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The Analysis of Process Accidents Due to Risks in the Petrochemical Industries—The Case Study of Radiation Intensity Determination Proportional to Distance from Tank Level

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Abstract

Today, one of the basic methods in engaging the decision making of senior managers for securing the organizations regarding assessing risks that the industries face, is the analysis of outcomes of processing accidents. The development of process industries is always associated with an increased risk of accidents. Therefore, paying attention to this case is a priority for the safety units in the oil refineries and petrochemical plants. The aim of this study was to investigate safe distance between the storage tanks of gasoline tanks in the petrochemicals of South Pars Region; comparisons to the American petroleum institute were studied. The maximum of length of flame and the ratio of length to radius of flame were measured 20 m and 2.6 m respectively. If occurrence of leakage and pool fire in one of these tanks, the maximum intensity of thermal radiation was equal to 13.7kw/m^2. Hence, there is a possibility to control of fire at a distance of 15 meters from the tanks to heat radiation due to a pool fire, thereby, domino effect does not occur in the event of fire.. The fire is controllable but in case of leakages aggregation and creation of flammable ponds around these tanks, the gathered radiator intensities have immediate explosion potential in the tanks. So, it is proposed, besides increasing the distance between the storage tanks, other measures like quality and safety inspection planning of the connections and controlling instruments of the tanks, inspection of the fire lighting equipment like hydrants, monitors, fire hose reels are done and performance of reaction maneuvers in emergency conditions can take place

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and be documented and planned.

Keywords

Process Accidents, Pool Fire, Fire Safety

1. Introduction

The process industries have production, storage and use of flammable chemicals material units. Therefore, these industrials are most apt and prepared industries for facing the risks and explosions [1]. Always fire and explosions have enormous implications for human resources and financial capital. For example, in 1997, the explosion of pressure pipeline in the French Vitzan Petrohemica occurred because of leakage of liquid gas and killed 57 members of the industry staff [2]. Also, in 1992, release of light Nephatan from the pressurized tank resulted in the explosion in the Bambi refinery and 35 experts were killed [3]. According to risk matrixes, the risks with consequence of death are the unacceptable and critical risks [4] [5]. The lack of safety inspections has basic role in such accidents. So, the planning of safety inspection programs, risk assessment detonation and fire and determine preventive measures based safety is essential in the different units of the refinery. The items of inspection programs and risk assessment detonation and fire must be including identifying the warehouses of flammable materials, value and operating parameters of material, leakage paths of material, identifying places and storage locations for flammable materials, value and their operating parameters, possible leakage paths, identifying scenarios possible and consequences of accident, identifying of preventive measures fire and explosion [6]. Although the processing facilities and equipment are used for productivity, profitability and also wealth production, but they have important (main) potential for damaging human being, property and the environment. Since the number of refineries and their products increased thus exposure to hazards is also higher for workers. For example, the accident of Felix borough in England in 1984 left 28 dead and 26 injured [7]. Another case of chemical accidents occurred in December 1984 in Bhopal, India [8]. Also, because of leakage and firing of oil (petroleum), from gas platform of BP company in Mexico gulf, 11 people died and the damage amounted to more than 40 billion $ and caused 22 percent decrease in shares and 63 percent decrease in profits [9]. In order to prevent the accidents, assessment and identification of the accidents and risks in the refinery units are very important. For multiple injuries resulting from accidents in processing industries are illness cases and cause injury and death, damages to property, environmental pollutions, decreasing production and profits, loss of reputation and credibility in the organization. In the following, the common scenarios relating to fire has been investigated in oil and gas industries.

1.1. Eruptive Fire

This kind of fire usually consists of flammable materials that are exited from a pressurized source and there have been source of ignition in the environment. The speed of flammables effects greatly on the kind of fire, because initially the exit speed must be high enough to be sent to the air into the jet, and secondly the flame will be constant at a point that the flame speed will be equal to the local velocity of the gas mixture. When the exit speed of flammables increases, the air increases (in the mixture) too and as a result fuel consideration decreases in the jet, the flame distances more from the fuel exit and finally when the flame is far enough, the fuel density is lower than the low limit of flammability and the fire (flame) extinguishes. In the modeling of eruptive fire, the thermal radiation is the only factor that is studied as the sample for the damage of this type of hazard. The aim of eruptive fire modeling was assessing to the jet diameter and length and the rate of thermal radiation of burning jet at any point. It must be noted that in the modeling diagrams, the limit of radiation rate due to fire that causes severe injuries to humans is considered as 37Kw/m^2 [4] [10].

1.2. Abrupt Fire

Abrupt fire is a non-explosive combustion due to gas cloud of flammable material releases in the air. In other words, if the gas is uniformly dispersed in the environment and its flame is without acceleration, the fire is non-explosive. But if the flammable gas cloud non-uniformity be concentrated in a tank, then be exposed with a spark, it will cause explosive in the gas cloud [11] [12].

1.3. Pool Fire

It is possible to release a flammable liquid from equipment into the environment. Around the releasing source, a liquid pond may be formed and gradually evaporated. In case that the vapors of the pool reach to the ignition source, fire breaks out and forms pools that are flaring. This kind of fire is called pool fire, it must be noticed that the resulted vapors of pools reach to the ignition source and the resulted flames return back to the pool then caused fire. The outcome of a pool fire is assessed by the rate of radiation [11] [12]. The consequences due to the thermal radiations are different from burns to death. The domino effects of thermal radiations on equipment installations of the refinery industries are clearly evident. In the case, the outcomes caused by radiation internally, the exposure time played basic roles. The English standard BSS908, 1990, has been presented for the effects of the thermal radiation dose (**Table 1**).

2. Work Description Method

The type and the system characteristics must be described; also the work limits that consist installations and activities and conditions must be studied, identified and defined. So, in this study, the pool fire, and the effects of thermal radiations of the gasoline storage tank were studied in the utility unit in one of the South Pars petrochemicals in Iran. Also, distances between storage tanks have been studied according to the American petroleum institute standard (API's Standards).

Table 2 shows the data (information) relating the damage caused by thermal radiation on the equipment and installation of processing industries.

Description of Work Methods

In the following, the said tank specifications and the considered scenarios for this aim is described in details (**Table 3**).

Using the following formula [14], the flame length of the pool time is calculated.

$$\frac{L}{D} = 42\left[\frac{M}{r_a\sqrt{gD}}\right]$$

Table 1. Thermal rate and its effect on the human body [13] [14].

Thermal Rate (KJ/m^2)	Radiation Intensity (Kw/m^2)	Effects
65	2.2	Body damage and bone ache
125	4.2	First level-critical burning
200	6.7	First level-Sevier burning
250	8.3	Level 2-burning
325	1.8	Level 3-burning

Table 2. The rate of thermal radiation intensity and its effect on equipment and installations [13] [14].

Radiation Intensity	Effects
15	Wood firing , when there is an ignition source
25	Automatic firing of wood
4	Ruins of glass
12	Plastic melting
20 - 18	Destruction of thermal isolation
37.5	Damage to the process equipment
100	Damage and breaking of the steel destruction

Table 3. Characteristics of cases and scenarios.

Parameter	Size/Type/Rate
Each tank diameter	20 m
Tank height	20 m
API Tanks interval based on standard	15 m
Welding point	27 centigrade
Relative humidity	70 percent
Gasoline burning rate	0.55%
Surface radiation power	44 Kw/m^2
Scenario description	Leakage from the upper level the tank
Capacity of each tank	20,000 liters
Modeling target	Determining the proportional radiation intensity to distance from tank level
	Determining the proportional radiation intensity to distance from ground level

Here, we have L for the flame length, D is the flame diameter, M is the rate of mass burning in kg/m^3 and r_a is the air density in kg/m^3 and g is the acceleration of gravity that equals to 9.8 m/s^2. It is worth noting that the calculation of eruptive fire characteristics can base on AP1521 [15].

The thermal radiation coefficient can be calculated according to the heat transfer from the source and on the following formula base:

$$t = 2.02 \times \left(P_w X\right)^{-0.09}$$

Here, P_w is partial pressure of water vapor and X is the distance [16].

Also, in this study, we use the following formula to determine maximum thermal radiation intensity in the horizontal distances from the effected source. Here, I is equal to the thermal radiation in KW/m^2, SEP is equal to the surface emission in KW/m^2, and VF is equal to visibility factor and t is equal to the thermal heat transfer power and the guidance wave in the water vapor [16].

$$I = SEP \times VF \times t$$

3. Result

On the basis of results, maximum flame length is 20 meters and maximum flame-to-flame length is 2.6 m. For determining the thermal radiation intensity in the ground level, the visibility coefficient item must be calculated. The method used to determine the visibility coefficient is based on two criteria that determine the reception amount on the ground level. The first standard is L + H, that here H is equal to the height of the tank and the second standard is equal to H. The difference between these two standards is equal to the visibility coefficient of flame. The nearest distance of the first tank is 15 meters (**Table 4**). **Table 5** shows that the maximum of thermal radiation intensity in this distance is equal to 13.7 Kw/m^2 and if the wind direction is in the path of the No. 2 storage tank, the thermal intensity will be much larger. According to the determined permissible limit for damage (37.5kw/m^2), it can be concluded that the determined distance on API standard [16] for the tanks is enough. If the fire caused in the first tank do not be extinguished quickly, or that the second tank is not cooled properly, the intensity of radiant heat of the first tank evaporates flammable material in the second tank. Then, the vapor flux in the second tank is increased, thereby; second tank causes the explosion in other tanks in a distance of 15 meters from each other.

4. Discussion

In order to manage the firing extents in every processing industry, proportional protection and control measures must be done, and continuously elimination of hazards situation be followed up. Therefore, quality control and inspection, risk assessment, service and maintenance of process pipes, isolator pumps, and safety valves are es-

Table 4. The thermal radiation intensity according to distance from ground.

Distance from the Ground	Thermal Transfer Coefficient	Vision Coefficient			Thermal Radiation Intensity
		L = L + H	L = H	Partial Vision Coefficient	
15	0.783	0.404	0.392	0.212	0.4
20	0.763	0.294	0.268	0.230	0.9
30	0.763	0.184	0.141	0.043	1.4
40	0.717	0.126	0.084	0.043	1.3

Table 5. Thermal radiation intensity based on the distance from the tank.

Tank Distance in Meter	15	20	30	40
The distance proportion radiation reception place to pool fire	1.5	2	3	4
Vision	0.398	0.298	0.159	0.99
Thermal transfer coefficient	0783	0.763	0.763	0.717
Radiation intensity (Kw/m^2)	13.7	9.4	5.1	3.1

sential in order to prevent equipment corrosion.

This point is very important that all the safety and control systems, like the control valves, alarms, the alarming and extinguishing systems, must be tested and checked regularly and have high capability of performance in all the processing activities steps [17]. All the firing sources in the industries must be performed and documented; all of the procedures of firing risk assessment must be updated. Also, in order to control static electricity in the process units of the refineries, bonding and grounding are the simplest ways [18]. The phase prelaunched of systems and process industries is one of the most important phases because the nature of work has a very high risk rate of fire and explosion. So, for the risks control in this phase, the safety work policy and procedures, safe work permit systems, emergency response procedures and training programs for personnel must be considered before the implementation of this phase. Also, in order to control the spread of fire, it must be design a safe distance and the range for sources of flammable, explosive and toxic materials from other fire sources in the process industries. Determining the safe distance from the location of aid and rescue, fire-fighting units, fire extinguishing equipment and fire detection and alarm systems is very important. The water spreading system must be considered for protection against the thermal radiation to NFPA15 standard. Thus, the use of the water spreading systems for cooling of the tanks body containing flammable materials to prevent the occurrence of fire and explosion can be effective [19].

4.1. Fire Extinguishing

According to the determined scenarios, the strategies and equipments of fire extinguishing like hydrants, monitors, firefighting car (vehicles), hose reels, and the reaction equipment in the emergency conditions must be inspected and assessed. These designs must be programmed according to reaction design in the emergency conditions. All fire-fighting equipment must have high reliability. All workers in refineries and process industries must have been trained about risk of fire and explosion chemical material, toxic hazards and fire extinguishing.

4.2. The Final Results

A comprehensive planning to risks control is the fundamental approach to the risks management in the process industries. The aim of the is to process planning, assess and recognize fire risk, and assess the probability and severity of consequences, and so, develop guidelines and engineering controls to prioritize the control measures. In the study, current fire scenarios and methods of determining thermal radiation intensity arising from eruptive fire and pool fire and the limit of its damage relating pool fire in gasoline storage tanks in one of the South Pars area Petrochemicals was described. The process planning for managing process dangers in the refineries and petrochemicals includes identification of hazards and documenting the instructions and control of the engineering systems. Therefore, in order to manage and eliminate the risks of fire and explosion, implementation of safety audits, assessing regularly and periodically of process, simulation maneuvers of process and review of control procedures is essential.

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Conflict of Interest Statement

The authors have no conflict of interests to declare.

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