Original Article

Hazard Identification and area analysis in the Siraf Gas Condensate Refinery using the HAZID method

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ABSTRACT

The present study aims to identify hazards and analyze work areas in the Siraf Gas Condensate Refinery using the HAZID method. The research method is descriptive-analytical. One of the needs of the operational safety report is to illustrate that the operation, construction, design, facility maintenance, storage equipment, and related infrastructure that could pose major accident hazards within the refinery are safe and reliable. Several new refineries are under construction in Europe. The chemical specifications of crude oil are not fixed. Globally, crude oil extracted often has high acidity, which significantly affects plant maintenance and quality control strategies, especially regarding corrosion. Additionally, temperature and operational capacity impact corrosion and other failure modes. Thus, the refinery operations challenge is to sustain existing refinery facilities (which are often aging) and productivity (possibly beyond their initial design life). This issue needs decisions regarding the continuous operational period (lifespan) of the refinery based on factory data obtained from review strategies (and today increasingly according to risk-based inspections in the UK).

Keywords: Hazard Identification, Work area analysis, Gas Condensate Refinery, Refinery facilities

Introduction

Occupational health and safety management plays a crucial role, which is essential for successful business management. In addition, sustainable strategy development for an organization should not only focus on increasing the organization's production value but should also be studied in conjunction with other aspects like effective economic performance, resource utilization, environmental protection, and occupational safety and health. In most developed countries, industrial sector growth is encouraged due to its significant contribution to the development of the economy. Companies have also been striving to create a safe environment, and increasing the workforce's engagement with safety management is a sensitive problem as it impacts human lives, and organizations should propound it more than just a cost-profit relationship [1].

Despite the clear requirement to manage safety and health, many companies do not invest the necessary resources. This may be because of a lack of motivation, skills, knowledge, or confined resources among staff. Another obstacle may relate to managers prioritizing low employee costs over other organizational issues. Costs are also a significant concern, as companies often feel a lack of necessary capital to invest in health and safety but fail to recognize the importance of such investments. Effective management of injuries, incidents, and poor health reduces risks and probably increases profitability. However, these affairs are not always recognized by organizations. To foster a prevention culture, actions are required both in the workplace and through regulatory compliance, engineering controls, technological advancements, and the introduction of occupational safety and health management systems, as well as changes in managed culture to obtain a positive safety culture in manufacturing industries, including economic units primarily assigned to converting chemical, physical, and mechanical materials into new products [2].

Strategies for controlling hazards are divided into 4 main groups: [1] eliminating hazards, [2] reducing the consequences and frequency of risks, [3] transferring risks through sharing and insurance, and [4] accepting risks.

Factors contributing to the insurance of an incident can be classified as unsafe conditions of environment, materials, and equipment, unsafe behavior of operators, defects in design and technology, lack of training and safety, inadequate organizational structure, lack of workplace inspections, hazards or unsafe physical situation found in facilities, equipment, tools, machinery, transportation means, energy, and materials. The derived hazardous conditions highlight the protective role that becomes more pronounced for each case where there is a probability of risk, and the higher the risk, the higher the protection [3].

It is important to classify environmental factors of hazards, such as physical hazard factors, and environmental agents with a physical nature that can lead to adverse physical impacts depending on their concentration, exposure, and intensity. Among these factors are: vibrations, noise, abnormally high or low pressure, lighting, non-ionizing radiation, high or low temperatures, ultraviolet rays, infrared, lasers, masers, ultrasonic waves, ionizing radiation like gamma rays, X-rays, proton radiation, alpha and beta particles. Chemical risk factors encompass any natural or unnatural substance, whether natural or synthesized during manufacturing, handling, transportation, storage, or utilization that may be present in the environment in the form of dust, smoke, gas, vapor, irritants, corrosives, choking or toxic effects in volumes that could potentially harm individuals in contact with them, as well as biological hazards derived from exposure to diseases or contact with living organisms, like fungi, viruses, parasites, bacteria, and any organism that could cause allergies, diseases, or infections. Indeed, psychological hazards associated with work-related physical stress are psychological risks influenced by the work performed on individuals. They largely depend on subsequent characteristics of employees: work pressure, and job dissatisfaction, which are factors of risk leading to stress, burnout, or failure, and in turn, the psychological injuries caused like depression, including neurological diseases that limit work capacity. This classification also includes risks due to ergonomic issues associated with repetitive manual work, where operators are at high risk of injuries caused by poor body posture or exertion during work. Specific sources of risk include electrical hazards that can lead to traumatic injuries from falls, injuries due to severe muscle contractions, deaths from abdominal filtration, injuries and deaths due to internal burns, permanent injuries due to toxic effects of burns, permanent damage because of nerve tissue destruction, among others, and mechanical risk factors (scrapes, cuts, tears). In conclusion, it is notable to explain natural risk factors caused by natural phenomena like floods or abnormal tremors. The present study aims to identify hazards and analyze work areas in the Siraf Gas Condensate Refinery using the HAZID method.

Materials and Methods

Hazard Detection and Investigates in Work Areas in the Construction and Production Sector Using the Methodology of HAZID

HAZID studies are conducted for the gas condensate refinery complex under development, located on the coast of the Persian Gulf in the Tambak region of Iran (50 kilometers west of Assaluyeh). The liquid hydrocarbon feedstock is supplied from the existing gas refinery in the mentioned area. This complex has a gas condensate refinery with a capacity of 60,000 BPSD × 8, which includes feedstock input equipment, production output, facilities, and conventional processing units necessary for producing LPG, light and heavy naphtha, kerosene (jet fuel), and diesel [4].

The main sections of this complex are as follows:

Eight condensate distillation units (CDU) for the fractionation of condensate into LPG, stabilized light naphtha, stabilized heavy naphtha, kerosene, and diesel.

Eight LPG treatment and recovery units to meet the specifications of LPG products for storage and export.

Eight naphtha hydrogenation units for producing nitrogen-depleted and desulfurized light and heavy naphtha cuts.

Eight middle distillate hydrotreating units (MDH) for producing refined kerosene (jet fuel) and ultra-low sulfur diesel (EURO V).

Eight hydrogen production units (HPU) for generating the hydrogen needed for the middle distillate and naphtha hydrotreating units.

Eight steam generation units, nitrogen systems, compressed air systems, and cooling water systems for producing nitrogen, steam, compressed air (plant), and utility air and cooling water in each refinery.

Amines treatment unit.

Sour water stripping unit (SWS) for treating sour water generated from processing units.

Sulfur recovery unit (SRU) for producing liquid sulfur for freezing, granulation, and export.

Feedstock and product storage tanks.

Utility units to service processing units.

Breakwater facilities for export.

HAZID Styles

The balance between conducting the study early enough to influence major decisions but late enough to allow for the collection of sufficient information for an effective review leads to three types of study styles. These styles are categorized based on their concept into HAZID, FEED HAZID, and detailed engineering HAZID [5].

FEED HAZID

This analysis is applicable when a single or competitive process is being developed to the point where the process flow diagram, material balance, design philosophy, equipment list, and planning for review are available. At this point, the HSE concept of the project design should be able to identify major hazards. Based on the information, the analysis can be applied to both internal and external hazards, as well as nearby hazards related to processes and operational services. Thus, they will be able to make initial engineering decisions regarding the following:

Process technology;

Capacities;

Savings philosophy;

Operations concept;

Layout considerations;

Prevention of worsening, pollution, protection, isolation, etc.

Detailed engineering HAZID

Safety engineering, in collaboration with process engineering, will conduct HAZID for each process area defined in Section 2. The HAZID operation is performed on a unit-by-unit basis, incorporating all available engineering documents, particularly P&IDs, PFDs, and planning drawings. The contractor will review the FEED HAZID for any transitional comments. The contractor will examine potential causes and consequences of fire, explosion, release of toxic materials or flammable chemicals, and spills of hazardous chemicals. The goal of the review is to identify and describe potential HSE hazards. It will also recognize the likelihood of continuous releases from installed equipment and examine their effects on the environment. In the initial phase of the HAZID session, the topic of hazardous materials present in the area will be reviewed. The HAZID study will be facilitated by qualified HAZID facilitators, and the company will represent all participants in the HAZID review [6].

HAZID study at the Siraf Gas Condensate Refinery

Collaboratively with other review studies and structured brainstorming, the coordinating role is vital for the success of the review. The coordinator will be responsible for the following:

Leading participants in the HAZID technique;

Generating brainstorming sessions;

Managing discussions without compromising the creativity of the process;

Identifying key issues raised by participants;

Recording and documenting findings to ensure that the entire duration of the meeting reflects the identified points accurately.

The coordinator needs to recognize HSE issues as they arise, requiring a broad range of technical expertise to apply to the type of development under review. When the coordinator identifies nodes that need to be studied, which may include several types of facilities or individual items within facilities, the performance of that node will be discussed, and participants will confirm it before it is recorded. The coordinator will then review the node using a checklist, and within each section of the checklist, the following methods will be employed [7]:

The coordinator introduces a category from the checklist and then asks participants to pay attention to each of the guiding words.

In each case, participants analyze each guiding word (facilitated by examples provided in the checklist) to identify the potential hazards and their effects that may be recorded in the draft sheets.

The brainstorming process is then utilized to identify all potential hazards or causes of hazards. During this process, the coordinator may suggest examples from the checklist's expansion section. However, these expanded sections must be presented through examples and not as a closed list that limits the brainstorming activity of the participants.

Participants analyze appropriate controls that should generally be in place to prevent or mitigate each hazard. At this time, participants may suggest additional solutions to minimize remaining risks.

Finally, participants determine an initial risk ranking without additional solutions.

Note: The HAZID checklist is comprehensive but not exhaustive, and brainstorming may be necessary to identify unknown or new resources

Risk Identification program for the development plan of the Siraf Refinery using the HAZID method

The IOOC (Iranian Offshore Oil Company) is planning to expand the area located on the coast of the Siri Island complex, southeast of Siri Island in the Persian Gulf, Iran. The collection of gas and NGL recovery project on Siri Island includes the existing reception facilities expansion, the new gas field addition, and the construction of gas condensate transition lines, gas compression (compressed gas), and processing facilities with related utilities (electricity, water, and gas) [8].

Potential major hazards that could impact the performance and reliability of the plants include the accidental release of process materials and various possible outcomes, such as:

Dispersion of vapor/gas (including toxic hazards when sour materials are released).

Instantaneous combustion leads to fire and radiation hazards.

Delayed ignition results in a vapor cloud explosion and damage from overpressure.

Liquid pool ignition.

Boiling liquid expanding vapor explosion (BLEVE) due to the ejection or contact of the burning pool with the pressurized liquid vessel.

The plant location is divided into 9 fire zones with spacing and fire protection designed to prevent the spread of accidental fire events to other areas of the plant.

The fire zones are defined as follows:

Fire Zone 1 (FZ 1) - Executive management building, chemical storage, workshop, and laboratory.

Fire Zone 2 (FZ 2) - Central control building and fire water system (Area 39).

Fire Zone 3 (FZ 3) - Gas fuel (Area 31), instrumentation and HVAC services (Area 32), nitrogen (Area 33), powder production (Area 44), diesel storage (Area 40), and substation.

Fire Zone 4 (FZ 4) - Dehydration and mercury removal (Area 12), NGL recovery (Area 13), NGL gas separation (Area 14), LPG cooling and status summary (Area 15), propane gas refrigeration (Area 16), local control building, and chemical inspection.

Fire point 5 (FZ 5) - Supply of compressed gas (zone 10), removal of acid from the gas (zone 11), combustion of acid from the gas (zone 19), stabilization of condensates (zone 20), generation of steam (zone 30), desalination or sweetening of seawater (zone 35), extraction of minerals from water (zone 36), discharge tanks (zone 42), and inspection of chemicals.

Fire Zone 6 (FZ 6) - Storage tanks for condensates, propane, butane, and pentane.

Fire Zone 7 (FZ 7) - Ignition and release of residual fuel by gas pressure (Area 41), and waste disposal by burning in a pit (Area 42).

Fire Zone 8 (FZ 8) - Input separation and reception facilities (NASR) (Area 01), liquefied gas (LPG) compression (Area 02).

Fire Zone 9 (FZ 9) - LPG loading dock.

The worst-case hazardous event that can be confirmed in each unit and its potential outcomes are documented in the HAZID worksheet. The analysis of confirmed hazard events regarding the architectural layout of the plants led to the identification of DAE (Designated Areas of Explosions) in fire-prone areas. These events illustrate the worst credible scenarios for modeling outcomes. For further details, refer to document Nr SIRB-00-SA-ST-0002.

Due to the size of the fire areas in DAE, areas on the west and east sides of zones 3, 4, and 5 have been selected for better assessment of potential impacts on adjacent equipment and areas. Fire areas without potential (not having fire potential), for loss of containment (1 and 2), were not considered in this analysis. Fire Zone 7, the area of concern for radiation, will be addressed during the EPC phase of the project.

Control of major Hazards in European crude oil Refineries as a cross-border risk study method

This section examines the behavior of organizations in monitoring and controlling risks under the supervision of the community of countries affected by those risks, serving as a model for global cooperation in controlling operational hazards and developing refinery industries. Each member country has its representative agency to follow up and monitor. The JRC (Joint Research Centre), one of the services of the European Commission, acts as a technological and scientific reference center for the European Union. This center serves the general interests of member countries while pursuing its specific and independent management and safety strategy. The JRC's mission is to offer customer-oriented technical and scientific support for the monitoring, implementation, development, and conception of EU policies. The mission of the safety and health executive is to ensure the proper control of environmental hazards in the changing workplace to protect the health and safety of individuals [9].

The main objective of this document is to offer a set of information that reflects the performance status of the European Union, hoping that this document can assist inspectors and Seveso inspection programs inappropriately improving and reviewing their performance [10]. Multiple approaches may have a similar effect in controlling this type of major hazard, and this document does not comprehensively present all possible options for this. Furthermore, the editors note that the purpose of providing information about the operational methods employed in a specific country is to offer descriptive information that may be useful. In any case, the intent of this document is not to fully describe the inspection methods of each of these countries, as these methods inherently vary between regions and sometimes among the competent authorities responsible for inspections [11].

Inspection work has always been one of the very dynamic and powerful tools for the authorities of the member countries of the European Union to enforce the Seveso II directive. Therefore, the European Commission, along with the qualified authorities responsible for implementing Seveso II, has long maintained this area as a technical cooperation priority at the EU level. There is a strong and mutual commitment to continue cooperation to enhance the inspection methods' effectiveness and ensure a sustainable method for interpreting the needs of Seveso II via inspections by member countries [12].

The Seveso inspection programs aim to provide a series of publications on topics related to the efficient implementation of the inspection needs of the Seveso II directive, results, and important points of technical change, study, and analysis. The goal of these publications is to facilitate information sharing about the operational and experience methods of member countries to promote greater continuity, effectiveness, and transparency in the Article 18 implementation of the directive. These programs are managed by the group of technical working of Seveso II inspections of the European Commission, which consists of inspectors nominated by the committee members of competent authorities to implement the Seveso II guidance across the EU. The coordination of the group of technical work is carried out by the Major Accident Hazards Bureau of the JRC of the European Commission with the support of the Directorate-General for the Environment [13].

The guidebook “Improving Major Hazard Control in Crude Oil Refineries: Key Points and Results” is part of a publications series related to Seveso inspections. The series of publications is one of several designs in situ or in the current environment that supports the implementation of the directive, with financial backing from the European Union. The Joint Visit Program (MJV) for inspections of Seveso II, in particular, is one of the main sources of this series of publications. The aim of the MJV program, established by the European Commission in 1999, was to serve as a tool to enhance technical exchanges among Seveso II inspectors from member countries. The goal of this program is to promote the alignment and sharing of best inspection practices via a systematic information exchange system. These visits are likely to be hosted by various member countries (hence they are bilateral) and are targeted at the performance of inspectors from other member countries (and through joint visits) responsible for assessing admission with the Seveso II directive concerning industrial facilities [14].

The MJV program is managed using the Major Accident Risks Bureau in deliberation with the technical working group of Seveso II inspections. Since 2005, the program of MJV has promoted visits focused on specific interest topics to Seveso inspections as determined by the group of technical working. The inspectors' participating observations and results in these workshops will be published as part of the Seveso inspection publications whenever possible. The technical working group is responsible for increasing information exchange and joint research among member countries to improve the quality and coordination in the Seveso II commitments implementation by authorities of Seveso inspection. The findings of such studies may also be published singly on the website of Seveso inspections or integrated with MJV summaries in the Seveso inspection publications [15].

For more information on inspections of the Seveso refinery, please visit the website that presents the results and recommendations of this working group at http://sevesorefineries.jrc.it. You can also find valuable information on the MAHB website (http://mahbsrv.jrc.it) and http://sevesoinspections.jrc.it. These sites provide helpful resources regarding Seveso legislation, management of related risk, its implementation, and evaluation projects.

The report on the execution of HSE inspection operations documents the objectives and actions for the Joint Visit Program (MJV) concerning crude oil refineries, hosted by the competent authority of Seveso II in the UK from March 8 to 10, 2006. The design of this document aims to gather information and share it appropriately with other inspectors. This document contains results and observations from inspectors' discussions and other specialists participating in the MJV, as well as suggestions for their implementation and recommendations for future actions [16].

Especially, the MJV emphasized the urgent need for targeted knowledge sharing among operators and competent authorities to create a broad base of knowledge and awareness in several areas, including [17]:

- Lessons learned from near-misses and accidents in refineries.
- Incident reporting and strategies particular to refineries.
- Safe operational indicators for utilization in the industry and by competent authorities.
- Inspection results, maps, and strategies.
- How to enhance human performance when working in complex systems.

Several practical solutions were proposed to facilitate knowledge sharing in these areas, including:

- Exploring the capability to share near-miss reports based on the EU.

Creating a suitable practical guide for incident investigation and reporting in refineries.

Organizing another specialized workshop for oil refinery safety.

Developing and implementing safety performance measurement indicators for utilization in the industry and by competent authorities.

This report summarizes the discussions and presentations that happened during the joint visit. Additionally, multiple presentations are available in the document appendix, and information related to inspections by the Major Accident Hazards Bureau of Seveso and the Seveso refinery website can be downloaded from http://sevesorefineries.jrc.it and http://sevesoinspections.jrc.it.

Council directive 96/82/EC on the Hazards control of dangerous substances

Between March 8 and 10, 2006, the UK Health and Safety Executive held with fifteenth joint visit by the committee of the European Union's qualified authorities for the Seveso II directive (CCA) implementation. The chemical industry sector of the Health and Safety Executive, along with representatives from the environment and Scottish Environmental Protection Agency, were the qualified authorities for the Seveso II directive in the UK.

This was the second joint visit of phase two, conducted as a working group focused on crude oil refineries. Crude oil refineries are operational in most EU member countries. Overall, European refineries account for just over 12% of global refining capacity. Currently, the establishment of 130 refineries in Europe has been highlighted by volunteer countries, Sweden, and Norway (see Appendix 2). Most of these refineries are classified as top-tier sites. While the production of these products is essential for most national economies, processing large volumes of flammable hydrocarbons poses major accident hazards that can impact nearby communities significantly in the event of a plant failure and containment loss. Major refinery accidents like Texas City (USA), Karlsruhe (Germany, 2004), Puertollano (Spain, 2003), and Killingholme (UK, 2001) illustrate the potential for catastrophic (and sometimes fatal) consequences. It is essential for regulatory authorities to ensure that refinery operations effectively manage risks and continuously strive to decrease risk [11].

Given the significant commonality among individual refineries and the presence of numerous multinational refineries, competent authorities need to adopt a cohesive approach to the European oil refinery legislation. One of the topics discussed in the MJV was improving the control of major hazards in crude oil refineries, which was seen as a method to move toward this goal.

Conclusion

The MJV program is supported by the European Commission, on behalf of the competent authorities committee for the Seveso directive (CCA) implementation and the Directorate-General for the Environment, with management overseen by the MAHB (Major Accident Hazards Bureau) of the Joint Research Centre of the European Commission (http://mahbsrv.jrc.it/). This program began in 1999 to strengthen the information exchange among inspectors of European Seveso II regarding inspection methods and measures of efficient accident prevention. The program is funded by the European Commission and the competent authorities of member states for the implementation of Seveso II. Each MJV includes a workshop that addresses regular methods and experiences related to Seveso II inspections (Phase 1) or specific topics (Phase 2).

This program provides member countries with the opportunity to gain a deeper understanding of what is acceptable under Seveso and acceptable safety in an inspection context. Specifically, as this program is linked to various technology and industrial sectors, it provides a broader platform for reviewing and improving safety management assessment tools and strategies, facilitating a collaborative exploration of effective approaches aimed at hazard control and safety. The program has taken root in the belief that member countries can learn from each other and work constructively together to resolve joint issues, thereby enhancing their skills and technical efficiency regarding relevant inspection programs.

Participants in the session include inspectors representatives from member states and volunteer countries. Often, several industry specialists also participate to provide a specific industrial perspective and enhance communication and transparency between the regulated community and inspection authorities.

Phase two of the MJV places a strong emphasis on disseminating results, ensuring that all Seveso inspectors in Europe have the chance to profit from the technical changes of the MJV. Consequently, this report will be published as the Seveso inspection series part and will be made available free of charge to EU inspectors and other organizations and experts interested in the subject, both within and outside Europe.

The specific goal of the workshop is to detect priorities, criteria, and strategies for risk decrease in hazardous facilities and to exchange practical experiences related to intervention methods and objectives, aimed at improving reception with the Seveso II directive in Europe. Examples of anticipated outcomes include:

Detection of common safety problems and typical approaches (including strategic, technical, systematic, etc.) to address them.

Recommendations for establishing a refinery inspectors network that can assist each other in prohibiting accidents and hazardous consequences.

Suggestions for advancing cooperation on effective interventions with international/refinery facilities to maximize the effect of these interventions.

Detection of mechanisms and tools necessary to strengthen such collaborations at the European level.

The organization and structure of the workshop consist of a combination of presentations and case studies along with group discussion sessions (comprising 10 to 12 representatives). These groups will discuss and share information to reach a common understanding of the four workshop topics mentioned below: Before the session begins, a discussion sheet regarding each of these topics and strategic questions about improving major hazard control in crude oil refineries will be provided to participants. Key points will be summarized and reported during each discussion. The noted summaries will also be given to the session organizers, and much of the information in the report will be according to these summaries as well as the discussions and presentations that occurred during the session.

This workshop was held for inspectors responsible for implementing the inspection Seveso II Directive No. 2 (Article 18) requirements in crude oil refineries (Council Directive EC/82/92 on the major accident risks control involving dangerous substances). At the request of the competent authorities in the UK and the MAHB (Major Accident Hazards Bureau), the necessary conditions for participating candidates were as follows: practical knowledge of refinery facilities and activities and associated hazards, practical experience in applying Seveso II and relevant national legislation, willingness to actively take part in the workshop, and commitment to publish the results obtained from the workshop in their countries.

A significant number of representatives participated, including 29 agents from 20 European countries (including representatives from volunteer countries to the EU, Croatia, and Romania), most of whom were inspectors of hazardous refinery sites. Additionally, agents from the refining industry participated to help provide an industrial perspective and highlight the importance of their experience in this field. It was also clear that industry and qualified authorities were interested in improving the information exchange regarding safety problems and experiences, as well as seeking advanced solutions. In total, 7 industrial representatives from the UK Oil Industry Association, the Clean Air Council in Europe (CONCAWE), and the European Process Safety Centre attended.

Other invitees included representatives from operational forces, such as the General Union of Workers and Transport; and a board member from the US CSB (Chemical Safety Board). It was hoped that this event would assist European regulatory authorities in reaching a more enlightened perspective and connecting their work with their counterparts in member countries across Europe.

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