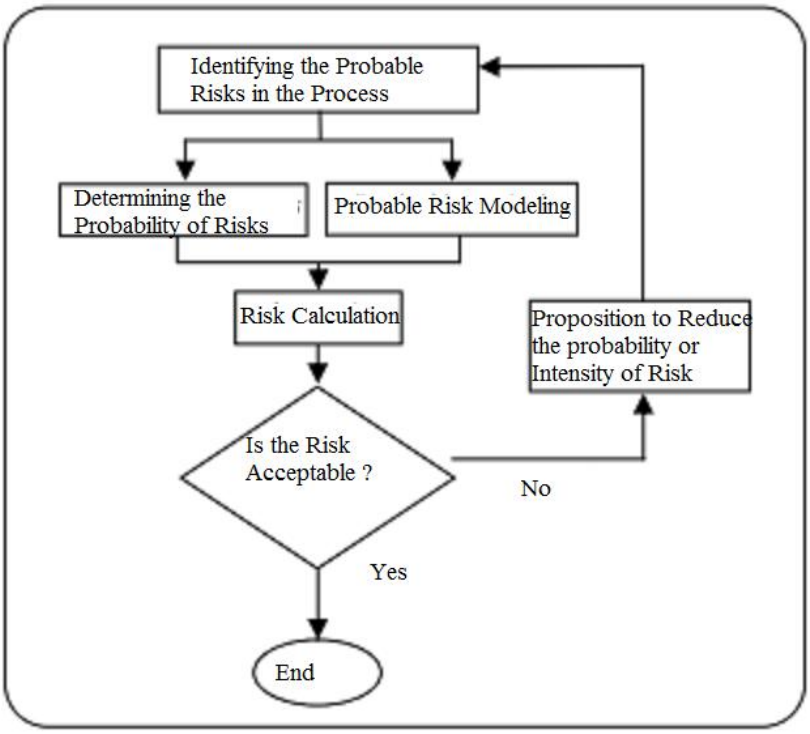

Fig.1. Risk assessment steps

What if and Checklist are two common methods to determine the risks in a process. After determining the possible risks, outcome analysis and the intensity of risks need to defined and modeled. For example, if the leakage of toxic material is one of process risks, more accurate definition is possible by the operational conditions and the level of released [discharged] materials. The level of risk is determined by the intensity of outcomes and the repeatability of occurrence. As a result, the individual and collective risks can be calculated in an area affected by a device or activity. Accordingly, similar-value risk lines are drawn known as Quantitative Risk Analysis. If the level of risk is high, the project of factory is reviewed to reach an acceptable level of risk [4, 16, 10]. Crisis management and emergencies, assessing the consequences of accidents and human error analysis has been the subject to multiple studies in Iran. Islam Kashi et al. (2009), in their study entitled" Outcome Analysis of Process Accidents in Refineries", studied and analyzed the probable process accidents in one of Iran`s oil refineries, and the regions of Oil Pipeline and Telecommunication using PHAST. Pseudo-component method was replaced with the

Multi-component method to increase the modeling accuracy and it was employed to model combined hydrocarbons such as LPG, crude oil, petrol, etc. [3].

Habibpour (2012) studied the industrial installations concerning various probable risk scenarios in order to prevent the industrial risks in his study entitled "Outcome Analysis for Process Accidents in NGL1200 Gachsaran, Iran using PHAST" [2].

Islam Kashi and Habib Pour, S. (2012), in their study entitled "The Case Analysis of Process Accident Risk Assessment Software Packages using Shepherd Risk, and PHAST", first defined the principles and risk-assessment-related standards. Then, they compared the advantages and disadvantages of these two software packages [1].

2. MATHEMATICAL MODELING OF EVENTS

Mathematical models can be used to estimate the effects of accidents. These models consist of a set of equations that describe events and can predict some issues such as thermal radiation resulting from fire, maximum pressure caused by the explosion, the direction and distance traveled by the pieces that are thrown, or gradual change in the atmospheric concentration after release. The first step to predict such phenomena is to estimate the amount of materials in an accident and emission rate. This is achieved by initial condition models. These models are based on fluid dynamics and heat transfer and require the exact or estimated temperature and pressure of materials. This leads to uncertainty because these parameters might change by gradual changes of conditions. If a tank is heated by the fire, the temperature and pressure are likely to rise. The quality of change will depend on the rate of fire. The definition itself creates some other problems. In order to calculate the output flow rate from a hole of a pressure vessel, the shape and the size of the hole are required. This information, however, is not accessible. As a result, simplifying assumptions or standard initial events are used in models. Some models describe the effects of different types of fire, atmospheric emissions, and explosion. The level of complexity varies in these models. Accordingly, using these models simplifies the work. These models, however, create major errors. Theoretically, more complex models are expected to give relatively accurate responses; however, they require a wide range of information which is not accessible. After determining the characteristics of an accident, damage assessment models are employed to predict its effects on people and properties. The best way to evaluate the thermal radiation or toxic effects on people and equipment is to use Probit equations. Probit equations are terms which link the accident and the level of damage on the exposed population. In this regard, using tabulated values are common to predict the level of damage on people and properties [6, 7, 13].

3. RESEARCH ASSUMPTIONS

In order to predict the leakage in pre-defined scenario, specific conditions related to equipment need to be taken into account. The assumptions related to the quality of leakage, broken pipe, etc. need to be considered. If a general quantitative risk assessment is required, a set of assumptions are considered regarding leakage accidents. This way, the most important accidents which affect the risk assessment are identified by a conservative and systematic approach.

Leakage Accidents in Tanks and Pressure Vessels:

The following leakage events usually occur in pressure vessel, reactors and process containers:

- The sudden discharge of all materials
- Continuous discharge of all materials in 10 minutes with fixed delivery rate.
- Continuous discharge from one hole with 10 mm effective diameter.

If the discharge happens in liquid section of the container, pure liquid is released and evaporation is not modeled in the hole (sudden evaporation occurs outside of container) [4, 16].

Leakage Accidents in Atmospheric Tanks:

In atmospheric storage tanks, the pressure equals one atmospheric or a little higher. The leakage occurs in the following cases:

- Sudden discharge of all material
    - Directly to atmosphere
    - From tank to a second healthy tank :
- Continuous discharge of all materials in 10 minutes with fixed discharge rate:

  - Directly to atmosphere
  - From tank to a second healthy tank
- Continuous discharge from one hole with 10 mm effective diameter.
  - Directly to atmosphere
  - From tank to a second healthy tank

Leakage Accidents in Pipes:

- Complete rupture and leakage from cross-sectional area (from both sides)
- Leakage from a hole (10% of pipe nominal diameter) (maximum 50 mm)

For complete rupture and leakage from cross-sectional area, C_D=1. It is assumed C_D=0.62 for other modes. It is assumed that there is no knee in pipes and the wall roughness is 45 mm.

3. MODELING MIXTURES

Pseudo-component is a common approach in studies focusing on outcome analysis concerning the calculation of mixtures. In this modeling method, the composition of the mixture is considered constant during different stages. As a result, the percentage of material in the storage tank is as equal as that of discharged material. In this approach, the characteristics of the mixture are obtained by averaging of components. These characteristics are considered pure material characteristics in modeling. In Multicomponent modeling method, the behavior and condition of the mixture are far more accurate. The differences between these two methods are:

- Phase equilibrium Modeling
- Modeling changes in the composition of the mixture during discharge

As it is known, the bubble and dew point temperatures are equal for pure materials. However, there is an area in a mixture where the material becomes two-phase. Since similar modeling is used in Pseudo-component approach for the pure material and mixture, mentioned two-phase area is not modeled. Therefore, the material might be reported in vapor phase, while it is, in fact, in two-phase. Such error affects different aspects of evaluation. On the other hand, the percentage of materials is different in liquid and vapor phases. Lighter and volatility materials are mainly present in vapor phase. Heavier and less volatility materials are, however, present in liquid phase. The balance between these two phases changes in different stages of the emission. As a result, the percentage of components is different in each phase. Such changes are not taken into account in Pseudo-component approach. So far, studies have focused on Pseudo-component approach. In this study, Multi-component method is employed to estimate the behavior and characteristics of materials. Therefore, the modeling results yield far more accuracy, making the study distinctive. For example, in multi-component liquid evaporation, the whole mixture is considered one material with one boiling point in Pseudo-component approach. In Multi-component method, boiling range, however, is taken into account [8, 12, 16].

4. REFINERY UNDER CONSIDERATION

One of South Pars Gas refineries (5^{th} Refinery- Phase 9 and 10) is studied. 57 million cubic meter gas is daily produced by 20 wells of two wellhead platforms. The platforms are non-residential and they are equipped with remote control. Compounds which consist of mixed gas, gas condensate, and water in a two-phase, without being separated at sea are transferred to land through two 32-inch and 105 km submarine pipelines. After cooling, propane produced at the refinery enters 45000 m^3 tanks. These fixed roof tanks are equipped with pumps which transfer the liquid propane to dock for loading. There is always some Boil Of Gas (BOG) which must be liquefied and returns to the tank. Since climatic conditions which are effective in the modeling results of outcome analysis need to be considered. Recorded meteorological information (temperature, humidity, wind speed, etc.) can be employed. In this regard, the meteorological data were extracted (Assaluyeh Synoptic Meteorology Station). The data show that climatic changes occur in two periods within a year. The first period include spring and summer and the second period covers fall and winter. Therefore, dominant climatic condition is employed for scenario modeling. Table 1 lists the summary of meteorological information.

Table 1. Selected meteorological information

Weather condition- First six month of Year (Spring and Summer)

Temperature	32°C
Humidity	50.4%
Wind Speed	7.5 m/s
Atmospheric Stability	C

Weather condition- Second six month of Year (Fall and Winter)

Temperature	22°C
Humidity	57.5%
Wind Speed	8.5m/s
Atmospheric Stability	D

Selected Scenario

This study aims to model the most important hazards in the unit. To this end, equipment which contained high volumes of hydrocarbons at high temperatures and pressures were selected as scenarios. Table 2 lists the equipment.

Table 2. Defined scenario for each equipment

Scenario	Equipment
Sudden discharge of all material	LPG storage tank
Discharge in 10 minutes	
Leakage (10mm diameter)	
Broken pipe	Export LPG and Flow pump
Leakage (the hole is 10%of pipe diameter)	

5. OUTCOME MODELING RESULTS

Table 3 illustrates simulation results. In fireball, 4, 12.5, and 37.5 KW/M^2 areas represent the threshold of severe pain, second degree burns and plastic machinery melting and the risk of immediate death and potential damage to all equipment and existing structures, respectively (meter). Concerning getting away from center of the flash fire, enclosed area to fire concentration (LFL) and half fire concentrations (0.5 LFL) as a dangerous area are considered dangerous areas where a spark can lead to fire.

Table 3. simulation results in the latter half of the year

	Fireball			Flashfire		Explosion			Jet fire		
	4	12.5	37.5	0.5LFL	LFL	0.020	0.1379	0.206	4	12.5	37.5
Sc-1	608	289	-	2119	1534	480	120	90	-	-	-
Sc-2	-	-	-	1600	900	-	-	-	990	508	735
Sc-3	-	-	-	11	6	-	-	-	31	11	-
Sc-4	180	106	34	752	588	76	20	16	670	460	300
Sc-5	-	-	-	248	177	-	-	-	160	130	100

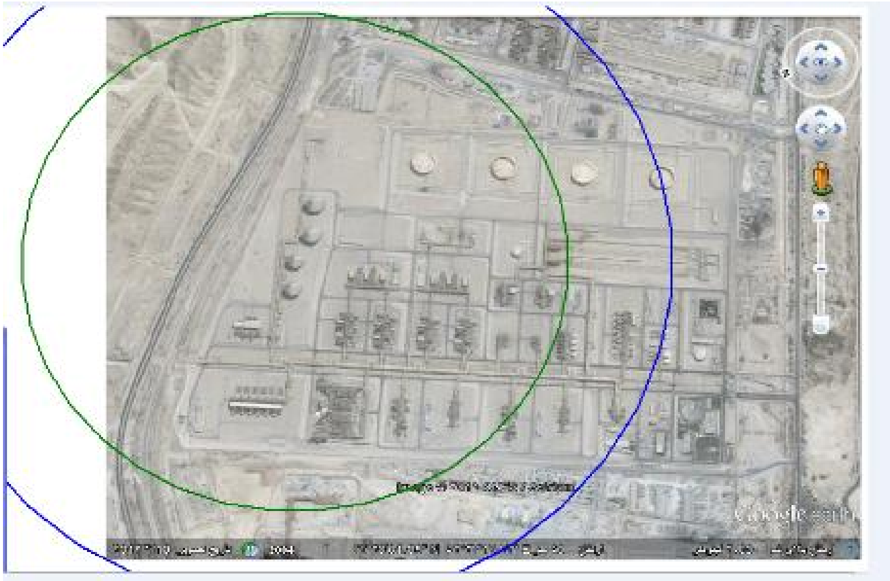

Fig.2. Flash fire area

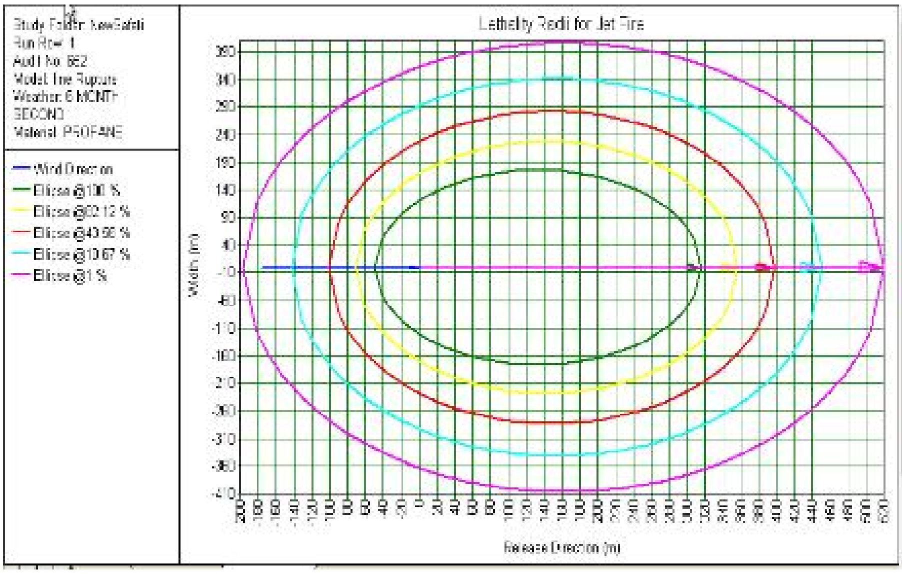

Fig.3. The area related to mortality rate resulting from Jet fire

Fig.4. The area related to maximum concentration resulting from release

6. FINDINGS

As it can be seen in Fig. 2, if no spark happens in flash fire section, most of flash fire section is associated with the sudden crack of propane tanks, covering 2100 meter area. Fig. 3 shows the mortality rate for jet fire, indicating that it would cause 100% damage in 50-m radius. Since operator`s residential placement is in this area, personnel will die in case of an accident. Fig. 4 shows the maximum concentration resulting from release along with the wind direction. According to the propone flammability, the road in north side of refinery would cause human casualties.

7. CONCLUSION

In flash fire area, if no spark happens in flash fire section, most of flash fire section is associated with the sudden crack of propane tanks, covering 2100 meter area. In fireball section, the highest area at risk is related to the withdrawal of all materials within ten minutes, propane pipeline fractures, and withdrawal of the material at an angle of 45 degrees to horizon which is associated with the high pressure propane transfer pipe line. In explosion area, the highest outcome is associated with the sudden explosion o tank due to sudden withdrawal of large amount of propane. This leads to building glass breakage in 480m radius and indirect losses caused by throwɔ equipment 120 m radius. In fireball section, the most important hazard is related to sudden explosion of tank which causes second degree burns until 300 m radius. According to the results, any type of mentioned accidents would cause human causalities, leaving irreparable financial damage.

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How to cite this article:
Boluirian A, Givehchi S and Nasrabadi M. A study to design the emergency reaction plan for LPG tanks in 5th refinery, south pars gas-condensate by using phast software. J. Fundam. Appl. Sci., 2016, *8(3S), 332-344.*