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REVIEW

Review of the role of safety engineers in the prevention and mitigation of fires during oil and gas plant design

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Abstract
There are several hazards associated with oil and gas plants, but fire and explosion are the most destructive events. To minimize the possibility and consequences of negative events and hazards, a variety of industries, such as oil and gas, require a substantial amount of health, safety, and environmental engineering expertise. Fire safety engineers play a very significant role in developing fire safety designs and analyses during the design stage. As part of this process, other departments, such as process, instrumentation, and piping, are consulted. While there has been a considerable amount of research conducted on safety-related issues in the past, including safety culture, management, risk assessment, safety instrumented systems (SIS), and inherent safety implementation, no study has addressed the role of safety engineers in preventing and mitigating fires. This review examines the roles and responsibilities of safety engineers during the design process of oil and gas plants in a comprehensive and general manner with the objective of preventing and mitigating fire hazards.

Keywords Fire science · Fire tetrahedrons · Piper alpha oil platform · Emergency shut down (ESD) system · Plot plan · Fire water network · Fire and gas system (FGS) · Hazardous area classification · Passive and active fire protection · Risk assessment

1 Introduction

In chemistry, fire refers to an exothermic chemical combustion process in which the rapid oxidation of a material caused by combustion, which occurs when fuel or another substance ignites and combines with oxygen, releasing light, heat, and flamex (Pyne 2019). An exothermic process is defined as a process or reaction in which energy is released from a system into the surrounding environment due to heat, light, electricity, or sound (Yutao et al. 2021). It would be impossible to imagine life without fire. Among the most fundamental requirements for human survival is the availability of fire. There is no doubt that fire has played a significant role in the development of society (Clark and Harris 1985; Goudsblom 1992; Gowlett 2016). A global network of critical infrastructure supports the oil and gas industry today, making it one of the most significant contributors to the global economy. As oil and gas projects utilize and produce a considerable amount of flammable liquids and gases, fire poses one of the greatest risks (Alnoaimi and Mazzuchi 2021). Each year, people suffer burn injuries due to the uncontrolled ignition of flammable chemicals and other materials that they work with. Accidental fires and explosions can result in fatalities, severe injuries, property damage, environmental damage, and disruption of business operations on a long-term basis (Chettouh et al. 2016; Tong et al. 2016).

It is the purpose of this paragraph to provide a brief explanation of the science behind fires. Initially, a fire triangle was used to demonstrate the three elements necessary for a fire to occur: oxygen, heat, and fuel (Pédrot and Tabareau 2020; Bickerton 2012; Stein 2011). The discovery of a fourth element, a chemical chain reaction, was a consequence of further research into fire (Panchal 2014; Gisborne 2004). Fire triangles were changed into fire tetrahedrons (also known as fire diamonds, pyramids, or combustion triangles) to reflect the fourth element as shown in Fig. 1 (Panchal 2014). In order to initiate combustion or a chemical reaction, a certain amount of energy is required, which is initially provided by an ignition source (Popescu and Pfriem 2020). As soon as ignition is complete, the combustion reaction releases

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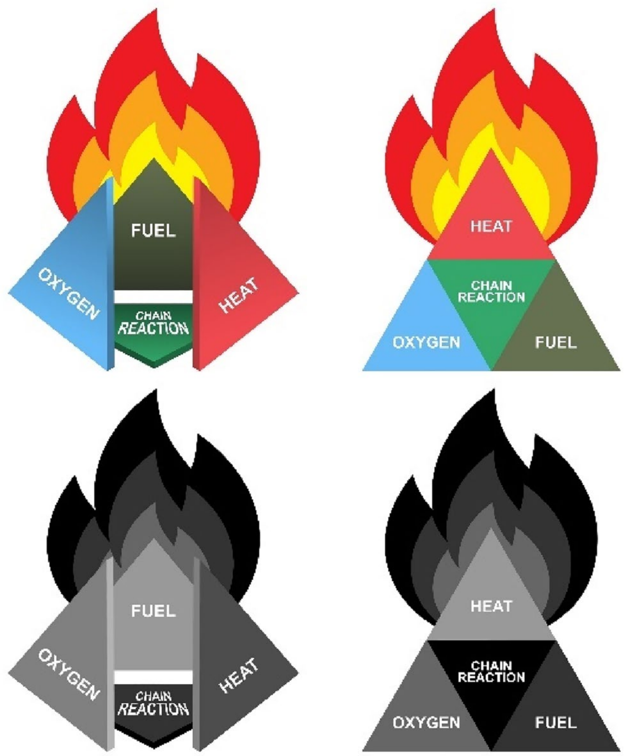

Fig. 1 Fire tetrahedron or fire diamond (Courtesy: Shutterstock)

sufficient energy to continue without the assistance of an ignition source. (Popescu and Pfriem 2020). Chemical reactions and ignition can be initiated by a variety of sources of energy, such as electrical sparks, static electricity, naked flames, hot surfaces, impact, and friction (Bryan et al. 2013). The combustion process in a fire occurs when fuel reacts with oxygen to produce heat energy (Reinhardt et al. 2001; Trollope 1984; Hartzell 1996). A combustion process can occur slowly or rapidly depending on the amount of oxygen available to it (Reinhardt et al. 2001; Trollope 1984; Hartzell 1996). It is possible for hydrocarbon fuels to undergo complete combustion or incomplete combustion, depending on the amount of oxygen available (Reinhardt et al. 2001; Trollope 1984; Hartzell 1996). It is only when there is sufficient air available that the process of complete combustion can take place. Hydrocarbon fuels, such as methane, contain carbon and hydrogen atoms which react with oxygen in an exothermic reaction to produce carbon dioxide and water (Lyon and Cole 2000). Carbon dioxide is a pollutant in the atmosphere. There is an incomplete combustion when there is not enough air or oxygen available. As a result of incomplete combustion, other pollutants are produced rather than carbon dioxide. There is still production of water, but there is also production of carbon monoxide and carbon (Beyler 1983). Incomplete combustion releases less energy than complete combustion. As a result of incomplete combustion, black smoke primarily consists of elemental carbon. A flash fire, a pool fire, a jet fire, and a fireball are all examples of fires that have different effects. However, they are all caused by combustion reactions triggered by an ignition source (Pula et al. 2005). This review does not address the explanation of different types of fire.

The Piper Alpha project was one of the most significant examples of devastating fires and explosions occurring on an oil platform (Cullen 1993). In the North Sea, the Piper Alpha oil platform was located approximately 120 miles (190 km) north-east of Aberdeen, Scotland. From this platform, Occidental Petroleum (Caledonia) Limited (OPCAL) began producing oil in 1976 (Miller 1991). A period of oil production was followed by gas production from the field. At its peak, Piper Alpha produced more than 300,000 barrels of crude oil per day, making it one of the largest offshore oil platforms in the UK. As a percentage of the total crude oil production in the country at the time, this represented approximately 10% of the total production (Harker 1998). There was a gas leak from one of the platform's condensate pipes that caused the Piper Alpha disaster on July 6, 1988. A gas leak caused a fire and explosion that resulted in the death of 167 people. As a result of the accident, it became the deadliest offshore oil rig accident in history. With a total insured loss of approximately £1.7 billion, it was one of the most costly man-made catastrophes in history (Drysdale and Sylvester-Evans 1998).

A variety of industries, such as oil and gas, require a significant amount of health, safety, and environmental engineering to minimize the possibility and consequences of negative events and hazards (Iakovlev and Pesterev 2022; Mearns and Yule 2009). According to previous explanations, fire and explosion are the most destructive events and major protentional hazards that can occur in oil and gas plants (Nolan 2014; Suardin et al. 2009). The purpose of safety engineers is to combine engineering knowledge with knowledge of health and safety in order to develop procedures and design systems that protect people from illness and injury as well as property from damage (Verma et al. 2010; Roland and Moriarty 1991). A safety engineer is also responsible for ensuring that noise levels, emissions, water contamination, and other contaminants to the environment are within acceptable limits in accordance with legal and standard requirements (Baron 2015). Two aspects of safety are important in oil and gas plants: process safety and personnel safety. It is possible for process safety hazards to cause serious accidents, such as the release of potentially flammable, reactive, explosive, or toxic materials, the release of energy (such as fires and explosions), or a combination of both (Khan et al. 2015; Sanders 2015). Therefore, when it comes to the roles and responsibilities of safety engineers in the prevention and mitigation of fire hazards, the current review study mostly focuses on process safety. A fire and explosion occurred on an offshore platform due to process safety hazards as illustrated in Fig. 2. Fire and explosion are two of the main concerns for workers on offshore platforms and rigs. Several factors have contributed to fires and gas explosions, including malfunctioning equipment, poor or incomplete maintenance, a lack of employee training, and employer negligence (Jafarov et al. 2021).

2 Body

The body of the review consists of two sections; the first part is a systematic review of past pieces of literature on safety engineering and management in the oil and gas industry in order to identify their strengths, weaknesses, and gaps in each and every previous study. In the second part of the paper, you will find the author's proposals for roles and responsibilities for safety engineers for regard to fire prevention and mitigation considerations based on industrial experience and international standards in order to fill in the gaps of the past studies, based on industrial experiences and international standards. Among the many national and international codes and standards that are available to engineers, it is worthwhile to note that many of them, such as the American Society of Mechanical Engineers (ASME), American Petroleum Standard (API), International Organization for Standardization (ISO), International Electrotechnical Commission (IEC), Norwegian petroleum standards (NORSOK), as well as the Occupational Safety and Health Administration (OSHA), serve as reference materials for safety engineers during the project.

2.1 Review of past literatures

Using risk assessment as a tool, the first study in the section discusses safety engineering's role and systematic performance in the oil and gas industry (Kashwani and Nielsen 2017). As was explained earlier, the oil and gas industry is considered to be one of the most hazardous industries. The process of risk assessment involves identifying a threat, also known as a hazard, and estimating the risk it poses. Risk assessments are conducted by organizations to identify potential hazards that could negatively affect their operations (Yang et al. 2018; Srivastava and Gupta 2010; Thuyet et al. 2007). Safety engineers and other engineers in the oil and gas industry utilize a variety of risk assessment techniques, including qualitative, semi-qualitative, and quantitative approaches, including fault trees, event trees, and failure mode and effect analyses (FMEAs) (Petrovskiy et al. 2015). In the study, risk assessment is aimed at four main elements in oil and gas projects: people, environment, assets, and reputation (Kashwani and Nielsen 2017). Although this study emphasizes the importance of risk assessment in the oil and gas industry and the misinterpretation of this system among some personnel and management, no details are provided regarding risk assessment methods, models, or the role of safety engineers in implementing such systems and assessments in this study. In a related study, emphasis has been placed on the importance of safety leadership and culture to prevent accidents in oil and gas projects (Ojuola et al. 2020). A third study is devoted solely to the role of safety culture in organizations in order to establish safety and reliability (Mearns and Yule 2009). This paper examines occupational safety and how globalization may influence the attitudes, beliefs, and behavior of disparate 'national' workforces working for the same multinational organization across the globe (Mearns and Yule 2009). Again, this study focuses primarily on the safety culture and cultural differences between different project teams from different countries regarding safety management and does not cover safety engineering. In the field of safety engineering, safety instrumented systems (SIS) play an important role (Fang et al. 2008). Safety instrumented systems (SISs) are systems that contain control elements, sensors, and logic solvers that monitor parameters and values within a plant and ensure that they remain within certain thresholds (Fang et al. 2008). Another study associated with safety engineering discusses some key modeling issues for SIS reliability performance quantification, and illustrates their implementation in a Markov model (Jin et al. 2011). During the design and operation of a process plant, inherent safety is a proactive approach to hazard/risk management. Based on the lifetime costs of a process and its operation, an inherently safe approach is the most cost-effective option (Khan and Amyotte 2002). It is generally believed that an inherently safer design eliminates rather than controls hazards, particularly by reducing the amount of hazardous materials and hazardous operations within the facility (Hendershot 2011, 2012). In spite of this, it is unlikely that a technology or

Fig. 2 Fire and explosion on an offshore platform caused by process hazards. (Courtesy: Shutterstock)

process will be inherently safer in the event of all possible hazards. According to the latest study, inherent safety has not been utilized as widely as other techniques, including Hazard and Operability Stud (HAZOP) and quantitative risk assessment. It is due to a number of factors, including a lack of awareness and the absence of a systematic methodology and tools (Khan and Amyotte 2002). Therefore, the main focus of this study is only on inherently safer designs, (Khan and Amyotte 2002) while other risk mitigation and elimination measures, such as HAZOP, are briefly discussed as a primary responsibility of safety engineers in this study. In another study, three different methods of risk assessment were combined, including quantitative risk assessment (QRA), to assess the severity of fire and gas explosions occurring on the oil and gas floating production storage offloading (FPSO) (Suardin et al. 2009). There is an interesting book focusing on the details of fire safety engineering tasks and responsibilities in structure design (Purkiss and Li 2013). In order to design structures that can withstand the effects of fire, a series of complex design decisions must be made. In this book, Fire Safety Engineering Design of Structures, practicing fire safety engineers will learn how to design structures that are fire resistant. Expert design advice, as well as historical data, are presented in this text, as well as details of standard industry design decisions (Purkiss and Li 2013). The book focuses on a specific area of fire safety engineering, such as structural detail design, and does not provide a comprehensive overview of fire safety engineers' roles and responsibilities. The book does, however, cover some of the main roles of safety engineers in relation to fire safety, such as fire detection system designs, escape routes, and active and passive fire prevention measures It is common for oil and gas plants to use both active and passive firefighting systems. (Tugnoli et al. 2012; Spitzenberger et al. 2016). Active fire protection systems are designed to extinguish fires. A passive fire protection system can reduce the spread of a fire or prevent it from igniting in the first place. An active firefighting system consists of a pressurized water ring feeding hydrant, fire monitors for manual firefighting, and a deluge system for automatic firefighting. An example of passive fire protection would be the use of fireproof insulation on structures in order to mitigate the effects and heat of a fire (Huang et al. 2020). Another area of research that is of interest is safety management. It is commonly understood that safety management involves the application of principles, frameworks, processes, and measures designed to prevent accidents, injuries, and other adverse consequences caused by the use of a product or service (SKY Bray 2022). This function is intended to assist managers in fulfilling their responsibilities in designing and implementing operational systems by identifying and correcting system deficiencies (SKY bray 2022). This is done either by predicting system deficiencies before errors occur, or by analyzing safety incidents from a professional perspective. Management of safety involves a systematic approach, including the necessary organizational structure, accountabilities, policies, and procedures (SKY bray 2022). It has been demonstrated that there is a lack of safety management and its negative impact on the oil and gas operator companies in Nigeria in one study (Nnadi et al. 2007). The implementation of safety management systems (SMS) can be difficult when oil and gas companies operate in an environment with a number of human, cultural, technical and operational constraints that adversely affect safety. Furthermore, in order to ensure safe operations in the oil and gas industry, it is also imperative that high standards of transparency and compliance with laws and legislation be met (Nnadi et al. 2007). What is the relationship between safety management and engineering? Safety managers are responsible for enforcing safety practices, training, and prevention efforts on a day-to-day basis; safety engineers are responsible for designing systems, technology, environments, and processes that assist safety managers in performing their duties (Roland and Moriarty 1991).

According to the literature review, the following information is already known about the safety in the oil and gas industry:

- The use of risk assessment by safety engineers as a tool for identifying and mitigating hazards;
- Various risk assessment tools are used by safety engineers such as HAZOP, quantitative and qualitative risk;
- Safety culture plays a critical role in establishing safety and reliability within organizations;
- In safety engineering, safety instrumented systems (SIS) consist of sensors, logic solvers, and actuated valves as final elements. SIS is primarily used in process safety engineering to increase safety and reliability
- Some issues and challenges related to SIS implementation;
- As part of the design and operation of a process plant, inherent safety implementation is an extremely critical concept and practice to eliminate hazards to the maximum extent possible;
- The responsibilities of fire safety engineers in relation to the design of structures based on fire risk considerations based on standards, practical experiences and field data;
- Tasks related to fire safety engineers, such as fire detection systems and emergency escape routes;
- The challenges associated with establishing safety management within organizations;

2.2 Identified gaps

There has been no prior study that examines the various essential tasks for safety engineers in oil and gas projects in a comprehensive and multidisciplinary manner based on industrial experience and practices. As opposed than previous studies, this study provides a comprehensive overview of the roles and responsibilities of safety engineers in oil and gas and process plants to prevent or mitigate fire. Based on the literature review, the following gaps have been identified regarding the tasks of a safety engineer in cooperation with other departments in order to mitigate or prevent fires:

- Emergency shut down (ESD) systems and the role of safety engineers in their implementation;
- Considering the safety of the plant layout in collaboration with the engineers responsible for piping layout;
- The role of safety engineers in the prevention and suppression of fires;
- Fire and gas detector design and selection by safety engineers;
- The role of safety engineers in the classification of hazardous areas; and
- Design of emergency exit routes by safety engineers.

2.2.1 Emergency shut down (ESD) system

Generally, an Emergency Shutdown (ESD) system is used to stop the operation of a process and isolate it from incoming or outgoing connections or flows in order to reduce the probability of an unwanted event occurring, continuing, or escalating. An ESD system is designed to protect personnel, to safeguard the facility, and to prevent environmental impact from a process event (Zhu et al. 2020; Oubre et al. 1977). In contrast to other facility safety systems, the ESD system responds to hazard situations that may have an impact on the overall safety of the entire facility. As a result, it is considered one of the most critical safety systems that can be installed in any facility. A hydrocarbon facility without an ESD system may experience excessive flow or pressure during an incident, which may result in the destruction of the entire facility. ESD is, therefore, considered one of the main instrumentations and control systems.

A standard known as IEC 61508 has been developed as a reference standard for safety engineers to evaluate and measure the safety of safety instrumented systems (SIS), such as ESD (International Electrotechnical Commission (IEC) 2010). As described in IEC 61,508, there are four levels of safety integrity levels (or SILs) applicable to safety instrumented systems, such as safety valves and instruments that are concerned with ESD or other relevant systems. SIL consists of four levels, 1, 2, 3, and 4. A greater SIL number indicates a higher level of safety and reliability. As a result, SIL1 has the lowest level of safety while SIL4 has the highest level of safety (International Electrotechnical Commission (IEC) 2010; Faller 2004; Smith and Simpson 2020). Typically, ESD systems are classified as either SIL2 or SIL3 (Bae et al. 2016). ESD's SIL may be determined by the criticality of the incident. When an ESD is used to shut down an entire plant instead of a single piece of equipment, it is more significant. The IEC 61,508 standard can be used to calculate the system reliability and correlate the probability of failure of a device or system based on SIL. In the context of safety critical systems, such as ESD, safety engineers are responsible for ensuring that the SIL is sufficient. In order to perform an analysis or review of SIL, safety engineers should collaborate with other disciplines such as piping and valves, process and instrumentation. In Fig. 3, an emergency shutdown valve is shown installed on the gas service piping to shut down the gas line production in the event that there is a problem.

2.2.2 Plant layout

A second critical safety engineering activity is the layout of the plant. Layout of a plant involves understanding the space requirements for the facilities as well as their proper arrangement in order to ensure that the production cycle can progress continuously and steadily (Naik and Kallurkar 2016; Watanapa et al. 2011). There are many important documents associated with the layout of the plant, including the plot plan (Suzuki et al. 1991). An industrial plant plot plan shows schematically the location of equipment, roads, buildings, support infrastructures, and other constructions as well as their dimensions and distances from one another. A plot plan is essential for obtaining permits as well as determining the safety of personnel and the environment. Several rules and principles related to safety engineering govern the location of various units and equipment. As an example, if toxic or hazardous materials are handled, a layout may be required to isolate equipment that may pose a threat. For example, flare stacks and furnaces may be separated from other parts of the plant. Those equipment areas that handle

Fig. 3 An ESD valve is installed in the gas piping system. (Courtesy: Shutterstock)

acids or other toxic materials that can cause damage to equipment or endanger personnel should be grouped together and isolated (Toghraei 2015). Considering that gas compression units have a high probability of catching fire, they should be kept away from vital units such as power generation and manned areas such as living quarters in order to ensure safety (Lecheheb et al. 2006). As a matter of fact, there is a separation distance provided between the plant units to limit or prevent the spread of fire to specific areas within the plant.

2.2.3 Fire protection and firefighting

It is typical for oil and gas plants to use both active and passive firefighting systems. The purpose of an active fire protection system is to extinguish a fire. Passive fire protection can prevent a fire from spreading or prevent it from igniting (Zuccaro 2012). A fire water system is the main active fire protection system (Rao et al. 2014). A fire water system usually consists of four parts; the first is fire water, which may be sea water (Wang and Shih 2018). It is necessary to use fire water demand calculation sheets in order to determine the quantity of firewater to be used. In addition, a pumping system is used to ensure that there is sufficient water flowing for the extinguishing of fires (Nolan 2011). Thirdly, a fire water network consists of piping headers that transport fire water from the pumps to the fire locations through rings (Peterka et al. 2022). The fire ring is equipped with a large number of isolation valves, which are usually ball valves or butterfly valves (Sotoodeh 2018). Through these valves, damaged parts can be isolated while the rest of the system is kept supplied with water. Finally, hydrants, nozzles, sprinklers, or other local devices that direct water to areas where fires need to be extinguished are included in fire water systems. Water is supplied to the suction of a firefighting appliance through a fire hydrant. Essentially, a fire hydrant (see Fig. 4) is a visible connection point, which allows firefighters to access a water supply (Rosenberger 2017). The deluge is another essential safety system for firefighting. Deluge fire protection systems utilize unpressurized dry piping and open sprinkler heads. It is directly connected to a water supply, and when activated, a deluge valve releases water to all open sprinkler heads. Upon activation of a heat or smoke detection system, the valve turns on (Baalisampang et al. 2017). Passive firefighting involves the application of fireproofing to structures, equipment, and piping components. Thus, critical equipment and pipes are prevented from falling as a result of a fire, which prevents it from escalating. It is generally the responsibility of safety engineers to determine whether a structure, pipe, or piece of equipment must be fireproof.

Fig. 4 During the fire incident, a fire hydrant was connected to a hose. (Courtesy: Shutterstock)

2.2.4 Fire and gas detection

An instrumented system designed to detect fires or gas leaks is referred to as a fire and gas detection system. It is composed of a sensor (or sensors), a logic solver (or logic solvers), and a final control element (or elements) (Hoefer and Gutmachera 2012). The FGS system can be configured with a variety of sensors, including smoke detectors, flame detectors, and temperature sensors. When a fire or gas is detected, a fire and gas detection system will sound an alarm and take automatic steps, such as isolating electrical supplies and connections. Fire and gas detectors are located in process plants and buildings by a safety engineer who determines their number, location, and type. It is the responsibility of safety engineers to prepare an engineering document called a fire and gas detection layout drawing. This document generally illustrates the arrangement and layout of fire and gas detectors. Multiple sensors or detectors are commonly used to improve the safety and reliability of a system, especially when one of the detectors does not function as expected. When designing FGS, many factors must be taken into consideration, including safety, functionality, reliability, cost, and simplicity (Reddy et al. 2020). Safety engineers are also responsible for generating the fire and gas detection table or matrix. This table specifies the actions to be taken upon detection of fire or gas, including alarm activation, process shutdown, etc. A fire and gas detector can be seen in Fig. 5 in an oil and gas production facility.

2.2.5 Hazardous area classification

The use of electrical equipment in hazardous areas is associated with a number of safety issues, including corrosion, inadequate maintenance, and improper electrical wiring. A common cause of electrical equipment failures in hazardous areas is that fixed electrical equipment or portable electrical

Fig. 5 Fire and gas detector. (Courtesy: Shutterstock)

equipment is not properly rated for the hazardous area. Electric equipment can cause a fire or explosion when used in, around, or near an atmosphere containing flammable gases or vapors, flammable liquids, or combustible dusts (Bottrill et al. 2005; Rankin 2007). Hazardous (or classified) locations or areas are those in which there is a possibility or risk of a fire or explosion as a result of an explosive atmosphere or mixture (Tommasini 2013). A leak, spill, or fault may result in the release of combustible gases, vapors, or dust into the atmosphere in such areas or plants. Most hazardous areas are located in large facilities such as chemical processing plants, oil production platforms, tank farms, refineries, storage tanks, ships, warehouses, and similar locations. In general, area classification involves analyzing and classifying the environment in which explosive gas atmospheres may occur. This is done in order to facilitate the selection, installation, and operation of equipment that will be used safely in such environments. There are two main objectives of area classification: to determine the type of hazardous zone and its extent. In order to protect both personnel and the plant, it is imperative that this explosive atmosphere cannot be ignited. In conjunction with the other disciplines, the safety discipline shall prepare a hazardous area classification and restricted area drawing. Generally, it is the responsibility of experts or highly qualified personnel, such as chemical engineers or process engineers, to identify hazardous (classified) locations within a plant (Bozek et al. 2014). Once the initial process and instrumentation line diagram (P&ID) is available, an area classification must be performed and will be updated periodically until the plant is operational. A piping and instrumentation diagram (P&ID) is a detailed diagram that shows piping, process equipment, and instrumentation (Toghraei 2019; Ishii et al. 1989). A periodic update of the classification is necessary even during the life of the plant in order to take into account any potential changes to the original plat or any new sources of pollution. Hazardous areas are areas containing explosive concentrations of combustible materials, gases, vapors, dusts, fibers, etc., either as a result of the normal operation of the process or as a result of leaks. "Explosive atmosphere" is often used to describe this situation. Alternatively, a safe area is one in which no ignitable concentration of combustible materials exists at any time. Three categories of hazardous areas are recognized: zone 0, zone 1, and zone 2. As indicated by the classification zones, zone 0 has the highest level of safety concern, while zone 2 has the lowest level of safety concern.

2.2.6 Emergency exit and evacuation

In the event of an emergency, emergency exit routes must consist of continuous and unobstructed paths of travel from any point within the workplace to a place of safety. It is also critical to practice emergency procedures in the event of a fire in order to ensure a safe evacuation. An emergency exit route consists of three components: emergency exit access, emergency exit route, and emergency exit discharge. During a fire, the emergency escape system designed by safety engineers in the workplace or plant must be maintained effectively in order to ensure effective evacuation. In order to ensure everyone's safety, all fixtures and fittings, including fire doors, staircases, corridors, fire detection and alarm systems, firefighting equipment, notices, and emergency lighting, must be designed and installed (Jinzhang and Fengxiao 2022).

3 Conclusion

The oil and gas industry, for example, requires substantial expertise in health, safety, and environmental engineering in order to minimize the possibility and consequences of negative events and hazards. Process industries and facilities handle a substantial amount of flammable and combustible materials on a daily basis. Moreover, these materials may be handled at extremely high temperatures and pressures, where explosive, corrosive, and toxic properties may be present. As a result, it is inevitable that oil and gas processing facilities will be subject to fire risks due to the nature of their work. Fire safety engineers play a very important part in establishing fire safety design and analysis during the design stage of the plants. This is done in cooperation with other departments such as process, instrumentation, and piping. Despite the fact that there have been many previous studies dealing with safety-related issues such as safety culture and management, risk assessment, safety instrumented systems (SIS), and inherent safety implementation, there has never been a study that discusses the role of safety engineers in fire prevention and mitigation. As a result of this review, the roles and responsibilities of safety engineers during the design process of oil and gas plants have been reviewed in a comprehensive and general way in order to prevent and mitigate fires. This paper discusses the various responsibilities of safety engineers, such as the establishment of ESD systems, the classification of hazardous areas, the design of smoke and fire detection systems, the layout of plants, the design of active firefighting systems, and the design of passive firefighting systems. Next section contains some future studies that are suggested to be conducted on the role of safety engineers in the oil and gas industry during the design phase of the project.

4 Recommendations of additional work

1. It is recommended that a separate study be conducted to examine the various risk assessment techniques and models used in the oil and gas industry as well as their strengths, weaknesses, and limitations.
2. There is a need for separate research regarding the tools and techniques that safety engineers use to identify and mitigate risks in the oil and gas industry.
3. An evaluation of the relationship between safety engineering and management is required in a future study.
4. There is a need for a more detailed review of safety engineers' detail design engineering with regard to active and passive fire protection systems.
5. There is a need for a detailed analysis of how hazardous area classification is performed by safety engineers.
6. Review of national and international standards that safety engineers are used during detail design engineering

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