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HAZOP and ALOHA Analysis of Acetone

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Abstract

A potential hazard can happen because of a technical and personal failures, natural disasters, terrorist attacks, and fires. The potential hazards can be dangerous for human health and environment, also cause economic losses. In an industrial plant, prevention and control of these consequences have an importancy. Hazard and Operability Analysis (HAZOP) is a technique for a system evaluation and determination of risk management of hazards. In particular, HAZOP is used in order to determine potential hazards in a system and operability problems. Moreover, Areal Location of Hazardous Atmosphere (ALOHA) is the potential hazard modelling programme, which is used to plan chemical emergencies.

Acetone, a colorless liquid also known as propanone, is a solvent used in manufacture of plastics and other industrial products. The most hazardous property of acetone is its flammability. Acetone is a solvent widely used in the chemical industries and stored in large volumes, therefore, acetone is an important source of danger for chemical processes.

In this study, acetone was investigated to be a hazardous chemical using HAZOP and ALOHA software in order to prevent and control a big hazardous event in an industrial plant.

Keywords: HAZOP, ALOHA, SEVESO, acetone

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1. Introduction

Many flammable, toxic, and explosive chemicals are stored and used for production of compounds in chemical industries. These materials can cause hazards resulting danger for human health and environment. The equipment failures, natural disasters, fires, and technical problems can be reason for hazardous industrial accidents [1].

A major industrial accident happened in Seveso-Italia in 1976 because of an explosion occured in a reactor and caused human health problems. After this accident, 82/501/EEC Directive (SEVESO I) released by the European Union for control and preventation of major accidents, SEVESO II released in 2012, and Seveso III replaced by SEVESO II in 2016 [2].

Risk assessments and precautions should be applied from industries for determination and prevention of potential hazards occured by accidental cases resulting deaths, economic loss, and also environmental problems. The risk assessment is important which includes the stages as hazard identification, analysis, and risk evaluation. Also, lots of simulation programmes can be used in order to examine the effects of possible hazards. Hazard and Operability analysis (HAZOP) is a popular technique for hazard identification and risk ranking in hazardous facilities. HAZOP study is a well-known and effective risk assessment technique for identifying the potential hazards and operability problems in hazardous industries [3]. Therefore, Areal Location of Hazardous Atmosphere (ALOHA) is a software programme designed for modelling toxic hazards from chemical releases, thermal radiation from chemical fires, and vapour explosions scenarios of risk assessments for human and environment [4].

In the presenting paper, acetone was examined to be a model compound using HAZOP and ALOHA programmes for prevention a big hazardous event in a chemical industry.

2. Material and Methods

In this section, acetone was investigated through HAZOP and ALOHA programmes.

2.1. Hazard and Operability Analysis (HAZOP)

HAZOP is a risk management technique used to identify potential hazards in existing or planned plants. The aim of the programme is to decrease risk and ensure the safety of workers in plant environments. A HAZOP study is performed by an interdisciplinary team of experts including engineers, chemists, and safety officers to determine risks, process hazards, and design flaws.

2.2. Areal Location of Hazardous Atmosphere (ALOHA)

ALOHA has physical, chemical, and toxicological properties data library for thousands of pure chemicals and chemical solutions. The programme gives a chance to predict how quickly chemicals are releasing directly or from tanks and gas pipelines over time with release scenario modelling to be fire, Boiling Liquid Expanding Vapor Explosions (BLEVEs), toxic gases, and vapor explotions with evaluation of different types of hazards such as toxicity, flammability, thermal radiation, and overpressure.

Hazard categories modelled using ALOHA programme are given in Table 1.

Table 1 . Hazard Categories Modelled using ALOHA programme [5].

Scenario / Source	Direct Source	Tank	Puddle	Gas Pipeline
Vapor Cloud	Toxic vapors	Toxic vapors	Toxic vapors	Toxic vapors
Vapor Cloud (flash fire)	Flammable area	Flammable area	Flammable area	Flammable area
Vapor Cloud (explosion)	Overpressure	Overpressure	Overpressure	Overpressure
Pool Fire	NA	Thermal radiation	Thermal radiation	NA
BLEVE (fireball)	NA	Thermal radiation	NA	NA
Jet Fire	NA	Thermal radiation	NA	Thermal radiation

ALOHA can estimate hazardous chemical release threat zones including toxic, gas clouds, fire, and explosions. ALOHA can display three threat zones in a single graph which shows the thermal radiation effects on people who are exposed and able to get into a shelter within 60 seconds, longer exposure duration can cause serious other effects even at lower radiation level. The red threat zone represents the worst hazard between these red, orange and yellow threat zones. The threat at point graph shows specific information about hazards at specific locations. In toxic treat zone graph, the red, orange, and yellow areas represent the regions predicted greatest, medium and low exposure levels where chemical concentrations are predicted to exceed the corresponding Acute Exposure Guideline Level (AEGL). The flammable thread zone graph shows the estimated flammable area which a vapour cloud explosion or flash fire could happen after release begins [6].

ALOHA can estimate the chemical cloud dispersion based on the toxicological and physical characteristics of the compounds, atmospheric conditions, and specific circumstances of the release [6]. Also, concentration at point graph displays chemical concentration versus time. The source strength graph shows the release rate of the chemicals, burn rate, and evaporation rate depending on the substance and event.

2.3. Acetone

Acetone is a colourless liquid which evaporates easily, flammable, soluble in water, ethanol, ether, etc. and used for making drugs, plastics, fibers, and other chemicals. Acetone can be readily ignited under almost all ambient conditions. Acetone properties are given in Table 2.

Table 2 . Acetone Properties [7,8].

Name	Acetone, β-ketopropane, Dimethyl ketone
Molecular formula	CH_3COCH_3
Vapor pressure	247 kPa at 20ºC
Melting point	-94.6ºC
Boiling point	56ºC at 101 kPa
Flash point	-20ºC
Auto ignition temperature	465 ºC
Explosive limits	2.5 (LEL)–13.0 (UEL) vol.%

2.4. NFPA 704 Fire Diamond

NFPA 704 Fire Diamond is a standard system for the identification of the hazards of materials for emergency response and developed by the National Fire Protection Association to inform about hazards association with the material (Fig.1).

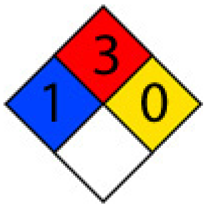

Figure 1. NFPA 704 fire diamond rating.

The label contains four coloured diamond shapes and each colored diamond associated with different type of hazard. Blue, red, yellow, and white represent the health hazard, flammability hazard, instability, and special hazards, respectively. Blue dimond health hazard can be classified to be deadly, extreme danger, dangerous, slight hazard, and no hazard (Table 3).

Table 3 . Health Hazard Values Descriptions [9].

Health Hazard Values	Desription
4 – Deadly	Materials that under emergency conditions can be lethal.
3 – Extreme Danger	Materials that under emergency conditions can cause serious injury.
2 – Dangerous	Materials that under emergency conditions can cause temporary incapacitation or residual injury.
1 – Slight Hazard	Materials that under emergency conditions can cause significant irritation.
0 – No Hazard	Materials that offer no hazard beyond that of ordinary combustable material.

Table 4 . Flammability Hazard Values Descriptions [9].

Flammability (fire) Hazard Values (Flash points)	Desription
4 – Below 73ºF	All liquids and gases with a flash point below 73ºF and a boiling point 100ºF.
3 – Below 100ºF	All liquids and gases with a flash points at or below 73ºF and a boiling point at or above 100ºF and those liquids having flash point at or above 73ºF and below 100ºF.
2 – Below 200ºF	All liquids with a flash points at or above 100ºF and below 200ºF or solids that readily give off vapors.
1 – Below 200ºF	All liquids, solids and semi solids with flash points at or above 200ºF.
0 – Will not burn	Materials that will not burn, including any material that will not burn in air when exposed to a temperature of 1500 for a period of 5 minutes.

Yellow diamond reactivity can be explained using the explosive, unstable, and stable terms etc. (Table 5).

Table 5 . Reactivity Values Descriptions [9].

Reactivity Values	Desription
4 – May Detonate	Materials readily capable of detonation or explosive reaction at normal temperatures and pressures. Includes materials that are very sensitive to heat, shock, or light.
3 – Explosive	Materials which when heated and under condinement are capable of detonation and which may react violently with water.
2 – Unstable	Materials which will unergo a violent chemical change at elevated temperatures and pressures but do not detonate.
1 – Normally stable	Materials which are normally stable but may become unstable in combination with other materials or at elevetad temperatures and pressures.
0 – Stable	Materials thet in themselves are normally stable, even under fire conditions.

Therefore, white diamond special hazard can be classified to be water reactive, oxidizer, cryogenic, corrosive etc. (Table 6)

Table 6 . Special Hazards Descriptions [9].

Special Hazards	Desription
W	Water Reactive. Reacts with water in an unusual or dangerous manner.
OX	Oxidizer. Allows chemical to burn without an air supply.
SA	Simple ssphyxiant gas.
CRY	Cryogenic material.
COR	Corrosive material.
POI	Poisonous material.
	Radiation warning signal.

Table 7 . Acetone Fire Diamond Values Descriptions.

Diamond	Hazard	Value	Description
	Health	1	Can cause significant irritation.
	Flammability	3	Can be ignited under almost all ambient temperature conditions.
	Instability/ Reactivity	0	Normally stable, even under fire conditions.
	Special		

3. Results and Discussion

3.1. HAZOP and ALOHA Analysis of an Experimental Set-Up System for Acetone

Based on the experimental study carried out by Chang et al. (2011) [10] (Fig. 2), stainless steel spherical tank which contains pure acetone was examined for HAZOP (Table 8) and ALOHA performed for case of BLEVE, tank explodes, and chemical burns in a fireball according to parameters given in Table 8. Thermal radiation threat zone results are given in Fig. 2.

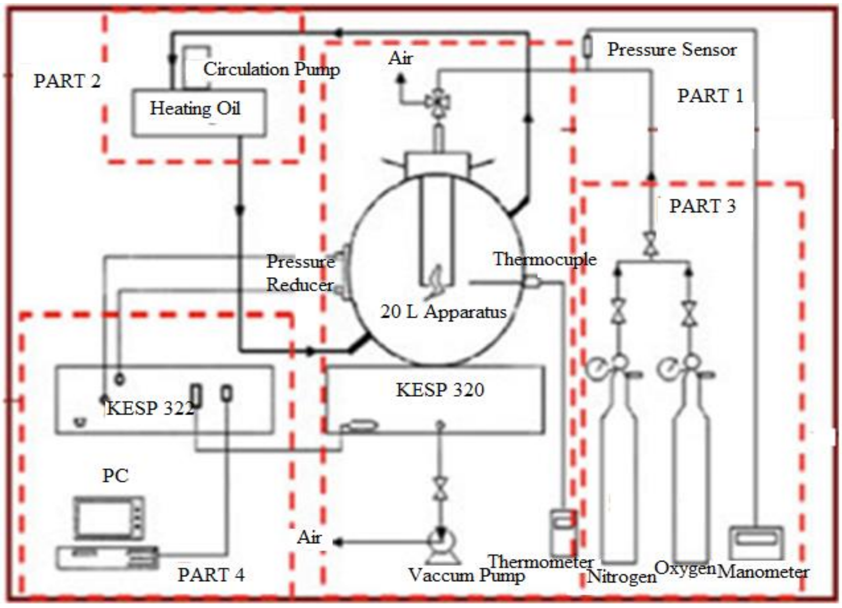

Figure 2. Schematic diagram of the experimental set-up acetone and its control system [10].

Table 8 . HAZOP for Acetone.

No	Guide word	Element	Deviation	Possible causes	Consequences	Action Required
1	Less	Initial temperature	Less initial temperature	No acetone vapour	No generation and no well-mixed gas phase	Valve control
2	Less	Initial pressure	Less initial pressure	No acetone vapour	No generation and no well-mixed gas phase	Pressure sensor
3	Less	Heating oil	Less heating oil	Less initial temperature	No generation and no well-mixed gas phase	Valve control
4	No	Ignition	No ignition	No electric current	No explosion	Electric supply control
5	More	Heating oil	More heating oil	More initial temperature	Early explosion	Valve control

Table 9 . ALOHA Input Parameters for Acetone [11].

Input Parameters Chemical Name	Acetone
Ambient Weather	22.7° C temperature 77% relative humidity, partly cloudy
Tank Properties	Spherical Tank 20 L volume 200° C intertal temperature 79% full Tank contains liquid
Scenario	BLEVE, tank explodes and chemical burns in fireball.

Threat Modeled: Thermal radiation from fireball
Red : 23 meters --- (10.0 kW/ (sq m) = potentially lethal within 60 sec)
Orange: 33 meters --- (5.0 kW/ (sq m) = 2nd degree burns within 60 sec)
Yellow: 51 meters --- (2.0 kW/ (sq m) = pain within 60 sec)

On the plot at Fig. 3, the red, orange, and yellow areas represented the damaged regions. The red threat zone shows the 10 kW/m^2 thermal radiation extends 23 meters in all directions and potentially lethal within 60 seconds which means will cause the loss of lives in this area. The orange threat zone displays the 5 kW/m^2 thermal radiation extends 33 meters in all directions and 2nd degree burns within 60 seconds results in serius injury. The yellow theat zone shows the 2 kW/m^2 thermal radiation extends 51 meters in all directions and pain within 60 seconds results in slight injury.

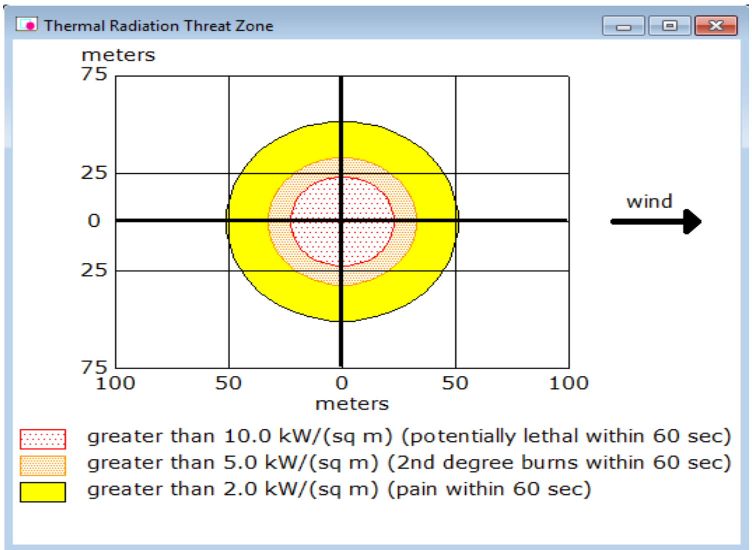

Figure 3. ALOHA thermal radiation threat zone results for case study one [11].

Conclusion

Acetone is a toxic material and its dispersion can be dangerous for human health. According to an experimental study using a stainless steel tank which contains acetone as a model compound was investigated using HAZOP and ALOHA programmes in the presented paper. The thermal radiation results obtained were used to calculate the probability of burn injuries due to acetone tank accident in a real scenario. The jet fire scenario showed very little impact as compared to that of the fireball radiation and BLEVE generated blast overpressure. The fireball results show an area of about 23 m radius badly affected and the calculated loss corresponds to actual loss of life and property as verified from the ground data.

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