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Prevention of Catastrophic Incidents in Port and Hazardous Substance Storage Terminals by Implementation of Process Safety Management

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Abstract: *It has been observed worldwide that process safety management system is implemented in chemical process industries only. The nature and scale of risk associated with the large-scale and concentrated storage of bulk hazardous substances is ignored in earlier years. But incidents such as Buncefield in the UK in 2005 and the Caribbean Petroleum Refining explosion in 2009 illustrate the catastrophic consequences of a loss of containment and further damage to people, environment, asset and reputation of the organization and country. Occupational Safety and Health Administration's (OSHA) Process Safety Management (PSM) requirements are often exposed to this "check box" mentality. Process Safety Management (PSM) comprises the proactive identification, evaluation and prevention of loss of primary containment events in a chemical process due to any failure(s) in the Process, Procedure, Equipment, or Components. Simply put, it deals with the Loss of Primary Containment (LOPC) of Highly Hazardous Chemicals (HHC).*

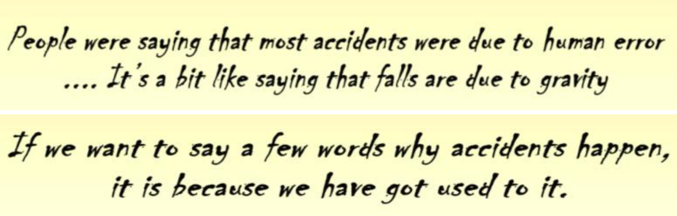
Keywords: Safety management

I. INTRODUCTION

Most accidents occur because we do not know how to prevent them but because we do not use the information that is available. The recommendations made after an accident are forgotten when the people involved have left the plant; the procedures they introduced are allowed to lapse, the equipment they installed is no longer used, and the accident happens again (Refer Figure 1 to 12). It is vital to assess the process and the risks involved properly to prevent incidents occurring in any Process facility.

1.1 WHY PSM IS IMPORTANT?

If we recall our past, between 1997 and 2013, there have been numerous incidents at storage facilities that have caused serious injuries and fatalities to employees.



People were saying that most accidents were due to human error
.... It's a bit like saying that falls are due to gravity

If we want to say a few words why accidents happen,
it is because we have got used to it.

- In 2013, a facility that stored and distributed compressed propane gas was largely destroyed by a series of fires and explosions. After receiving spent propane gas cylinders, employees would "bleed" any remaining gas into the air before the cylinders were cleaned and reused.
- In 2008, a nearly 90-year-old storage tank catastrophically failed and released approximately 2.1 million gallons of liquid fertilizer. The collapsing tank seriously injured two employees, and the chemicals flowed over containment berms. Investigators determined that defective welds likely caused the tank failure, and inspectors condemned another tank at the same facility that presented an "imminent danger" of failure.

- In 2005, a fire and subsequent explosion(s) destroyed a facility that stored and distributed compressed gas, and propelled debris and projectiles. The incident was traced back to propylene gas cylinders in the facility's storage area that were directly exposed to sunlight. High temperatures from the sunlight exposure increased cylinder pressure enough to cause flammable vapors to leak from the cylinders and catch fire. Heat from the initial fire caused other cylinders to leak gas. The fire spread throughout the storage area and eventually consumed nearly 8,000 cylinders of compressed gas.
- In 1997, three firefighters were killed by flying debris from an explosion in the storage area of a pesticide distribution facility. Investigators concluded that the explosion was most likely caused by a sack of thermally unstable material that had been placed too close to a hot compressor discharge pipe. The heat from the pipe caused the material to decompose and release flammable vapors, which eventually ignited and exploded. The investigators recommended that safety programs to review hazards should be implemented at all facilities that store, manufacture, handle, or use hazardous chemicals (EPA 1999).

II. INCIDENTS THAT DEFINE PROCESS SAFETY

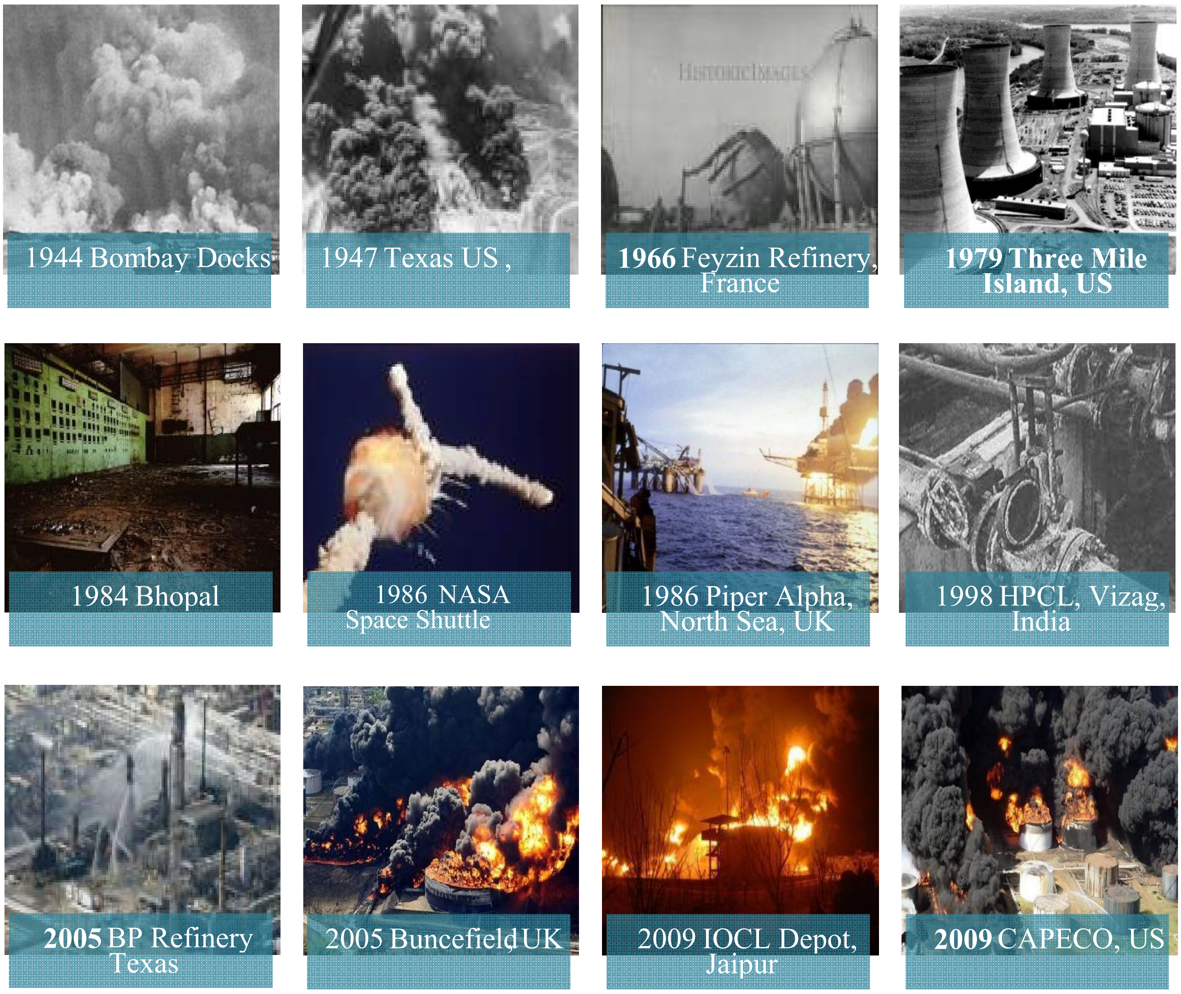

1944 Bombay Docks
1947 Texas US ,
1966 Feyzin Refinery, France
1979 Three Mile Island, US
1984 Bhopal
1986 NASA Space Shuttle
1986 Piper Alpha, North Sea, UK
1998 HPCL, Vizag, India
2005 BP Refinery Texas
2005 Buncefield UK
2009 IOCL Depot, Jaipur
2009 CAPECO, US

Figure-1 Chemical Process Incidents

III. LITERATURE REVIEW

This chapter provides an extensive review of the literature bordering process safety management in the oil and gas industry. Due to the extensive scope of this study, the literature review is divided into two chapters. Chapter two is geared towards providing a detailed overview of process safety management while chapter three examines the impacts of climate change on oil and gas operations. For this chapter, the first section gives a broad overview of process safety with regard to its underpinning concepts and principles. It also highlights the reasons that make process safety very important subject matter, as well as what it can offer as a discipline.

The next section gives an overview of the oil and gas industry in terms of its importance, activities, sectors and regions. It also discusses past, current and future trends and advancements in the oil and gas industry. The next section of this review analyses accident trends and causation factors in the oil and gas industry worldwide, with special attention given to accidents where multiple fatalities have occurred.

Next, human factors are discussed vis-à-vis process safety management in the oil and gas industry. Next, health and safety laws, regulations and standards in the oil and gas industry are examined. This includes health and safety regulatory frameworks in countries such as the USA, the UK, Norway and China. Afterwards, a detailed review of the current PSM systems, models and frameworks is carried out. It highlights the origin of these frameworks, the industries they are applicable to, their theoretical frameworks, their principles of application, their PSM elements and their advantages and drawbacks.

Key Definitions and Scope of the Variables

a. Accident: - "any unplanned event that resulted in injury or ill health of people, or damage or loss to property, plant, materials or the environment or a loss of business opportunity" (UKHSE 2013).

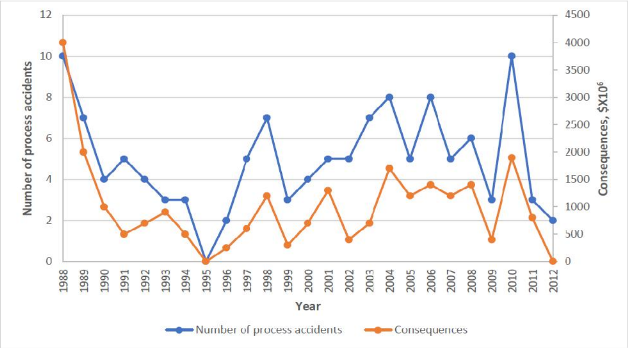
b. Process safety: - A professional discipline that involves managing the operational integrity of processes and systems (AIChE 2014).

c. Process safety management (PSM): - The combination of management and engineering skills to prevent dangerous substances like petroleum products and chemicals, as well as energy, from losing containment and causing toxic releases, fires, explosions, structural collapse and other catastrophic accidents (Energy Institute 2016).

Overview of Process Safety

There has been an increasing rate in the production, refining, distribution and storage of energy and chemicals due to continuous social and technological advancements (Mearns and Yule 2009). This has prompted an inevitable upsurge in the complex nature of processing plants, thus posing new hazards and risks that ought to be mitigated (Azadeh et al. 2015). However, Abdolhamidzadeh et al. (2011) suggested that process accidents have constantly increased over the years with various levels of severity.

Therefore, Mayotte et al. (2007) recommended that process safety research be inculcated as part of our everyday lives in order to aid the sustainable development of our environment. PSM incorporates several steps to ensure operational excellence and performance enhancement.



Accident trend analysis from 1988 to 2012 adapted from Khan et al. (2015)

Figure shows that over the last four decades, process accidents and their consequences have decreased on average. Arguably, better safety precautions, good management, weighty punitive measures, better regulations and workers' awareness, etc. are likely factors that are driving better process safety management, thus the downward trend in Figure in recent times (Aziz et al. 2014). However, there appear to be new safety threats from contemporary issues such as climate change impacting on oil and gas operations (Cruz 2010).

The process industry also cuts across sectors like agriculture and food processing (Hall and Howe 2012), mining (Wang et al. 2014), pharmaceuticals (Angel de la O Herrera et al. 2015), biotechnology (Calvo Olivares, Rivera and Núñez Mc Leod 2014), nuclear (Morrow, Kenneth Koves and Barnes 2014), energy (Pittiglio, Bragatto and Site 2014) and renewables (Casson Moreno et al. 2016).

This is one of the reasons why the oil and gas industry remains a major player in the process industry, especially in terms of process safety management. Most of the high profile accidents that have occurred in the process industry can be attributed to the oil and gas sector including the Flixborough disaster in 1974, the Alexander Kielland collapse in 1980, the Bhopal gas tragedy in 1984, the Piper Alpha disaster in 1988, the BP Texas refinery fire in 2005 and most recently the Deepwater Horizon blowout in 2010 (Ismail et al. 2014).

In order to establish a common ground between the benefits of the industry's products and the urgent need for safety in its operations, Khan et al. (2015) suggested that there needs to be a holistic process safety management system which will embody the process safety, financial, social, economic and sustainable aspects within its framework.

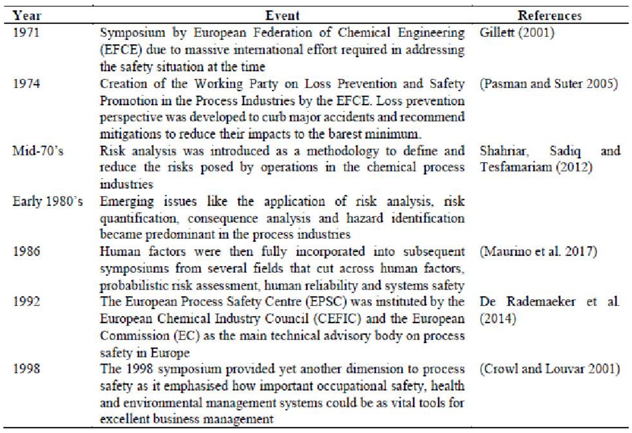
Therefore, the Integrated Process Safety Management System (IPSMS) model was designed by Theophilus et al. (2018) to incorporate various elements from different existing PSM models, systems and frameworks to form a more holistic model. However, this model is yet to be validated and tested in any sector of the process industry. Also as earlier mentioned, it fails to incorporate contemporary issues in the oil and gas industry such as impacts of climate change on oil and gas operations.

Past, Present and Future Trends of Process Safety

Past trends

The chemical process industry has witnessed a shift in interest towards intrinsically safer plants in the last decades, which has led to the development of the field known as process safety (Planas et al. 2014). Gillett (2001) traced the origins of process safety back to 1971, when motivated professionals from the European Federation of Chemical Engineering (EFCE) identified during a symposium in Newcastle upon Tyne that massive international effort was required in addressing the safety situation at the time.

Past trends of process safety



Year	Event	References
1971	Symposium by European Federation of Chemical Engineering (EFCE) due to massive international effort required in addressing the safety situation at the time	Gillett (2001)
1974	Creation of the Working Party on Loss Prevention and Safety Promotion in the Process Industries by the EFCE. Loss prevention perspective was developed to curb major accidents and recommend mitigations to reduce their impacts to the barest minimum.	(Pasman and Suter 2005)
Mid-70's	Risk analysis was introduced as a methodology to define and reduce the risks posed by operations in the chemical process industries	Shahriar, Sadiq and Tesfamariam (2012)
Early 1980's	Emerging issues like the application of risk analysis, risk quantification, consequence analysis and hazard identification became predominant in the process industries	
1986	Human factors were then fully incorporated into subsequent symposiums from several fields that cut across human factors, probabilistic risk assessment, human reliability and systems safety	(Maurino et al. 2017)
1992	The European Process Safety Centre (EPSC) was instituted by the European Chemical Industry Council (CEFIC) and the European Commission (EC) as the main technical advisory body on process safety in Europe	De Rademaeker et al. (2014)
1998	The 1998 symposium provided yet another dimension to process safety as it emphasised how important occupational safety, health and environmental management systems could be as vital tools for excellent business management	(Crowl and Louvar 2001)

Similarly, Pasman and Suter (2005) identified these topics to have emerged from the lessons learned in the 1960's which indicated that conditions leading to accidents were complex, testing techniques were insufficient, impacts of accidents were underrated and there was no system approach for preventing them. However, De Rademaeker et al. (2014) suggested that it was viewed by some parties as a profit-making scheme as opposed to being a tool for damage and loss control. Likewise, Hendershot (2009) asserted that this view was strengthened by the occurrence of the Flixborough disaster just two days after the Delft symposium; thus reiterating failures in process safety measures at the time. After this period, there has been massive attendance witnessed in process safety symposiums both from academia and industry (Bridges and Tew 2010). However, De Rademaeker et al. (2014) stressed that this figure has decreased in recent times due to funding cuts and economic reasons.

In 1986, human factors were then fully incorporated into subsequent symposiums from several fields that cut across human factors, probabilistic risk assessment, human reliability and systems safety (Maurino et al. 2017). Mearns et al. (2001) highlighted various aspects that were considered such as performance measurement, operational discipline, adequate information and communication, training, drugs and alcohol, stress, procedures and instructions, crew resource management, environment and social climate, as well as motivation.

In 1992, the European Process Safety Centre (EPSC) was instituted by the European Chemical Industry Council (CEFIC) and the European Commission (EC) as the main technical advisory body on process safety in Europe (Pasman and Suter 2005). The EPSC (2018) is predominantly involved in the planning and implementation of process safety results from conferences and publications etc.

Likewise, Sklet (2006) confirmed that safety instrumented systems and the recent IEC 61511 standard were rolled out as reliable foundations for process protective structures. A more technical viewpoint also saw more innovations like the Markov models, fault trees and reliability block diagrams as breakthrough advancements that could be useful in evaluating the safety integrity levels (SIL) of complex systems and their components, failure modes and rates (Distefano and Puliafito 2007).

Present Trends

De Rademaeker et al. (2014) suggested that the 21st century has offered a more dynamic approach to loss prevention through the incorporation of social, economic and ecological factors into design criteria to ensure sustainable development. The Layer of Protection Analysis (LOPA) was introduced to the EPSC during the late 1990s as a basic tool for risk assessment (Wasileski and Henselwood 2011).

However, more recent years have seen improvements in the Information Technology (IT) industry with regard to process safety, where there has been an integration of electronic permit-to-work systems and computer-aided design (CAD) systems with safety application tools (Dimian and Bildea 2008).

Another method suggested by Dekker (2016) is the just culture approach which is an inherent method of promoting an inquisitive attitude, immunity to complacency, dedication to excellence and merging corporate self-regulation and personal accountability in process safety issues.

However, some bottlenecks have been identified in successful process safety implementation including the urgent need for better solutions, a lack of communication, increased complexity of process operations, no emphasis on leading indicators and failing to learn from past experience (Mohd Shariff, Abdul Aziz and Abdul Majid 2016). Consequently, resilience engineering has been suggested as a vital management and analytical tool for coping better with unstable process states and avoiding unsafe conditions (Azadeh et al. 2014).

There were some new topics added for discussion during the 14th EFCE LP symposium as shown in Table 2.2. These new topics cut across various aspects like suitable process safety indicators and metrics, the role of top management in internal safety communications, public accountability, a blame-free culture, differences in personnel and process safety, long-term sustainability, the relationship between safety and economics, as well as safety and customer perception (De Rademaeker et al. 2014).

IV. FUTURE TRENDS

Further into the 21st century, there have been several attempts to make progress in methods, approaches and concepts in process safety (Knegtering and Pasman 2009). However, Vidal et al. (2004) argued that this progress can only come about through in-depth research; where one of such postulations was made in the Process Safety Research Agenda for the 21st century by a group of professors in the Department of Chemical Engineering, Texas A&M University.

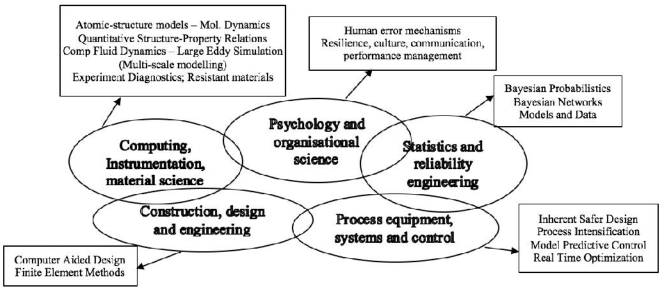
De Rademaeker et al. (2014) further stressed that Chemical Engineering students in various universities and research institutes were only encouraged to write safety reports and put on personal protective equipment in the laboratory, without properly educating them on the intricacies of process safety. Due to these factors, coupled with the numerous process accidents investigated by the U.S. Chemical Safety Board (CSB), the curriculum requirements for chemical engineering has been modified by the U.S. Accreditation Board of Engineering and Technology (London 2013).

Students were also required from 2012 to have in-depth knowledge of the operations of chemical process equipment, both technically and in regulatory terms, to conform to environmental, safety and health regulations (ABET 2014). Fischhoff (2013) stressed that despite the fulfilment of global needs provided by process industry products, there still remains a low level of tolerance for acute risks posed to the environment, as well as increasing rates of injuries and fatalities.

Key areas covered in the Process Safety Research Agenda for the 21st century adapted from De Rademaeker et al. (2014)

1. Natural hazard triggering technological disasters (NaTech)
2. Application of process safety to drilling operations
3. Easy-to-implement process safety methods for industry
4. Integration of databases for process safety improvement
5. Standardization of process safety standards
6. Process safety management knowledge: transfer, improved access, dissemination
7. Life cycle/maintenance
8. Safety technologies, layers of protection and migration systems
9. Mechanism to import process safety into emerging technologies
10. Safety culture
11. Organisational/human factors: difference between people and technology
12. Integration of occupational safety with process safety
13. Resilience engineering
14. Complex systems
15. Critical infrastructure protection
16. Consequence analysis
17. Risk management
18. Inherently safer design
19. Hazardous phenomena

Due to the complex nature of systems that have been introduced in the process industry and the challenges they pose to engineers, Venkatasubramanian (2011) suggested that systems-thinking should be given more attention as the yardstick for assessing a chemical engineer's competence. During the 8th European Congress of Chemical Engineering held in Berlin in 2011, it was also identified that research efforts and process safety lessons were in rapid decline in Europe (Murray 2015). However, there have been significant advancements in engineering and science with regard to process safety as seen in Figure 2.2. For example, in areas like Belgium, KU Leuven has established many chairs in areas of process safety, including several process safety advancements in Delft, the Netherlands (De Rademaeker et al. 2014).



Future trends in process safety adapted from De Rademaeker et al. (2014)

Due to the shift in problems in the process industry arising from complex systems, wrong diagnoses of abnormal conditions and failures in risk management, Qureshi (2008) suggested that a more holistic approach was required to address the system as a whole from both the technical and organisational aspects. This is supported by Pitblado and Nelson (2013), who opined that barrier management was critical in effective process safety management. From a psychologist's perspective, Reason (2000) in the early 90s provided a Swiss Cheese model for human error and accident causation. This innovation was highly welcomed, as the increase in complexity of installations and cost-cutting by management led to the installation and automation of SIS integrated with safety culture promotion, performance indicators and safety management (Olive, O'Connor and Mannan 2006).

The Efficiency-Thoroughness Trade-Off (ETTO) was also introduced to increase efficiency by balancing time constraint factors with various decision-making scenarios in order to come up with various consequences (Hollnagel and Woods 2006).

Another strong point is the fact that from a technical perspective, causation could become less clear, just like a structural fracture at a molecular level, which reemphasises the need for resilience engineering as an adequate, timely and flexible risk-control measure that would tackle both technical and organisational factors (De Rademaeker et al. 2014). Hollnagel (2002) also recommended that the level of effectiveness for accident prevention is dependent on how early the underlying causal factors are detected.

In order to keep a system's hazards and their safety limitations within a safe region, the STPA identified the necessary risk controls, their time-frame for application, their hierarchy and their duration (De Rademaeker et al. 2014). Its application encompasses the organisational and technical structure of a process plant from design, operation, regulation and inspection (Abdulkhaleq and Wagner 2014).

The Bayesian Network (BN) has also been earmarked as a very important tool for designing models that simulate cause-effect relationships (Cai et al. 2013). After formulating a causal network, the BN uses fuzzy, probabilistic and deterministic quantity values, as well as empirical data and physical connections, for diagnostic and predictive analysis while also monitoring any uncertainties (García-Herrero et al. 2013).

Overview of the Oil and Gas Industry

The past decade has witnessed a significant increase in global energy demand, with USEIA (2017) projecting a 28% increase in world energy use between 2015 and 2040. The fastest-growing energy source is believed to be renewables with an estimated projection of 2.8% increase annually (Mustapa, Peng and Hashim 2010).

There are three major sectors within the oil and gas industry where these activities are carried out, which are the upstream, midstream and downstream sectors (Shuen, Feiler and Teece 2014). Integrated oil and gas companies such as Chevron Texaco, Royal Dutch Shell and ExxonMobil combine the activities of the upstream, midstream and downstream sectors (Spence 2011).

Other companies that are involved in oil and gas activities include equipment manufacturers and security companies that safeguard the assets and products within the industry (Aigboduwa and Oisamoje 2013). These various categories of oil and gas companies work together to ensure the smooth running of operations and activities within all sectors of the industry (Shuen, Feiler and Teece 2014).

However, Nkwocha (2014) opined that multinational oil and gas companies operating in developing countries have failed to comply with international process safety standards as they would normally do when operating in countries with effective process safety regulations. However, the BP Deepwater Horizon disaster and the BP Texas City refinery explosion offer a different viewpoint in that they occurred in the UK and the USA; two countries with the best process safety regulations (Ismail et al. 2014). Notwithstanding, Tombs and Whyte (2013) argued that companies who perpetrate acts of negligence leading to accidents in countries such as the UK and the USA are more likely to face the full consequences from criminal and civil perspectives as opposed to developing countries. This is buttressed by the BP Deepwater Horizon disaster where BP has had civil fines of over $60 billion to date (Theophilus et al. 2018).

Overview of Models of Accident Causation

Several models have been developed in order to understand the causal factors of accidents, as Hosseinian and Torghabeh (2012) have suggested that this is the first step to accident prevention or mitigation. However, Al-Shanini et al. (2014) argued that accidents were triggered by certain factors despite their minor or major scenarios and there was no such phenomenon as an accidental accident. Lund and Aarø (2004) asserted that a combination of failures would lead to an accident, while Kujath et al. (2010) highlighted the interactive and multifaceted nature of accident causal factors. Accident causation models have promulgated over the years and have been updated according to the increasing complexity of risks in various industries.

Human Factors and Process Safety Management

The interaction of psychological, situational and behavioural factors are evidently highlighted in accident causation models (Meghann 2016). Human factors are defined as the relationships between people, together with environmental, organisational and job factors which negatively affect work behaviour and undermine safety (Al-Shanini, Ahmad and Khan 2014). Similarly, Olive et al. (2006) portrayed human factors as an embodiment of psychological, behavioural, organisational, technical, environmental and job factors. Therefore, this provides a basis for designing a PSM system that can address each of these factors in order to enhance process safety.

Nonetheless, Norazahar et al. (2014) opined that accidents were mostly triggered by more than one causal factor but that some studies might tend to place emphasis on particular factors. Deacon et al. (2013) buttressed this claim by asserting that human error was commonly evident in most offshore accidents. Similarly, Cai et al. (2013) reiterated that human factors were present in most fatal offshore accidents irrespective of the other causal factors associated with them.

Bridges and Tew (2010) stressed that human factors were not adequately addressed by existing PSM frameworks, as seen in Table 2.7. Following the BP Texas refinery fire in 2005, the US Chemical Safety Board (CSB) urged that more attention should be given to human factors by the US OSHA (Murray 2015). The human factors that caused the fire and explosion included worker fatigue, no chain of command, poor ergonomics, poor operating procedures and a lack of communication when handing over shifts (Holmstrom et al. 2006).

Norway

The safety regulations in Norway are broadly divided into health, safety and environmental (HSE) regulations, as well as working environment regulations (PSA 2017). The HSE regulations aid in specifying and integrating HSE regulations in offshore and onshore oil and gas facilities, which are enforced by various regulatory authorities (Mendes et al. 2014). The Ministry of Labour issues various regulations under the Norwegian Working Environment Act which are enforced by the Norwegian Labour Inspection Authority (Hunter 2014). Table 2.10 shows the HSE and Working Environment regulations that have been instituted in the Norwegian oil and gas industry.

China

Countries like China have taken process safety on board by adjusting their legislative and regulatory framework by enacting the Work Safety Law in 2002 which emphasises key issues like record keeping, investigations, inspections, as well as the responsibilities of employers and employees (Zhao, Suikkanen and Wood 2014). They also used the C174 – Prevention of Major Industrial Accidents Convention to make their National Standard on the Identification of Major Hazard Installations in 2000 (Shi et al. 2008). The State Administration of Work Safety (SAWS) in China also released their pioneer PSM regulation in line with OSHA's PSM standard which addresses processes using hazardous chemicals (Zhao et al. 2013).

However, it is argued that these CIPs could lead to more catastrophes in the event of an accident due to the domino effects that may arise from the cluster of chemical companies within the same area (Zhao, Suikkanen and Wood 2014). Consequently, experts from the United Nations Environmental Programme (UNEP) have provided specialist training on emergency drills and risk identification methods to all occupants of a CIP (Zongqin 2004).

V. PROCESS SAFETY MANAGEMENT & ITS ELEMENTS

Process Safety is a disciplined framework for managing the integrity of hazardous operating systems and processes by applying good design principles, engineering, and operating and maintenance practices.

It deals with the prevention and control of events that have the potential to release hazardous materials or energy. Such events can cause toxic effects, fire or explosion and could ultimately result in serious injuries, property damage, lost production, and environmental impact.

Knowledge and Operational Control

1. Process Safety Information (PSI)
2. Operating Procedures (OP)
3. Hot Work Permit (HWP) – part of Safe Work Practices (SWP)
4. Training (TRG)
5. Contractor Safety Management (CSM)

Hazard Identification and Control

6. Process Hazard Analysis (PHA)
7. Management of Change (MOC)
8. Pre-Startup Safety Review (PSSR)
9. Mechanical Integrity (MI)
10. Compliance Audits (CA)

Incidents and Learnings

11. Emergency Response and Planning (ERP)

12. Incident Investigations (II)
13. Employee Participation (EP)
14. Trade Secret Protection

VI. PROCESS SAFETY ELEMENTS

14 Elements of a Process Safety Management Program

OSHA request that employers have a process safety management system in place that follows these 14 rules and practices:

1. Process Safety Information

Prior to conducting any process hazard analysis, employers are required by OSHA to develop a compilation of written PSM safety topics. This will help the employer and employees to understand the potential hazards of working with highly hazardous chemicals.

Information regarding the highly hazardous chemicals in a process must consist of the following:

- Permissible exposure limits
- Toxicity
- Reactivity data
- Corrosivity data
- Physical data
- Thermal and chemical stability data
- Hazardous effects of inadvertent mixing of different materials

Operating Procedure

Employers must establish and execute written operating procedures and tasks with clear instructions that reflect current practices. Instructions should emphasize hazards, health considerations, operating limitations, safety practices and special circumstances. These operating procedures must be up to date and readily available to employees involved in all covered processes.

Employee Participation

OSHA requires employers to consult with employees and employee representatives regarding the development of process hazard analyses and other elements of process management. They must also provide employees and their representatives with access to process hazard analyses as well as all relevant information. Worksite employees and contractor employees are included in this standard.

Learn how safety incentive programs can also improve employee participation in workplace safety practices.

Process Safety Management Training

OSHA mandates training for employees responsible for operating covered processes. The training should emphasize safety and health hazards, emergency operations and best work practices. Initial OSHA PSM training must be completed prior to starting the assignment. Refresher training should be completed at least once every three years.

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Contractor Training

OSHA requires contract employers to provide information and train their employees how to safely perform their jobs. Contract employers are responsible for confirming that their employees received training, are aware of potential process hazards, understand emergency action plans, are familiar with facility safety rules, and know to advise employers of any hazards. This includes contract employees on or near covered processes involved in maintenance, repair, turnaround, renovation, or specialty work.

Pre-Startup Safety Review

OSHA mandates a safety review for modified work sites and new facilities for the following reasons:

- To verify that equipment and construction are in accordance with design specifications
- To confirm that proper safety, maintenance, operating and emergency procedures are in place
- To assure that process operator training has been successfully completed

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Mechanical Integrity

OSHA requires on-site employers to develop and implement written procedures regarding the ongoing integrity of critical process equipment in the workplace. This ensures all equipment is properly designed, installed, and operating.

These PSM requirements apply to the following components and equipment:

- Piping systems (including components, valves)
- Pressure vessels and storage tanks
- Relief and vent systems and devices
- Controls (monitoring devices, alarms, sensors, interlocks)
- Emergency shutdown systems
- Pumps

Hot Work Permits

A permit must be kept on file for operations conducted on or near covered processes. The hot work permit must prove that fire prevention requirements were met prior to the beginning of operations. In addition, the permit must specify authorized work dates and location details. See how fire watch training and welding safety requirements are crafted to protect your workers while performing hot work.

Management of Change Process

Written procedures must be put in place to manage changes to process chemicals, equipment, technology, procedures, and facility processes. Work site employers and contract employers are required to train and inform employees of the changes prior to start-up. These procedures must be updated as necessary.

This management of change (MOC) process must confirm that the following considerations are addressed:

- The change’s impact on employee safety and health
- The technical basis for a proposed change
- Modifications to current operating procedures

Incident Investigation/Accident Investigation

Employers are required to investigate every incident in the workplace that resulted in or could have resulted in a catastrophic accident. The investigation should take place as soon as possible, and no later than 48 hours prior to the incident. A knowledgeable and experienced investigation team should analyze findings and write a report on the incident for operating personnel to review and make modifications as needed. All reports must be kept on file for at least 5 years.

Emergency Planning and Emergency Response

OSHA requires employers to have an emergency action plan and training for employees. In the event of an emergency, the entire plant should be prepared to handle hazardous chemical releases as well as follow other OSHA provisions.

Safety Compliance Audits

Employers are required to conduct a process safety management audit at least once every three years. These audits will confirm that the practices and procedures developed under the standard are satisfactory and are being followed.

Trade Secret Protection

Employers must comply with PSM by making all necessary information available to the following employees and representatives:

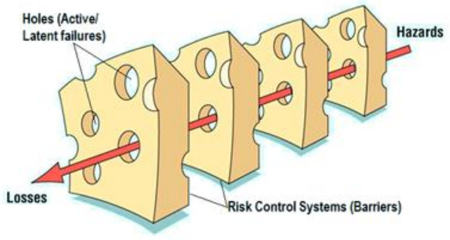
- Those performing compliance audits
- Those performing incident investigations
- Those developing process hazard analysis

VII. GUIDELINES FOR MONITORING PROCESS SAFETY PERFORMANCE:

Based on incidents – internal and external - refer Esso Longford (1998), BP Texas (2005) [17], Buncefield (2005) [16], BP Deepwater Horizon (2010) - it was realized that 'what is not measured cannot be improved'. Conforming to the management systems, it was important to have metrics in place to understand how effectively the PSM system was working to deliver its objective. This guideline identifies the areas monitored under process safety and provides measureable parameters/ metrics [termed "Process Safety Performance Indicators" (PSPIs)] for these areas to sustain and develop the PSM system at the industry.

Swiss-Cheese Model

One of the premier models used to represent event causation, the "Swiss cheese" model, was developed by Dr. James Reason, who is world renowned for his work in looking at how conditions in individual organizations contribute to accidents. Process Safety Incidents are generally caused by multiple events or failures that are active at the same time. This is better understood using the Swiss-Cheese Model, which shows an 'accident trajectory' passing through corresponding holes in multiple Risk Control Systems (barriers or layers of protection). Each Risk Control System represents an important barrier or safeguard within the Process Safety Management system, and a significant failure in even one of these may lead to a major accident.

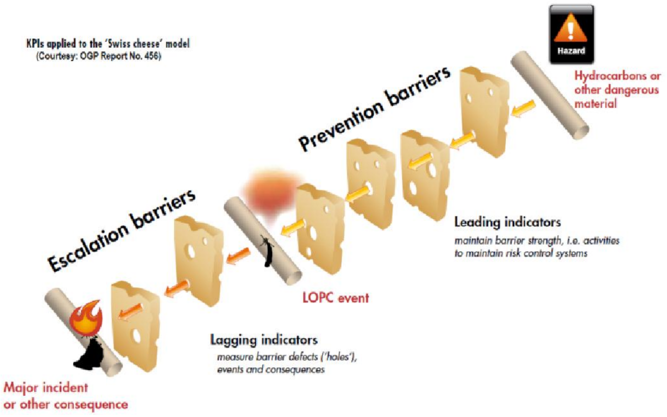


Representation of James Reason's Swiss Cheese Model

Reason describes two types of conditions in an organization that contribute to loss: active failures and latent failures. Active failures are unsafe acts committed by people who are in direct contact with the system and consist of slips, lapses, mistakes, procedural violations, etc. Latent failures are pre-existing conditions that can lie dormant in the system for many years before they combine with active failures to create an accident opportunity.

Leading indicators are a form of active monitoring focused on a few critical risk control systems/ barriers to ensure their continued effectiveness. Leading indicators require a routine systematic check that key actions or activities are undertaken as intended. They can be considered as measures of process or inputs essential to deliver the desired safety outcome.

Lagging indicators are a form of reactive monitoring requiring the reporting and investigation of specific incidents and events to discover weaknesses in that system. These incidents or events do not have to result in major damage or injury or even a loss of containment, providing that they represent a failure of a significant control system which guards against or limits the consequences of a major incident. Lagging indicators show when a desired safety outcome has failed, or has not been achieved.



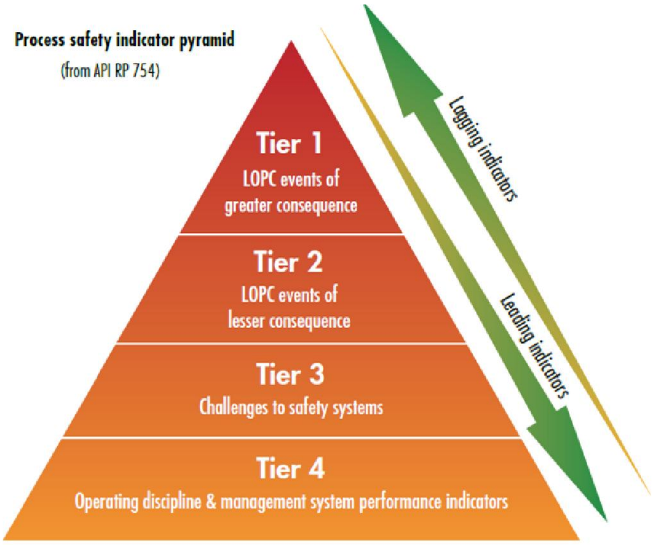
Leading and Lagging Performance Indicators relating to Risk Control Systems (Source: OGP [6])

VIII. PROCESS SAFETY INDICATOR PYRAMID

H. W. Heinrich instituted the Accident Pyramid based on his experience with the Insurance Industry in the early 1930s. This pyramid promoted two key concepts, viz.

a. safety incidents can be placed on a scale that represents the magnitude of their consequence;

b. many precursors/ lower consequence events occurred before an event of higher consequence.



API Process Safety Performance Pyramid (Source: OGP, API [1])

It is important to note that the scope of the Indicators differs at different levels within and out of the organization, as the impetus and drive provided at every level should be based on relevant inputs. Performance can be monitored at a number of organizational levels within a business and the information can be presented in a hierarchical manner. The nature of the indicators will vary depending upon the organizational level at which they have been set [5]. A summary of the Process Safety Performance Indicators (PSPI) monitored at the Top Management-levels could be found in Section 7.0. This should be used as a basis for creating Performance Indicators at the individual Process Unit-level (cascaded from top).

PRINCIPLES AND GENERAL RECOMMENDATIONS PRINCIPLES

1. Governments should provide leadership and create suitable administrative frameworks to facilitate the safety of oil terminals at all of their life-cycle stages.
2. The operators of oil terminals have the primary responsibility for ensuring the operational and process safety of oil terminals and the personal health of the operating staff.
3. Competent authorities should introduce and enforce adequate measures to ensure that the operators are committed to safety.
4. Appropriate measures should be taken in case of accidents. Emergency plans should be established by oil terminal operators (internal emergency plans) and by authorities (external emergency plans), and these should be compatible and regularly tested and updated. The plans should include descriptions of the easures necessary to control accidents and limit their consequences for human health and the environment.
5. For oil terminals that pose a potential risk to neighbouring countries, the concerned ECE member countries should inform each other of their emergency plans, endeavour to make such plans compatible and, where appropriate, should draw up joint off-site emergency plans. This is in accordance with the provisions of the Industrial Accidents Convention, which requires Parties to: (a) notify potentially affected Parties of hazardous activities (art. 4); (b) inform each other of their contingency plans (art. 8); and (c) to draw up, where appropriate, joint contingency plans to facilitate joint response (art. 8).
6. For oil terminals that pose a potential risk to neighbouring communities and land users due to their size or the presence of hazardous substances, the provision of information to and involvement of these communities and land users should be ensured for the purpose of drawing up an off-site emergency plan.
7. For the siting and intended post-operational land use of new major oil terminals, as well as proposed significant developments around existing oil terminals, the provisions of article 7 of the Industrial Accidents Convention have to be applied. It is important to ensure that the public is given an early and effective opportunity to participate in the decision-making relating to such developments that can potentially have significant adverse effects. The provisions of the 1998 ECE Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters and the 1992 ECE Convention on Environmental Impact Assessment in a Transboundary Context (Espoo Convention) should be also taken into account.
8. Regular exchange of information between oil terminal operators, authorities and relevant stakeholders (e.g., land-use planners, industry associations and chambers of commerce) regarding good practices, the improvement of oil terminal safety, past accidents and near misses should be ensured. 1.1.

GENERAL RECOMMENDATIONS

9. These Safety Guidelines and Good Industry Practices for Oil Terminals contain recommendations for the competent authorities and oil terminal operators in ECE member countries, as well as and key elements for taking action, in order to ensure a basic level of safety at oil terminals.
10. For the Parties to the ECE Industrial Accidents Convention, including the EU, the need to take actions can be derived from their obligations under the Convention as well as from national legislation, which generally includes a “General Duty Clause”, ensuring that owners/operators of hazardous installations have the responsibility for the safe operation of their installations.
11. When using these guidelines, competent authorities and operators should ensure that national requirements are met, taking into account efforts already made at the international level to avoid unnecessary duplication.
12. These guidelines should also be read in the context of existing international guidance, recommendations and standards concerning oil terminals. These guidelines constitute a minimum set of good industry practices to ensure a

basic level of safety for oil terminals. Alternative approaches, by applying different policies, measures and methodologies, are possible, provided they achieve a comparable level of safety.

13. Recommendations to the ECE member countries, competent authorities and oil terminal operators are set out in the following paragraphs.

14. ECE member countries should develop and implement policies and strategies to reduce the risks of accidents and improve preventive, preparedness and response measures in oil terminals.

15. ECE member countries should encourage oil terminal operators to demonstrate the oil terminal safety as part of the application for an oil terminal operating permit or similar arrangements. They should encourage operators to complement the oil terminal operating permit with a financial security or any other equivalent, on the basis of arrangements to be decided by the member countries, in order to ensure that all obligations arising under any permit issued, including closure and post-closure requirements, as well as any other obligations, can be met. This should include, e.g., insurance to allow proper settlement of any costs associated with an accident.

16. ECE member countries should adopt policies for the safety of oil terminals, including the safe transport, transhipment and storage of hazardous substances, aimed at limiting accidental consequences for human health and the environment. They should raise awareness and share experience and good practices through educational programmes and other means.

17. National legislation should be clear, enforceable and consistent with the requirements of the Industrial Accidents Convention in order to facilitate international cooperation on industrial safety, for example, in the development and implementation of external emergency plans.

18. ECE member countries should encourage the setting up of policies on insurance, civil liability and compensation for damage caused by the local and/or transboundary effects of industrial accidents. The ECE Protocol on Civil Liability and Compensation for Damage Caused by the Tran boundary Effects of Industrial Accidents on Transboundary Waters (Protocol on Civil Liability)3 may be used as a reference.

19. ECE member countries should establish a system of controls and land-use planning procedures with the involvement of the public.

20. National laws, regulations, policies and practices should take into account all the relevant stakeholders involved and should be consistent with international agreements and recommendations.

21. In accordance with article 17 of the Industrial Accidents Convention, competent authorities should be designated at the national, regional or local level that, alone or together with other authorities, have the necessary competences to ensure adequate monitoring and control of oil terminals. The independence and objectivity of the competent authorities should be ensured.

22. ECE member countries should ensure that the competent authorities are legally empowered and adequately resourced to be capable of taking effective, proportionate and transparent enforcement action, including, where appropriate, the shut-down of operations in cases of unsatisfactory safety performance and environmental protection by operators and owners.

23. ECE member countries should establish a system to ensure that information about incidents is evaluated at the national level to follow up on lessons learned.

24. ECE member countries should encourage and expect operators and owners, in following good practices, to establish effective, cooperative relationships with the competent authority, supporting best regulatory practice by the competent authority, and to proactively ensure the highest levels of safety, including, where necessary, suspending operations without the competent authority needing to intervene.

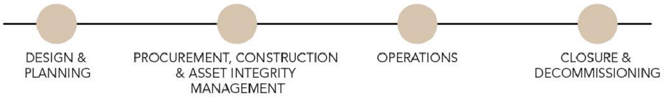
25. Competent authorities should maintain within their organizations expertise
relating to:
(a) Accident prevention, emergency preparedness and response;
(b) Inspection and audit;
(c) Permitting requirements for operation of the oil terminal.

IX. EXPERIMENT

Process Safety is the execution of Engineering, Operational, and Management activities focused on preventing catastrophic incidents associated with the hazardous chemicals involved in the process, such as fires, explosions, and/ or toxic releases. As such, it is a disciplined framework for managing the integrity of hazardous operating systems and processes by applying good design principles, engineering, and operating/ maintenance practicesnd processes.

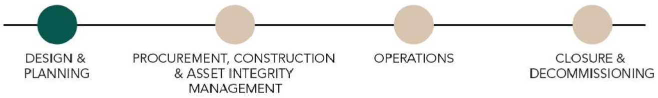
Process Safety Management (PSM) comprises the proactive identification, evaluation and prevention of loss of primary containment events in a chemical process due to any failure(s) in the Process, Procedure, Equipment, or Components. Simply put, it deals with the Loss of Primary Containment (LOPC) of Highly Hazardous Chemicals (HHC).The importance of Process Safety was underlined by a spate of chemical disasters around the world, and the IMC Integrated Management Systems took note to include Process Safety Management in its framework for managing chemical process safety risks.

Technical and organizational aspects of safety should be taken into account throughout the whole life cycle of oil terminals. This document covers the safety elements and activities to be addressed during the whole life cycle of an oil terminal: design and planning; procurement, construction and asset integrity management; operations; and closure and decommissioning.



Experiences from past industrial accidents should be integrated in all stages of the life cycle through an efficient feedback mechanism. he obligations for competent authorities are more general and are reflected already in the previous recommendations of part 1. The primary responsibility for safe operation of an oil terminal is with the operator. The following safety guidelines pertaining to technical and organizational aspects of the safety of oil terminals concentrate on the operator's duties.

1. DESIGN AND PLANNING



Industrial facilities' safety fundamentals and best operational practices are established during the design and planning stage. For facilities engaged in the manufacture, storage or transport of hazardous substances the whole scope of safety issues are the most important consideration. In most cases, oil terminals are classified as such facilities.

During the design and planning stage, there is an opportunity to foresee the location of all site components and, taking into account essential safety regulations and the operational experience (positive and negative) of similar facilities, to propose the best and the most secure technologies and equipment.

Design should comply with national standards, if available. In any case, the design of oil terminals should be conducted using good industrial sector methods and practices.

Design and planning stage results should be documented, and go through the required monitoring procedures controlled by the oil terminal operator and the inspection authorities, in accordance with the national standards.

ENVIRONMENTAL BASELINE

For new oil terminals, an environmental baseline condition should be established by the oil terminal operator and submitted to the competent authority, as part of the operating permit application. The baseline report should contain the information necessary to determine the state of soil and groundwater contamination, so as to make a quantified comparison with the expected state upon definitive cessation of activities (decommissioning).

ENVIRONMENTAL IMPACT ASSESSMENT

An environmental impact assessment (EIA) should be a precondition for the construction and operation of an oil terminal, or making major changes to the facilities at or operation of an existing oil terminal, if applicable according to the existing international and national legislation.4 The EIA should address the potential adverse impact of the oil terminal on the physical and social environment, in particular the aquatic environment. The general public and interested or affected persons should be able to comment and provide input to the EIA and also to comment on or object to the construction and operation of the terminal.

FACILITY SITING AND LAY-OUT

In the oil terminal design and planning stage, site-selection decisions should take into account the risk of exposing human populations and vulnerable habitats to the hazards of toxic and flammable materials. The consequences of "credible worst case scenarios" need to be considered during the conceptual basic engineering phase, before a large commitment has been made to a specific site location. The following parameters should be taken into account by the investor/future oil terminal operator:

(a) General lay-out of the facility: Is there an adequate buffer zone (safety distance) between the oil terminal and vulnerable habitats, populations or public facilities?;
(b) Domino effects: Are there nearby sources (equipment or installations) that could threaten the entire site by potential "domino effects"?;
(c) Containment considerations: secondary and tertiary;

LAND-USE PLANNING

For new oil terminals, the competent authorities have to take into account appropriate safety distances from transport routes, the locations of public-use and residential areas and areas of natural sensitivity or interest (vulnerable areas). If there is an accident, these distances should limit the consequences for human ealth and the environment to an acceptable level.

For existing oil terminals, the competent authorities have to consider relevant technical and/or management measures for those establishments in or close to vulnerable areas or other economic activities that involve hazardous substances.

SAFE DESIGN

Where they exist, national standards for equipment design and operation should be implemented and be the subject of inspection by the oil terminal operator and the competent authority. Wherever possible, the design of equipment within an oil terminal should be to GIP and incorporate learning from relevant incidents (e.g., the Bunce field Oil Terminal Fire and Explosion — see part 3).

Control room design and ergonomics, as well as effective alarm systems, are vital to allow front-line staff, particularly control room operators, to reliably detect, diagnose and respond to potential incidents. Key aspects for the design and operation of equipment related to hazard detection, control and response that have to be taken into account at three levels of protection (primary, secondary and tertiary) are set out in the subsections below.

HAZARD MANAGEMENT

The term "hazard management" refers to the process of hazard identification and risk assessment (HIRA), risk ranking and further controlling or reducing risks to acceptable or tolerable levels. Hazard management should be taken into account in the design and planning stage and all other stages of the life cycle of the oil terminal by the oil terminal investor, operator and all other key stakeholders, as appropriate.

In these guidelines the assumption is that the majority of oil terminals are hazardous activities with the potential to cause a major accident owing to the quantities of hazardous substances (as specified in annex I of the Convention) present on site.

EMERGENCY PLANNING

Potential emergency situations, including accidents with large-scale impact, exist during all life-cycle stages of a complex industrial facility. The best and the most non-hazardous technologies and equipment selection during the design and planning stage, a sound safety culture and a systems approach to process safety management, together, reduce the potential for a major accident, but do not exclude it completely. Therefore it is necessary to be prepared for the maximum credible worst case scenario.

EMERGENCY PLANS — GENERAL

Emergency plans for oil terminals need to be established before the competent authorities give permission for their construction, operation or closure. Such plans should be drawn up within the time frames set by local or international rules.

Emergency plans should be established and tested by the oil terminal operator (internal plans) and by competent authorities (external plans). Eventually, upon the request of the competent authorities, they should be tested together, to verify their interrelationships and interdependencies.

Emergency plans should be reviewed and updated when needed or where relevant, but at least every five years. At a minimum, reviewing and updating should also be considered in the following situations:

(a) After the occurrence of accidents or emergency situations at the site or following the issuance of lessons learned from accidents at other similar sites;

(b) When the structure of any of the emergency services has changed;

(c) When new hazards are identified that are associated with the oil terminal;

(d) When new technical knowledge or new technology is being developed that is considered relevant to the operation of the oil terminal;

INTERNAL EMERGENCY PLANS

Internal emergency plans should be part of the operating manual. The internal emergency plan, specific to each site and situation, should be developed and continuously revised.

Plans for notification of key personnel and the public should be an integral part of the emergency plan and should be prepared for both slow and rapid aggravating developments as well as instantaneous failure conditions.

In addition to the generic information set out in section 1.5.1, at a minimum internal emergency plans should include/address:

(a) The names and/or positions and contact data of persons in charge of liaising with the competent authorities in charge of the external emergency plan;

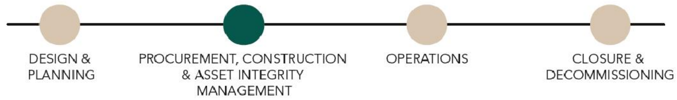
(b) Arrangements and devices for outgoing communications (initiating and activating the alert and call-out procedures) and for incoming communications (receiving warnings of incidents that have occurred);

EXTERNAL EMERGENCY PLANS

External emergency plans are prepared and implemented by the competent authority. Oil terminal operators are obliged to provide the authorities with all the necessary information concerning the potentially affected area and the potential impact of any accident on human health and the environment for the competent authorities to prepare the external emergency plan. The public should be given the opportunity to participate in the preparation and revision of the external emergency plans.

It should be also ensured that in border areas the contingency plans of the border regions of neighboring countries are compatible with each other and include contact details to allow proper notification. The public of neighboring countries should be given the same rights as the public of the country concerned to participate in the preparation and revision of external emergency plans.

2. PROCUREMENT, CONSTRUCTION AND ASSET INTEGRITY MANAGEMENT



ASSET INTEGRITY AND RELIABILITY

Asset integrity is a key element in maintaining process safety. It means the systematic implementation of activities that ensure that equipment is, on throne hand, designed, procured, fabricated, installed, tested and inspected in accordance with agreed specifications and, on the other hand, that it remains fit for purpose throughout its lifetime until it is decommissioned. Asset integrity activities range from equipment design to plant operators conducting routine rounds detecting leaks, unusual noise or other abnormal conditions. Reliability engineering is the process of evaluating how long a system and its components can be operated safely before they should be taken out of service for maintenance or replacement. Reliability engineering enables the planning of inspection and maintenance intervals, and is therefore of paramount importance for safety-critical equipment and instrumentation.

HAZARD MANAGEMENT DURING CONSTRUCTION AND COMMISSIONING

Oil terminal operators should have a procedure in place indicating which approach to HIRA will be used during the construction and the commissioning of the terminal.

Typically, risk assessments as described in the section on the safety report/declaration also apply during the operations phase. Pre-start-up safety reviews are often being used during commissioning, while other specific HIRA methods may be used, such as transport or fire and explosion risk studies for non routine tasks.

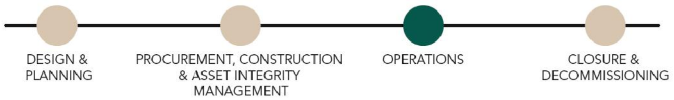
MANAGING THE LIFETIME OF AGEING ASSETS

All assets and infrastructure (facilities) are subject to ageing phenomena aside goes by. The term “ageing” in this context is not concerned with how old particular article of equipment is; it refers to its condition, and how that is changing over time. Ageing facilities are therefore facilities which are, or maybe, no longer considered fully fit for purpose due to age-related deterioration of its integrity or functional performance

Technical condition assessment

The technical condition assessment is a high-level review to identify high-risk equipment so as to ensure the safe and reliable continuation of production. The condition review may be based on site observations, a review of documentation and management systems and interviews of the personnel. It should cover the following elements: safety, operations history, engineering, documentation, inspection and maintenance. A risk-based equipment condition assessment model is used to rank the equipment, while considering its current operational disposition, the consequences of failure and the probability of its failure/unavailability. An asset risk register is compiled as a result of this technical condition assessment.

3. OPERATIONS



Oil terminals are industrial facilities where there is a high potential for large- scale accidents to occur due to the operations performed, the equipment installed and the hazardous substances handled or processed there. This potential is not present during the design and planning stage or even during the procurement, construction and asset integrity management stages. Various emergency scenarios, including large-scale accidents, occur only in the process of industrial activity, i.e., during the operational stage.

The workforce (experts of various specializations and qualifications) is one of the key components of any industrial activity. The safety of a facility depends greatly on its personnel. For staff to perform their tasks successfully, and avoid emergency situations, a systematic approach to industrial process safety management is necessary.

PROCESS SAFETY IN OPERATIONS

To manage operating systems and processes that handle hazardous substances a disciplined framework called process safety management is being use in both upstream and downstream oil and gas industries, as in the chemical industry. Personal or occupational safety hazards may impact human health through short- or long-term exposure to hazardous materials or by accidental injury to individual workers as a result of slips, falls or contact with machinery or moving objects.

Process safety hazards, on the other hand, can give rise to more severe consequences or major accidents involving the release of potentially hazardous materials, the release of energy (fires and explosions) or both; they can have catastrophic consequences and may result in multiple fatalities, economic loss ,botanical loss to property or severe environmental damage.

LEADERSHIP AND SAFETY CULTURE

A poor safety culture has been found to be a significant causal factor in major accidents. The leadership of senior managers, and the commitment of the chief executive, is therefore vital to the development of a positive safety culture.

The following seven elements are considered as essential features for establishing and maintaining a sound process safety culture:

(a) Establish process safety as a core value: The oil terminal operator and the workforce are highly committed to process safety and accept full responsibility for their performance. A strong operational discipline is adopted. As such, there is a strong individual and group intolerance for violations of performance norms;

(b) Enforce high standards of performance: Management performance standards and workforce expectations are fully understood, while adopting a zero tolerance policy for willful violations of process safety standards, procedures and rules;

(c) Provide strong leadership: Oil terminal managers act as a role model and "walk the talk" through visible and consistent support for selected process safety programs and established targets. Adequate resources are provided to support a high performance level, without creating initiative overloads for leaders and the workforce;

(d) Document the cultural values: The key principles and practices that characterize the foundation of the company values and beliefs are documented in clear statements and periodically reviewed;

(e) Empower employees at all levels: A positive and trusting work environment is aimed at, while avoiding a culture of blame and allowing maximum learning from incidents. The oil terminal operator should encourage effective communication lines and a mutual understanding between management and the workforce;

GOVERNANCE SYSTEM

The governance system as described hereafter comprises the management system and the framework of controls, which, together, assign the roles and responsibilities for managing the oil terminal hazards.

ROLES AND RESPONSIBILITIES

For safe operation and maintenance of the oil terminal, the operator has to put in place a control system in order to meet safety requirements and in particular to ensure reliable human performance at all levels, from managers and engineers to operators and craftsmen.

A clear understanding and definition of roles and responsibilities, and assurance of staff competence in those roles, are essential to achieve a high reliability of task execution for the control of major-accident hazards.

Oil terminal operators should ensure that they have:

(a) Clearly identified the roles and responsibilities of all those involved in managing, performing, or verifying work in the management of major hazards, including contractors and ship operators/crews;

(b) In particular, defined the roles and responsibilities of control room operators
(including in automated systems) in ensuring safe fuel transfer operations;

(c) Defined the roles and responsibilities of managers and supervisors in monitoring safety-critical aspects of fuel transfer operations;

(d) Implemented a competence management system, linked to major- accident risk assessment, to ensure that anyone whose work impacts on the control of major-accident hazards is competent to do so.

STAFFING AND WORK ORGANIZATION

Proper staffing, shift work arrangements and working conditions are critical tothe prevention, control and mitigation of major-accident hazards.

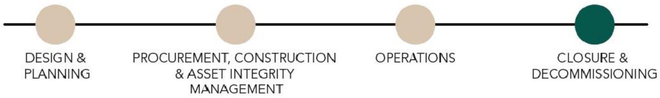
Oil terminal operators should ensure they can demonstrate that staffing arrangements are adequate to detect, diagnose and recover from any reasonablycredible hazardous scenario.

Oil terminal operators should develop a fatigue management plan to ensure that shift work is adequately managed to control risks arising from fatigue.

Oil terminal operators should review working conditions, in particular for control room and field staff, and develop a plan.

Oil terminal operators should provide guidance to ensure safe operations byadopting criteria for minimum staffing of the oil terminal at all times.

4. CLOSURE AND DECOMMISSIONING



TEMPORARY CLOSURE ("PRESERVATION")

The industrial facility can be considered for temporary closure, partly or completely, when there is insufficient fuel demand or raw material supply, in case of poor market conditions or due to other economic reasons. The following considerations are recommended as GIP during this deactivation phase, alsodenoted as "mothballing" or a "hibernation phase". A hibernation phase typically lasts about one year and should not last longer than three years, after which reactivation or decommissioning should take place. The oil terminal operator should develop a temporary closure plan, considering at least the following issues:

(a) The closure should not cause adverse environmental impacts or an imminent threat to human health at the site;

(b) The closure should not cause significant harm to or place a significant burden on public facilities and other plants or land areas adjacent to it;

(c) Existing components and waste should be properly and safely disposed ofor treated.

FINAL DECOMMISSIONING

Decommissioning means the permanently taking out of service of the plantor industrial facilities. Decommissioning includes dismantling, demolition and disposal of terminal buildings and infrastructure and, last but not least, dealing with the potential liabilities associated with the partial closure or complete cessation of the oil terminal activities.

Oil terminals should be closed:

(a) If the relevant conditions stated in the permit have been met and continuedoperations through lifetime extension are not justifiable from an economic viewpoint;

(b) At the substantiated request of the operator, after authorization of the competent authority;

Regulatory framework

It is vital to identify all the legal requirements as early as possible in the design and planning stage and to make contact with the appropriate authorities to understand their requirements. Besides the relevant international legislation, the oil terminal operator should identify the applicable regional and nation allegislation and compile an overall regulatory framework related to decommissioning issues.

Notifications

Appropriate notifications need to be made to different local and national authorities when decommissioning activities are planned. Additional pollution prevention measures or remediation can be required depending on the planned future uses of the land.

Environmental liability

Upon definitive cessation of activities, the oil terminal operator should assess the state of soil, water and groundwater contamination by the hazardous substances used, produced or released as a result of the terminal operations and compare this with the baseline conditions.

The oil terminal operator should apply sound risk assessment procedures to establish the actual environmental situation and the level of significance of the pollution of soil and groundwater following the cessation of its activities.

Details Of Process Safety Activates And Management Of IMC Ltd.

Process Safety Information (PSI)

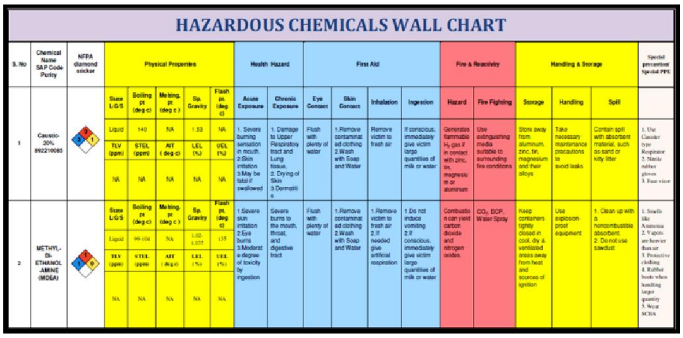
The compilation and continual updating of Process Safety Information (PSI) is key to ensuring the continued safety of any process industry including the IMC. As required by standards (Factory Rules, OISD GDN-206[10], OSHA, etc.), employers must complete a compilation of written Process Safety Information before conducting any process hazard analysis required by the standard. At IMC Limited the complete and updated Process Safety Information has been compiled and made accessible to all employees through a PSI Portal.

The information is managed by the Technical Services Department and monitored continuously for accurate information on process chemicals, technology, and equipment (OISD Requirement). For purposes of streamlining the process of maintaining the information, a PSI Co-Ordinator is in place.

The Process Safety Information shared include:

- Chemical Material Safety Datasheet (MSDS) for all process chemicals involved
- Basic Design and Engineering Package (BDEPs)
- Block Flow Diagrams Process Flow Diagrams (PFDs)
- Process & Instrumentation Diagrams (P&IDs) Critical Operating Parameters (COPs)
- Cause & Effect Diagrams for Process, F&G Systems
- Equipment Datasheets
- Alarms and Trip Settings
- Electrical Hazardous Area Classification (HAC) Drawings
- Chemical Storage Locations – Plot Plans
- Chemical Database.
- Data on Safety Relief Devices (PSV, etc.)

Hazardous chemicals wall chart



HAZARDOUS CHEMICALS WALL CHART

S. No	Chemical Name SAP Code Purity	NFPA diamond sticker	Physical Properties					Health Hazard		First Aid				Fire & Reactivity		Handling & Storage			Special precaution/ Special PPE
			State L/G/S	Boiling pt (deg c)	Melting pt (deg c)	Sp. Gravity	Flash pt (deg c)	Acute Exposure	Chronic Exposure	Eye Contact	Skin Contact	Inhalation	Ingestion	Hazard	Fire Fighting	Storage	Handling	Spill	
1	Caustic- 30% 892210083	0 3 1	Liquid	140	NA	1.53	NA	1. Severe burning sensation in mouth. 2.Skin irritation 3.May be fatal if swallowed	1. Damage to Upper Respiratory tract and Lung tissue. 2. Drying of Skin 3.Dermatitis	Flush with plenty of water	1.Remove contaminated clothing 2.Wash with Soap and Water	Remove victim to fresh air	If conscious, immediately give victim large quantities of milk or water	Generates flammable H_2 gas if in contact with zinc, tin, magnesium or aluminum	Use extinguishing media suitable to surrounding fire conditions	Store away from aluminum, zinc, tin, magnesium and their alloys	Take necessary maintenance procautions to avoid leaks	Contain spill with absorbent material, such as sand or kitty litter	1. Use Canister type Respirator 2. Nitrile rubber gloves 3. Face visor
			TLV (ppm)	STEL (ppm)	AIT (deg c)	LEL (%)	UEL (%)												
			NA	NA	NA	NA	NA												
2	METHYL-DI-ETHANOL AMINE (MDEA)	1 1 0	State L/G/S	Boiling pt (deg c)	Melting pt (deg c)	Sp. Gravity	Flash pt (deg c)	1.Severe skin irritation 2.Eye burns 3.Moderate degree of toxicity by ingestion	Severe burns to the mouth, throat, and digestive tract	Flush with plenty of water	1.Remove contaminated clothing 2.Wash with Soap and Water	1.Remove victim to fresh air 2.If needed give artificial respiration	1.Do not induce vomiting 2.If conscious, immediately give victim large quantities of milk or water	Combustion can yield carbon dioxide and nitrogen oxides.	CO_2, DCP, Water Spray	Keep containers tightly closed in cool, dry & ventilated areas away from heat and sources of ignition	Use explosion-proof equipment	1. Clean up with a noncombustible absorbent. 2. Do not use sawdust	1. Smells like Ammonia 2. Vapors are heavier than air 3. Protective clothing 4. Rubber boots when handling larger quantity 5. Wear SCBA
			Liquid	99-104	NA	1.02-1.035	135												
			TLV (ppm)	STEL (ppm)	AIT (deg c)	LEL (%)	UEL (%)												
			NA	NA	NA	NA	NA												

The PSI system is one of the effective systems implemented at IMC Limited with incorporating continuous updates. It is accessible to all employees and is available anytime. MSDS and Chemical Wall Charts are visually displayed in the field in all relevant spots.

Operating Procedures (OP)

As with any industry, it is a necessity to ensure that processes followed are uniform and don’t vary from person-to-person. For this purpose, IMC Limited has developed and regularly updates/ revises various Procedures. The

Procedures utilized are divided into Management Procedures (applicable to the whole unit), Standard Operating Procedures (SOPs) (applicable to the specific Units), Standard Maintenance Practices (SMPs) applicable to the Maintenance Activities in the.

The Procedures are made available to the employees through a common RIMS MOSS Portal. Standardization of the Procedures has been done and familiarization sessions are held for all employees on every revision or Procedure change.

Every critical activity in the field is studied meticulously and SOPs are created tailored to fit the respective plant and activity. Training is given for all concerned employees in the field. A Competency Test (Saksham) is conducted along with Interviews with the respective Area Managers, prior to deployment of Officers in the Field.

Hot Work Permit (HWP) – part of Safe Work Practices (SWP)

The Work Permit System based on OISD STD-105 as made mandatory by Rule 171 (1) of the Petroleum Rules, 2002, makes it a requirement to obtain permits for conducting Hot Work anywhere inside the Refinry Complex. Primary focus in the, where there may be a lot of flammable/ explosive materials is on Ignition Control. This is ensured by monitoring and regulating the Hot Work Permits issued.

As per OSHA PSM Rule requirements, the Hot Work Permit in the documents the Fire Prevention and Protection Measures undertaken prior to a Hot Job. Every such Job is treated as critical in the and Task-based Risk Assessment (TBRA/ JSA) with relevant higher level Authorizations are required. All permit records are duly maintained as per the standards.

A Hot Work Permit Registration Portal has also been developed and maintained by the Fire Department to monitor Hot Jobs in progress.

Training (TRG)

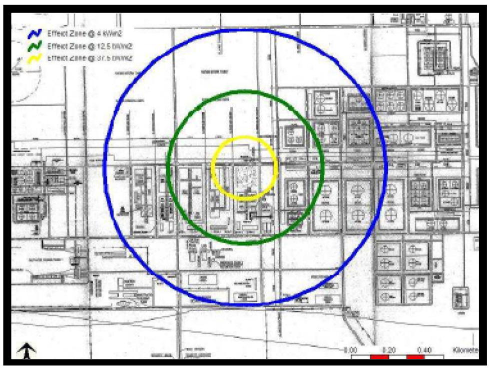
Based on OSHA Guidelines and OISD STD-154, Training Guidelines have been created for Mandatory Trainings to be held in the. Every person (visitor, employee, or contractor) is provided with a Safety Induction before entering the Complex. The Employees undergo a mandatory (OISD-154) 5-day training consisting of various Health, Safety, Environment and Fire Modules that include training on:

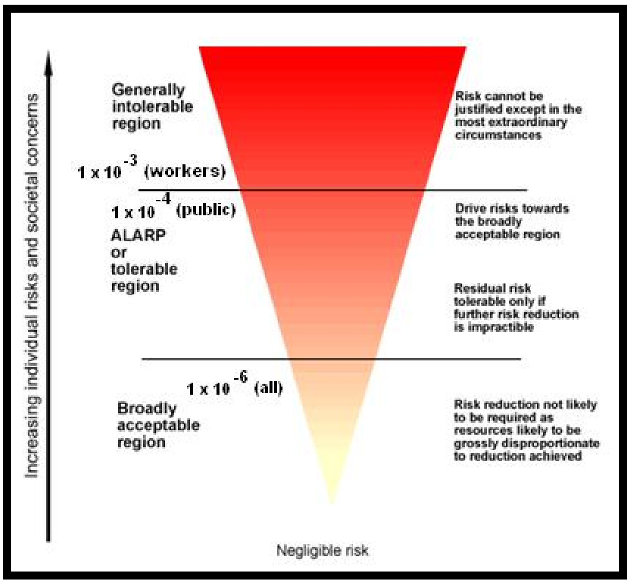
- Process Safety Management,
- Incident Reporting & Investigation,
- Toxic Gas Awareness (H2S),
- Work Permit System, and
- Hazardous Area Classification

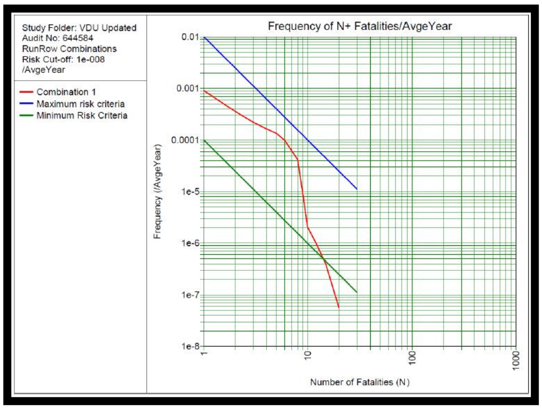
The employees that have already undergone the 5-day OISD training are provided a 2-day Refresher course in the same in conformance with OISD STD-Since, the whole complex is covered under the Work Permit System (WPS), a separate 1-day WPS Training is also conducted by the Safety Department to prepare personnel as Issuer/ Receiver/ Authorizing Party. The Health Department conducts a 2-day Basic First Aider Course in tandem to train all field personnel in Basic First Aid.

Training in IMC Limited has a prime place of reverence, as the Management places great emphasis on development of all its resources. A lot of specialized, Job-Specific and Personal Development Trainings are held throughout the year by the IMC Limited Learning Centre. Process-related or Operational Training is given to all new joinees in the field as well as by their reporting Departments prior to deployment. Validation testing is done through an online 'Saksham' Portal.

The various PHA Methods used





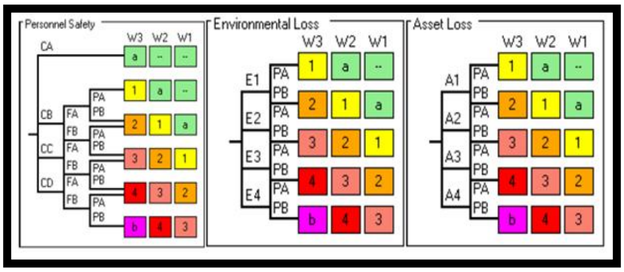


All PHA conducted in the IMC are done by multi-disciplinary teams consisting of experienced Employees. The Employees are also trained in the various PHA Methods used. A PHA Booklet has also been printed and circulated to aid in the knowledge dissemination.

The IMC has conducted SIL Classification and Verification studies for its Safety Instrumented Functions (SIFs), which primarily include the Trip Interlocks provided through process and equipment safeguarding logics. SIL Classification was earlier done in line with IEC 61511 using Risk Graphs (in 2011).

Recently, the Layer of Protection Analysis (LOPA) methodology was utilized to study the possible high risk scenarios, and assign relevant Safety Integrity Levels (SIL) based on latest revisions in IEC 61511 (2016) in 2020-21. Latest round of SIL Verifications was conducted in 2021 with respect to the SIFs classified in 2020 using Exida’sExSILentia software, and relevant recommendations for improvement identified.

Process Hazard Analysis (PHA)



Management of Change (MOC)

Due to IMC Limited's continuous growth and the need for improvement, various changes are required in the Intent behind the Design of the existing Plant. To ensure that any such changes don't introduce new hazards without control or override the existing controls, IMC Limited has created and implemented the Management of Change (MOC) Procedure in the Complex. The Procedure was drafted based on OISD GDN-178, OISD STD-206, the OSHA PSM Rule, and the CCPS Guidelines for the Management of Change of Process Safety.

The Change Management process does not end at the implementation stage. The change may require updation in PSI (P&IDs, Cause & Effect Diagrams), training of Field & Process Personnel based on the new modification, etc. Extensive Communication and Training is required to be completed as part of the MOC procedure.

Mechanical Integrity (MI)

In every major Process Incident studied in the past decades, the prime challenge posed has been to the System Integrity. The three Integrity Pillars of PSM, viz.

- Operation Integrity: Training, Safe Work Practices, SOPs;
- Plant Integrity: Hardware Design, Maintenance, Construction, Reliability;
- Design Integrity: Process Design, PSI, Engineering, Material of Construction

The OSHA PSM Rule and OISD GDN-206 require a Mechanical Integrity program in place to ensure that equipment are designed, installed and operate as intended without chances of failure. For this purpose, a Mechanical Integrity & Asset Reliability (MIAR) program is in place at the IMC. The PSM Mechanical Integrity requirements to the following equipment:

- Pressure Vessels and Storage Tanks
- Piping Systems (including components)
- Relief & Vent Systems and Devices
- Emergency Shutdown Systems (ESD)

Compliance Audits (CA)

Based on the various OISD, OSHA, other Statutory Rules & Regulations being followed, the IMC conducts Compliance Audits regularly to monitor the implementation and need for any change, and when there are any amendments made to existing standards or based on International Best Practices found. Based on any major External Incident Learnings, the IMC Departments also conduct checks to identify and plug any similar loop-holes in the system. Internal Safety Audits are usually conducted by the personnel from the IMC. While External Safety Audits have been performed by reputed auditors/ service providers. All the Audit Recommendations are tracked through the Safety Portal for implementation.

Emergency Response and Planning (ERP)

Emergency Planning and Response in the IMC is handled by both the Operations and Fire Department with aid from the Maintenance Departments. An On-Site Emergency Management Plan (OSEMP) has been implemented in the IMC. All personnel (visitors, employees, contractors) are instructed in the Emergency Response required, and Warning Systems provided during their Safety Induction. Separate OSEMP training sessions are also held.

The IMC has incorporated many statutory rules and guidelines for the formation and implementation of Emergency Response Plans, viz.

- Factories Act 1948: Schedule 1, Section 41B
- Petroleum & Natural Gas Regulatory Board (PNGRB) Emergency Response Regulations (2010)
- OISD GDN-168
- Manufacture, Storage and Import of Hazardous Chemicals (MSIHC) Rules, 1989: Rule 14
- NFPA 1600

The IMC has classified the On-site Emergencies into four types for monitoring, viz. Spill/ Leak, Fire, Injury, Traffic. The severity of the emergency determines the level and action required. Based on this, there are 3 levels:

1. Level 1: where the emergency can be effectively contained within the site or location, and there is no offsite impact;
2. Level 2: where the impact may spread beyond the site or location and additional resources are required to contain it;
3. Level 3: where catastrophic, off-site impact is probable and external aid is required to contain the emergency

In accordance with the framework of the OSEMP, IMC Limited conducts periodic mock-drills as per yearly schedules. Frequency is as suggested in the PNGRB Rules. For signalling the emergency, robust, inspected and well-maintained F&G Systems are placed in the field that signal the Fire & Gas Alarms/ Siren. Visual Beacons are placed at all plant areas that are activated due to F&G Detection Systems. Manual Call Point (MCP) and the Public-Announcement (PA) System are utilized for communication. In case of any emergency, all personnel are instructed to respond as per the OSEMP.

The Mock-Drill Scenarios are identified by the Fire Department in consultation with the Operations Department, who provide the Most Credible Scenarios for the Incident. The mock-drills are evaluated by a team of experienced professionals and the recommendations informed to all in the area at the end of the Drill. More scenarios that have been identified in the QRA Study have also been included. The actions based on the recommendations are also tracked in the Safety Portal.

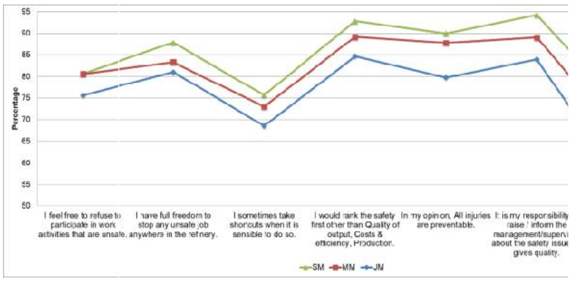
In case of any emergency, the Fire Team takes a turn-out to ensure quick and easy handling providing a back-up for the Area Owner. There is also a separate Auxiliary Fire Squad (AFS), maintained for the purpose of providing back-up fire-fighters in case of a prolonged or critical emergency. First Aid Training is provided to many personnel in the field to supplement the AFS and take care of any injured personnel till the arrival of the Para-medics.

Employee Participation (EP)

Employee Participation is a vital aspect of implementation of any Management Process. OISD, OSHA and other regulatory bodies require employers to consult and ensure employee participation including but not limited to the development and conduct of Hazard Assessments. At IMC Limited, the employees are engaged in various activities providing feedback to the Management Procedures, in creation of Standard Operating Procedures (SOPs), Procedural Revisions, the Management of Change Process, Process Hazard Analysis(including HAZOP, Fault Tree Analysis, What If, 5 Whys, etc.), Pre-Start-up Safety Review, etc.

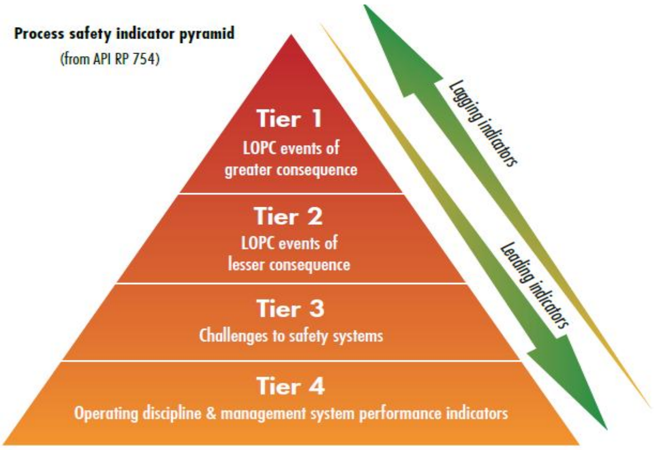
Beyond these various awareness & training sessions are conducted to enhance employee awareness and share knowledge. These sessions help gain insight into the actual workings/ practical issues that help improve our systems through constant positive feedback. Employees are also integral in the Safety Audits and Task-Based Risk Assessments (TBRA)/ Job Safety Analysis conducted in the field.

In keeping with the IMC's consistent developments and contributions to the field of Process Safety and our nation, IMC Limited was asked to help in establishing a Center of Excellence (CoE) in India with external institutions to help promote education and R&D activities in Process Safety. IMC Limited signed a tripartite Memorandum of Understanding (MoU) with the Indian Institute of Technology - Delhi (IIT) and GEXCON, a Norway-based international leader in fire and explosion safety experimentation and studies.



Monitoring Process Safety Performance

Most systems and procedures deteriorate over time, and system failures discovered following a major incident frequently surprise senior managers, who sincerely believed that the controls were functioning as designed. Used effectively, Process Safety Performance Indicators (PSPI) can provide an early warning, before catastrophic failure, that critical controls have deteriorated to an unacceptable level.



Any Incident reported is considered as a Process Safety Event (PSE) in Tier 1 or Tier 2 based on the rate of release, i.e. it has to satisfy both these criterion as per API & CCPS: Any Incident reported is considered as a Process Safety Event (PSE) in Tier 1 or Tier 2 based on the rate of release, i.e. it has to satisfy both these criterion as per API & CCPS:

1. Threshold Quantity: the amount of material released should exceed this stated amount for the concerned chemical. The MSIHC Rules20 also have a set threshold limit for most chemicals. The API & CCPS guidelines cover these and are more stringent.
2. Acute Release: The release within “1 hour” should be above threshold quantity, i.e. if a hazardous release exceeds threshold quantities but over a period of many days, instead of an hour, it will not be considered a PSE.

It is to be noted that PSM deals completely with Loss of Containment scenarios – Fire/ Leak (PSE) and probable Loss of Containment scenarios (Process Near Miss).

X. CONCLUSION AND FUTURE SCOPE

CONCLUSION

After completion of the study, It has been realized that the concept of PSM implementation is very much important in refinery and oil and gas installations but it is also very much important and helpful for bulk liquid storage terminals as well as in sea port. After learning from various internal and external incidents it has been realized that, PSM becomes very important framework for preventing catastrophic incidents. Some of the elements of PSM are very essential which are MIAR, PHA, Management of change, hot work permit etc. PSM gives the systematic and broader approach for monitoring critical activities in most careful manner. I found that A process hazard analysis (PHA) or evaluation is an organized and systematic approach to identifying and analysing the potential hazards associated with the processing or handling of highly hazardous chemicals. It evaluates and analyses possible causes and consequences of fires, explosions, releases, and spills of dangerous and flammable chemicals by focusing on equipment, utilities, human actions and external factors. Activities documenting and tracking implementation of corrective actions or safety improvements are not part of a PHA report. However, the PSM Rule requires a documented, integrated system for managing and monitoring action items. This system must assure that action items and recommendations are addressed and documented in a timely manner. OSHA UAS has also issued the guidelines for PSM compliance.

XI. FUTURE SCOPE

The intent of this element is to define the requirements to conduct a MIAR study, Process Hazard Analysis (PHA), Management of Change etc. on each process covered by the PSM Program. This critical element identifies the process hazards, evaluates the consequences and defines appropriate control measures to eliminate or minimize the severity of the hazard. The next step that follows developing these guidelines would be of course to test them in a pilot exercise at a chemical/hydrocarbon facility. Multiple pilots will help complete and refine these guidelines, and make them more practical to use. The natural step following those pilot exercises and improvement of guidelines is to use them to enhance the facility’s internal standards and procedures in order to help close identified gaps, develop systems that assist in making the PHA element easier to audit and monitor with the goal of steering the facility for continuous improvement of PHA element implementation.

To help assure that all hazards are identified and evaluated, PHA will be help to the following processes.

- Oil & Gas Processing
- Rubber Processing
- Petrochemical
- Cement Processing
- Pharmaceutical
- Water Treatment Process
- Toxic or Pesticide Chemical Processing
- Hazardous Waste Treatment Process
- Textile Processing
- Other Chemicals and Process Industries

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