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Applying a Hazard Area Classification Study on an (Liquefied Petroleum Gas/Synthetic Natural Gas) System in a Steel Factory to Highlight Major Hazards

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Abstract

As a global trend, safety has become the number one priority in all industries worldwide. This leads any organization either It is in the design phase or already in production to design or modify respectively it's layout and Installations to comply with safety standards. One of the most important hazards that are common in most industries, either it is petrochemical, non-petrochemical or even FMCG (Food Manufacturing and Customer Goods) industries, is the Explosion Hazard. According to the most recent fire statistics from the National Fire Protection Association (NFPA): An average of 37,000 fires occurs at industrial and manufacturing properties every year. These incidents resulted in 18 civilian deaths, 279 civilian injuries and $1 billion in direct property damage. It is a smart step to take a preventive action towards explosions, rather than a corrective action. As a matter of fact, as every industry requires a type of fuel – which is usually flammable- to run its operations, one of the most common units in all industries nevertheless what category it falls into, is the LPG/SNG (liquefied Petroleum Gas/Synthetic Natural Gas) unit. As much as this unit is important and mandatory to any industry, it is considered one of the most potential areas of explosions as well. Hazard area classification (HAC) is a study in which an industrial area is divided into zones according to the probability of the presence of combustible or flammable material in that zone. There are different standards for applying the study, and different outcomes according to the condition of the zone, this includes the material, pressure and temperature. In this paper we will discuss the HAC study of one of the most common units in industry, which is the LPG/SNG system. The aim of the study is to be a good reference for industries that have this unit or have a need to install it and needs to apply a preventive HAC study on it to mitigate explosion risk.

Keywords: Petrochemical; HAC; ATEX; SNG; LPG

Abbreviations:

LPG: Liquefied Petroleum Gas; HAC: Hazard Area Classification; EPD: Explosive Proof Document; FMCG: Food Manufacturing and Customer Goods.

Introduction

ATEX French: Atmosphere Explosible, English: Explosive Atmospheres is a study that is specialized in studying the causes of explosions and how to evade the root cause, starting from the design phase of a plant or a unit, passing by the operation phase [1] as shown in Figure 1.

Figure 1: Fire Triangle: Shows the three essential elements to make a fire.

The Triangle of fire consists of Fuel-Heat- Oxygen; eliminating one side of the triangle prevents the occurrences of fire, so ATEX study consists of three studies inclusively [2].

HAC- Hazard Area Classification- Focuses on the (Fuel) side of the triangle; it is specialized in studying each area of the plant and classifying it according to the flammable material present in it.

EPD- Explosive Proof Document- Focuses on the (Heat/source of ignition) side of the triangle; it is specialized in studying the source of ignition in the ATEX classified areas.

EX -Explosion protected- Equipment - It is the study concerned with equipment to be installed in the ATEX areas.

In this paper we will apply the first part of the ATEX study, which is the HAC study.

The first step in applying the HAC study is gathering info starting with MSDS - Material Safety data Sheet, Plant layout and Process description. Then, the flammable materials are pointed out and their usage is spotted on the plant layout. After that, HAC study is applied and each area is classified under one of three categories, according to the presence of the flammable material and its usage [3,4]. Each classified area has a range in which it is spotted out on the layout, this area is considered the hazardous area, where there is a probability of Explosion to a certain extend depending on the several aspects will be discussed below. Classifying an industrial area into explosive atmosphere (ATEX) zones gives a better vision of several aspects. First, the equipment to be installed in this area, also the instruction to the personnel who have assigned tasks in or around an ATEX classified area. Finally, this may require an action regarding this area like a change in condition, ventilation or even could be a design in the layout of the zone [5,6].

Hazard area classification

Concept: HAC study aims to classify the areas with a factory, building or any area of operation into zones depending on the probability of formation of an explosive atmosphere. Putting most of the vital factors in consideration to classify an area; this includes ventilation, materials being used in this area, type of operation and sometimes the layout [7].

Methodology: a-classification of zones: Zones are classified into (0, 1 or 2) for areas of flammable gases and vapors;

Zone 0: An area in which an explosive gas atmosphere is present continuously or for Long periods or frequently.

Zone 1: An area in which an explosive gas atmosphere is likely to occur in normal operation occasionally.

Zone 2: An area in which an explosive gas atmosphere is not likely to occur in normal.

Operation but, if it does occur, it will exist for a short period only [8].

Zones are classified into (20, 21 or 22) for areas of combustibles dusts:

Zone 20: A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is present continuously, or for long periods or frequently.

Zone 21: A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is likely to occur in normal operation occasionally.

Zone 22: A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is not likely to occur in normal operation but, if it does occur, will persist for a short period only [4].

Sources of release: For an explosive atmosphere to occur, there should be a flammable or explosive material to occur in a space, being mixed with air to give an explosive mixture. The concerned substances most probably will be included in process equipment's. This equipment may or may not release the substances, so it is important to identify the areas where there could be a possibility to release this substance in the atmosphere. Also, important to consider, that if an equipment cannot expectably contain a combustible or flammable substance, or there is no probability for it releasing a flammable substance it should not be identified as a source of release (for example, a welded pipe may not be considered as a source of release, but a flange on this line shall be considered) [9].

Release of flammable or combustible materials should be classified either (Continuous, primary or secondary) sources of release:

Continuous: It's a type of release where material is expected to be released for a long period or frequently.

Primary: It's a type of release where material is expected to be released occasionally during operation.

Secondary: It's a type of release where material release is not expected to occur in normal operation conditions, and if happened, it does happen for a short period of time.

Ventilation: Ventilation is an important factor while applying HAC study, it could decrease the grade of a classified zone or either eliminate it, it could be identified as the volume of air change around the source of release. This is including two factors, first is the degree of ventilation, the better the degree of ventilation is available in a place, the lower is probability of an ATEX media to occur [10].

The degree of ventilation could be classified to (high, medium or poor) ventilation as below:

High: It is the type of ventilation which if acquired will decrease the concentration of a flammable or combustible material to below its lower explosive limit. However, if the availability of this ventilation is not permanent, a HAC area could occur [11].

Medium: The type of ventilation which could result in a stable zone boundary.

Low: It's the type of ventilation which could not decrease the concentration of the substance during or after the release.

The other factor is the availability of ventilation, the more the availability of ventilation the less is the probability of HAC area is to be formed and vice versa, the availability of ventilation could be classified as either (Good, Fair and Poor) [12,13].

Good: Ventilation is present continually.

Fair: Ventilation present during normal operations and may be not available for short period of times.

Poor: Any other case that does not match good or fair is poor class.

The relation between ventilation, its availability and release type could be summarized as shown in Table 1.

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Grade of release	**Ventilation**						
	Degree						
	High			**Medium**			**Low**
	Availability						
	Good	**Fair**	**Poor**	**Good**	**Fair**	**Poor**	**-**
Continuous	Zone 0NE	Zone 0NE+Zone 2	Zone 0NE+Zone 1	Zone 0	Zone 0+Zone 2	Zone 0+Zone 1	Zone 0
Primary	Zone 1NE	Zone 1NE+zone 2	Zone 1NE+zone 2	Zone 1	Zone 1+Zone 2	Zone 1+Zone 2	Zone 1 or Zone 0
Secondary	Zone 2NE	Zone 2NE	Zone 2NE	Zone 2	Zone 2	Zone 2	Zone 1 or Zone 0
No release	Non-hazardous Area						

Table 1: Ventilation/Release relationship, table shows the relationships between the Ventilation and grade of release. Notes: Symbol (+) means 'surrounded by' Zone o NE, 1NE or 2NE, indicates theoretical zone which could be of negligible extent under normal conditions, they could be negligible [14].

Extent of the Zone: It is the distance starting from the source of the release to the point where the material is diluted below its lower explosive limit. This could be figured out from standards:

EI 15 - Model code of safe practice. Part 15: Area classification code for installations handling flammable fluids (Formerly referred to as IP 15).

NFPA 497- Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas.

NFPA 498 - Recommended Practice for the Classification of Combustible Dusts and of Hazardous Locations for Electrical Installations in Chemical Process Areas.

UNE 202007 IN- Application guide of UNE-EN 60079-10. Electrical apparatus for explosive gas atmospheres. Classification of hazardous areas [15]. The main objective of this study is to highlight the major hazards - in terms of ATEX - that could be spotted in an LNG/SNG system that may cause an explosion.

Case Study

Description of the system

This unit is used to provide LPG to a steel fabrication factory, where the presence of LPG and SNG is essential to the industrial process. The system (Figure 2) consists of storage tanks for Liquefied petroleum gas (LPG), they are filled by trucks that unloads the LPG through the truck station, then there is LPG pumping station that does pump the LPG to a synthetic natural gas (SNG) creation unit, where part of the LPG is vaporized and mixed with air to produce SNG, and the other un-vaporized part is pumped as it is to the industry, also part of it is directed to the flare.

Simple layouts for the unit

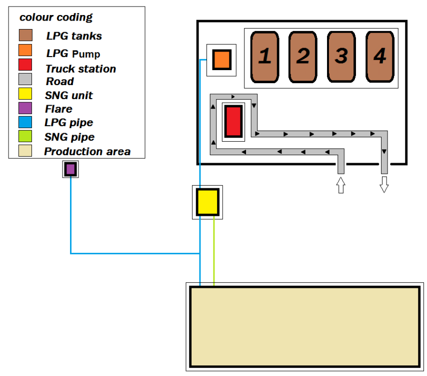

Figure 2: Plant layout, simple layout of the plant showing the LPG/SNG main components.

Process description: The LPG plant has four tanks which do contain LPG to be fed to the industry; the four tanks are filled with trucks through the truck station. The LPG is kept under pressure in the tanks, and then is sent to an SNG unit by a pump where it is vaporized and mixed with air to produce the SNG (synthetic Natural Gas) which is then sent to the production area by a compressor to be ignited. Another output from the SNG unit is sent to the flare.

Findings

Sl. No.	**Area of operation**	**Sources of ventilation /release**	**Classification**
1	**Identification:** Four LPG storage tanks **Ventilation:**	**Continuous:** Not identified **Primary:**	**Zone 1:** 1.2 m high above the tanks pool 1.7 m around each instrument

	Installed outside with natural ventilation **Substance:** LPG (70% Propane-30% Butane mixture) **Surrounding conditions:** Ambient temperature Tanks pressure around 5.5 bar	Not identified **Secondary:** Leaks in instruments, flanges and valves, Safety valves at 20 bar **Ventilation assessment:** Degree: High Availability: good	3.2 m around each valve 3.2 m around each flange **Zone 2:** 7.7 m around tanks pool 3.2 m around each safety vent **Gas group and temperature class:** IIBT2*
	Comments: As LPG is a flammable liquid under pressure, they are expected to cause an ATEX Explosive area; this will almost be around the flanges and vents, the areas which do have a high probability of leakage. Beside the area below the tanks also in case any of the tanks failures and create a pool of LPG below the tanks.		
2	**Identification:** LPG compressor unit **Ventilation:** Installed outside with natural ventilation **Substance:** LPG (70% Propane-30% Butane mixture) **Normal conditions:** Ambient temperature Around 5 bar	**Continuous**: Not identified **Primary:** Pump's connections **Secondary:** Leaks from instruments, flanges and valves **Ventilation assessment:** **Degree:** High Availability: Good	**Zone 1:** 0.4 m around each pump's connection **Zone 2:** 11 m around the whole unit **Gas group and temperature class:** IIBT2*
	Comments: LPG compressor does pumps a flammable liquid, so it also shall be classified, especially around the area where the flammable liquid could leak like the sealing of the pump. Also due to the high pressure of the liquid inside the compressor, the area around the compressor with a radius of 11m is considered hazardous, as any leakage would have a wider range of spreading		
3	**Identification:** Gas flare **Ventilation:** Outdoors Natural **Substance:** LPG (70% Propane-30% Butane mixture) **Normal conditions:** Ambient temperature Around 4 bar	**Continuous:** At the flare output, but it is ignored due to continuous ignition **Primary:** Not identified **Secondary:** Around gas seal **Ventilation assessment:** Degree: High Availability: Good	**Zone 2:** 1.3 m around every gas seal among the pipeline . **Gas group and temperature class:** IIBT2*
	Comments: As flare is a part of the unit where the LPG will always be present in order to keep the flare lit. It will be considered an ATEX area on the areas of high leakage probability. This will include the gas seals on the pipeline to the flare. The area is slightly reduced than the valves of the tanks, due to lower pressure present in the piping to the flare than the pressure inside the compressor.		
4	**Identification:** LPG unloading station **Ventilation:** Installed outside with natural ventilation **Substance:** LPG (70% Propane-30% Butane mixture) **Normal conditions:** Ambient temperature Pressure around 5 bar	**Continuous:** Not identified **Primary:** level indicator **Secondary:** Connections for LPG unloading Pump connections Safety valve **Ventilation assessment:** Degree: High	**Zone 1:** 1.7 m around the level indicator **Zone 2:** 4.5 m around the pump connections 0.4 m around the safety valve 1.7 m around any temporary connection **Gas group and temperature class:** IIBT2 *

		Availability: Good	
	Comments: LPG unloading station is the place where the trucks does unload the LPG into pumps directed to the LPG tanks. Areas of considerations here will be the connections of the hose which is used to unload the LPG, as well as the pump and safety valve in the truck. Level indicator is also considered as a primary source of release.		
5	**Identification:** SNG system - inside the cabinet **Ventilation:** Indoors Forced **Substance:** LPG (70% Propane + 30% Butane) **Normal conditions:** Air conditioner Up to 2.5 bar	**Continuous:** Not identified **Primary:** Not identified **Secondary:** Leaks from instruments, flanges and valves **Ventilation assessment:** Degree: Medium Availability: Good	**Zone 2:** 1.3 m around each flange 1.3 m around each Valve 1.3 m around each Instrument **Gas group and temperature class:** IIBT2* (Minimum)
	Comments: SNG unit is the place where the synthetic natural gas is produced by mixing vaporized LPG with air; the areas which shall be considered as well are the areas of potential leakage, like flanges, valves and instruments along the pipeline.		
6	**Identification:** Flame sensor/ Ignitor unit **Ventilation:** Indoors forced **Substance:** SNG (Methane) **Normal conditions:** Ambient temperature 150 mb Up to 3.7 bar	**Continuous:** Not identified **Primary:** Not identified **Secondary:** Leaks from instruments, flanges and valves **Ventilation assessment:** Degree: Medium Availability: Good	**Zone 2:** 0.6 m around each flange 0.6 m around each Valve 0.6 m around each Instrument **Gas group and temperature class:** IIAT1* (Minimum)
	Comments: It's the place where the SNG is ignited to be used in the industry, same areas of potential leakage are considered, with a lower range due to the lower pressure.		
* This is a gas group classification according to the minimum ignition energy (MIE) as follows (I for mining, IIA MIE>250 μJ, IIB MIE>96 μJ, IIC<96 μJ)			

Table 2: Shows the findings related to each of the LPG/SNG components.

Table 2 shows findings of HAC study: Some areas around the considered instruments are extended 10% than the recommended standard due to variety in wind speed and direction, as well as wide variety in ambient temperature due to changeable weather condition, in Table 3 table of recommendations shows the recommendations according to the findings and **Table 4 shows** Chemical properties of concerned materials.

Recommendations

Sl. No.	Situation	Recommendation	Additional information
1	The unloading hose usually leaks traces of LPG during transferring the fluid from the truck to the tanks through the station.	The hose should be replaced to prevent leakage of the LPG.	
2	The ambient temperature some days of the year rise in the summer, the truck used in loading usually not covered under the umbrella covered in the unloading unit.	Better to extend the umbrella in the unloading station to cover the part where the truck park to unload.	The umbrella better to be extended to cover the whole truck, also better to schedule the unloading in early morning to avoid the peak hot hours of the noon.

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3	By visual inspection the earthing of the unloading unit it appears that it needs to be rechecked as some cables appear loose.	The earthing needs to be checked that it is well connected.	
4	No sign is hang with instructions for unloading the LPG.	precautions could be taken to hang some signs labeled (Mobile phones prohibited) (no smoking) (work permit required at this area).	All workers should be instructed with these precautions and new comers to have induction training.
5	Several common electric devices are present with the range of classified ATEX area around the pipeline.	All electric devices should be replaced by alternative ATEX certified devices or could be removed out of range of ATEX zone.	Minimum requirements for zone 2: Synthetic Natural gas Category 3 Gas group IIA Temperature class T1
6	There were several ATEX classified junction boxes that do miss a fixing nail or two.	Junction boxes should have all fixing nails in place.	
7.	There is an emergency plan present, but with no details for an explosion scenario.	One ATEX oriented emergency plan should be set into place.	Expected scenarios that could cause an ATEX explosion: -leak on a flange or instrument on the NG pipe line -Spillage of LPG during unloading
8	Any change of the following should have a change in the HAC classification accordingly: -change in plant layout -change in Material used (especially adding new flammable or combustible materials) -change in operation conditions -change in process that may cause change in material used or relocating of devices or pipelines.	Incase no change occurs that requires updates in the HAC study, it should be updated on a three-year period. Surveys should be performed in ATEX classified areas for any unconformities.	

Table 3: Table of recommendations: shows the recommendations according to the findings.

Properties of material

Properties	unit	LPG	SNG
CAS Number	-	68476-85-7	68410-63-9
Molecular weight	-	≈46	≈15
Flammability limit	%v/v	1.9/9.5%	2.0/10.0%
Flashpoint	°C	- 104.4	-184
Boiling point	°C	<-40	<0
Auto-ignition Temperature	°C	430	537
Temperature class	-	T2	T1
Gas Group	-	IIB	IIA
Vapor density	-	1.5	≈0.5
Cp/Cv	J/kg·K	1.13	1.31

Table 4: Properties of material: Chemical properties of concerned materials.

Drawings of the zones (referring to standard IP15)

LPG storage tanks:

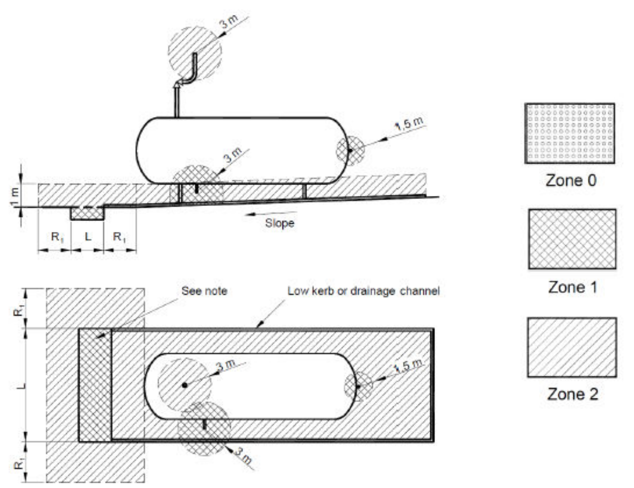

Figure 3: Zoning for Fuel tanks: a caption from standard IP15 showing the zones around a tank.

Zones in the diagram above are a screen shot of the standards, listed below:

Zone 2 of 3 m around the safety vents, Zone 1 of 3 m around every valve or flange and Zone 1 of 1.5 m around every instrument.

The standard is based on that in case of leakage there will be a pool created below the tank; this area will be classified as zone 2. Around each valve or instrument there will be Area 1 in case any leakage occurs. Also, a Zone 2 area will be classified around the safety valve of the tank as mentioned in the drawing (Figure 3). As mentioned, some of these areas are extended in the finding due to ambient conditions of the plant [16].

Conclusion

The case study discussed is meant to be a good reference for those who are willing to install an LPG/SNG unit in their industry, or already have it installed but need to apply a HAC study to it. It is considered a shortcut instead of going through standards to find the right zones; this paper would save lot of effort, money and time.

From the study we conclude that:

The areas we need to consider while dealing with a liquid fuel in a pipe line: Around valves, around flanges, around each instrument installed on the pipeline, Around the sealing of the pumps. The areas to be considered when dealing with liquid fuel in tanks: Around safety valve, around draining pot, creating a pool around the tank with a height of 1 m. Ventilation is one of the most important mitigation factors either it be natural or forced. The radius of the classified area around a pressurize system depends on the pressure inside the pipes. HAC does not consider the probability of an accident (like a forklift hitting the pressurized pipe causing leakage).

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