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Title

PROCESS SAFETY: PREVENTION – INTERVENTION – MANAGEMENT

Presented and publicly supported by:

Kortbi Abderrezak and Blaha Mustapha

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Dedications

Every challenging work needs self efforts as well as guidance from those who were very close to our hearts.

My humble effort I dedicate to my sweet and loving

Mother,

Whose affection, love, encouragement and prays of day and night make me able to get such success and honour.

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Blaha Mustapha

نبذة مختصرة

في الوقت الحاضر، أدرك كل منا أن الثروة الحقيقية للشركة تكمن في نظام الأمان الخاص بها والذي يمثل تحديًا كبيرًا. في هذا العمل، حاولنا التركيز على الجوانب المختلفة لسلامة العملية مع مراعاة تحديد مخاطر العملية من أجل منع حدوثها باستخدام تقنيات محددة. بالإضافة إلى ذلك، أوضحنا كيف يمكن للشركة التخفيف من عواقب أي حادثة عملية إذا حدثت بسبب فشل في نظام الوقاية. أخيرًا، في هذه الأطروحة، تمت مناقشة إمكانية ربط كل هذه التقنيات معًا في نظام إدارة قوي من أجل توفير تنظيم جيد لنظام سلامة العمليات لدينا.

الكلمات المفتاحية: العمليات، الحريق، السلامة، نظام الإدارة، الصيانة، الطوارئ، الأنظمة المجهزة، الانفجار، الوقاية، التدخل.

Résumé

Aujourd'hui, chacun de nous a compris que la vraie richesse d'une entreprise est dans son système de sécurité qui est un défi majeur. Dans ce travail, nous avons essayé de nous concentrer sur les différents aspects de la sécurité des procédés en tenant compte de l'identification des dangers du procédés afin de prévenir leur apparition en utilisant des techniques spécifiques. Par la suite, nous avons expliqué également comment une entreprise peut atténuer les conséquences de tout incident de procédé s'il se produit en raison d'une défaillance du système de prévention. À la fin, nous avons discutés sur la possibilité de relier toutes ces techniques dans un système de management afin de permettre une bonne organisation de notre système de sécurité des procédés.

Mots clés: Procédés, incendie, sécurité, système de management, maintenance, urgence, systèmes instrumentés, explosion, prévention, intervention.

Abstract

Nowadays, each of us has realised that the real wealth of a company lies on its safety system which is a major challenge. In this work we have tried to focus on the different sides of process safety taking into account the process hazards identification in order to prevent their occurrence by use of specified techniques. In addition we have explained how a company can mitigate the consequences of any process incident if occurs due to a failure in the prevention system. Finally, in this thesis, it has been discussed the possibility of linking all these techniques together in a robust management system in order to afford a good organisation for our process safety system.

Key words: Process, fire, safety, management system, maintenance, emergency, instrumented systems, explosion, prevention, intervention.

Content Table:

Abbreviations:

Abbreviation	Meaning
ATEX	Explosive Atmosphere
BLEVE	Boiling Liquid Expanding Vapour Explosion
BP	British Petroleum
BPCS	Basic Process Control System
CO_2	Carbon dioxide
EN	European Norm
FSA	Functional safety assessment
FAT	Factory acceptance test
FAFFE	First Aid Fire Fighting Equipment
HSE	Health and Safety Executive
HV	High voltage
HAZOPS	Hazard Operability
INRS	National Institute of Scientific Research
IEC	International Electrotechnical Commission
LOTO	Lock-out /Tag-out
LEL	Lower Flammable Limit
MOC	Management Of Change
NEBOSH	National Examination Board of Occupational Safety and Health

NP	Non-Programmable systems
PE	Programmable systems
PFD	Probability of dangerous failure on demand
PFH	Probability (average frequency of dangerous failures) of failure per hour
PPE	Personal Protective Equipment
PHA	Process Hazards Analysis
PTW	Permit-To-Work
SIL	Safety Integrity Level
SIS	Safety Instrumented System
SRS	Safety Requirements Specifications
SIF	Safety Instrumented Function
SOP	Standard Operating Procedures
UK	United Kingdom
UEL	Upper Flammable Limit
VCE	Vapour Cloud Explosion
WHO	World Health Organisation
WRULDs	Work Related Upper Limb Disorders

List of tables:

List of figures:

Glossary:

This part includes some definitions relating to Process safety classified in alphabetical order. These definitions, to which the reader will be able to refer throughout the reading of this thesis, make it possible to understand the terms used in the following chapters.

Failure: Loss of ability to perform as required.

Failure mode: Manner in which failure occurs.

Fault: Inability to perform as required, due to an internal state.

Fault avoidance: Use of techniques and procedures which aim to avoid the introduction of faults during any phase of the SIS safety life-cycle.

Instrument: Apparatus used in performing an action (typically found in instrumented systems.

Instrumented system: System composed of sensors (e.g.: pressure, flow, temperature transmitters), logic solvers (e.g. programmable controllers, distributed control systems, discrete controllers), and final elements (e.g. control valves, motor control circuits).

Input function: Function which monitors the process and its associated equipment in order to provide input information for the logic solver.

Logic solver: Part of either a BPCS or SIS that performs one or more logic function(s).

Mitigation: Action that reduces the consequence(s) of a hazardous event.

Output function: Function which controls the process and its associated equipment according to output information from the logic function.

Process risk: Risk arising from the process conditions caused by abnormal events (including BPCS mal-function).

Protection layer: Any independent mechanism that reduces risk by control, prevention or mitigation**.** It can be a process engineering mechanism such as the size of vessel s containing hazardous chemical s, a mechanical mechanism such as a relief valve, a SIS or an administrative procedure such as an emergency plan against an imminent hazard. These responses may be automated or initiated by human actions.

Programmable electronics PE: It is an Item based on computer technology; this may be comprised of hardware, software, and of input and/or output units. This term covers micro-electronic devices based on one or more central processing units together with associated memories. Examples of process sector programmable electronics include: smart sensors and final elements, programmable electronic logic solvers including and programmable controllers.

Programmable electronic system PES: System for control , protection or monitoring based on one or more programmable electronic devices, including al l devices of the system such as power supplies, sensors and other input devices, data highways and other communication paths, actuators and other output devices.

Software: Programs, procedures, data, rules and any associated documentation pertaining to the operation of a data processing system

System: Set of devices that interacts according to a specification.

Tolerable risk: Level of risk which is accepted in a given context based on the current values of society.

General introduction:

When we think about ‘safety’, we naturally think about the personal safety of individuals who could be affected, and the various, often more traditional actions that can be taken to reduce the risk of injury and ill health. Many types of personal accidents are quite common, simple and therefore reasonably foreseeable; their control measures are often well established and straightforward to implement. These include machine guarding, fire precautions, equipment checks, managing slips and trips and the use of personal protective equipment (PPE). We probably think about low personal accident rates or number of days without an accident as a measure of success.

By comparison, process safety (safety in high-hazard process industries) is rather more complicated. The so-called high-hazard process industries include chemical and oil and gas sectors. While they obviously suffer personal accidents like all other workplaces, there is also a potential for a major incident. This is because they deal with dangerous chemicals in large amounts and operate processes that, if not well monitored and controlled, can easily go spectacularly wrong, resulting in major fires, explosions and toxic releases, for instance. Major incidents like these are very infrequent events and can be difficult to predict (before they happen) because of the multiple causes and complexity of what leads to them. Neglecting seemingly small things (like an intermittently faulty alarm or general maintenance) can end up causing a major accident. In process safety, the emphasis is on the prevention of major disasters that have been historically an issue for the industry. Process safety needs both complex technical controls (on the plant itself) as well as a robust safety management system. It requires a good deal of specialist in technical engineering and management skill to get right. Leadership is important to give suitable high priority to process safety even though the standards and controls mean that incidents should be rare and may be outside the experience of operators.

Personal safety and process safety link together (clearly, there is a risk of slips, trips and falls occurring in any workplace); however, in process safety, the emphasis is on the prevention of the high-risk, large scale catastrophic events that, though thankfully rare, could have devastating consequences.

Most of cases, the best process safety is achieved by a safety process design intrinsic, whenever possible, combined, if necessary, with other systems of protection, based on different technologies (chemical, mechanical, hydraulic, pneumatic, electric, electronic, programmable electronics) and which cover all residual risks identified such as safety instrumented systems.

In case of failure of this prevention procedures and techniques, a fire safety management system and a fire emergency plan are created to ensure the mitigation of the severity of any incident including fire or explosions, they apply to all premises which are to any extent under the control of the company because fire is a hazard in any part of the premises. Its consequences include the threat to the lives or health and safety of relevant persons, damage to or loss of property and severe interruption to normal business activities or opportunities so all employees throughout the department must play their part in the creation of a safe and healthy working environment for all.

In order to link all the previous process safety strategies and to control their application, different management system techniques should be implemented within the company so they can take better decisions for the organisation and also to ensure that people are well included into the safety system. Management functions include planning, organising, staffing, leading or directing, and controlling an organization for the purpose of accomplishing a goal which is in our case to reduce the likelihood of hazards and to mitigate their severity if they accidently occur, all taking in consideration that management is about final results not efforts.

Problematic:

As explained above the field of industries and production is a precarious field. Unexpected releases of toxic substances, fires and explosions due to flammable liquids and gases in processes involving highly hazardous chemicals have been reported for many years, the consequences of which have been disastrous and their residual losses devastating, in many industries. Regardless of which industry, there is always the potential for an accident at any time resulting in the potential for disaster.

So what are the main characteristics of process related hazards?

What are the best techniques to prevent their occurrence and mitigate their consequences?

How to set up a robust risk management system to reach a high level of process safety?

Thesis organisation:

This thesis is divided into four chapters as follow:

- In the first chapter we will present the most significant definitions related to the fundamental terms of process safety. We will also determine and explain the main process hazards including fire, explosion and toxic releases by introducing the key characteristics of each one of them and their impact if accidently occur. At the end we clarified the benefits of prevention techniques and procedures.
- In the second chapter we will show how to prevent the occurrence of the process hazards at the early stage by implementing a good engineering safety design, in case of failure the prevention technique will need to be enforced by safety instrumented systems which will be explained in detail in this chapter.
- In the third chapter we will see how to reduce the fire effects by use of different techniques such as developing emergency plans and use of first aid fire fighting equipments. We will give the manner for prevention, protection and intervention of each process hazard all together with the good techniques of the first aids.
- The fourth chapter will document the risk management techniques used in the industry in order to reach a high level of process safety, we will introduce and explain what a permit to-work is used for, how to select and manage contractors, maintenance strategies for process plant and as well as the key principles of safe shift handover.

Finally this thesis will end with a general conclusion summarizing the work carried out and giving the main recommendations.

CHAPTER I

INTRODUCTION TO PROCESS SAFETY

Chapter 1: Introduction to process safety

Introduction:

Prevention is a very essential part of any company's safety system because it provides a bunch of benefits if well applied and monitored but still has some conflicts with the production goals, for instance, which leads to several types of accidents especially in process operations. At first we will define the most common technical words related to safety and precisely to process safety in order to understand the basics of this thesis. Secondly we will present the different types of hazards which can be caused by process errors and mistakes starting by fire which is the most common accident in process industries, fire has so many types and spreading forms which we will see in detail. After that an explanation will be provided about the different types of explosions which could be either physical such as BLEVE or chemical such as thermal runaways. And finally we will present the toxic substances different forms, their different routes of exposure and their effects on human's health if they are accidently or wilfully released.

1. General definitions:

1.1 Process safety: You will find various definitions of process safety but the one that we will use is: "a blend of engineering and management skills focused on preventing catastrophic accidents and near misses, particularly structural collapse, explosions, fires and toxic releases associated with loss of containment of energy or dangerous substances such as chemicals and petroleum products." (1)

1.2 Hazard: ''potential source of harm'' (2)
A hazard can be defined as something with the potential to cause harm and covers health, injury, loss of production and damage to plant and property. Typical examples could be something such as electricity, moving machinery and trailing cables.

1.3 Risk: "Combination of the probability of occurrence of harm and the severity of that harm. The probability of occurrence includes the exposure to a hazardous situation, the occurrence of a hazardous event, and the possibility to avoid or limit the harm" (3). Examples include contact with electricity resulting in electrical burns and tripping over cables.

The hazard represents a potential threat of harm while Risk is an assessment of exposure to this hazard.

1.4 Danger: a danger is a cause or source with the potential to cause damage: human injury, ill health, material damage, damage to the environment or more than one of these causes.

1.5 Accident: as an unintended or unplanned happening that may or may not result in property damage, personal injury, work process stoppage or interference, or any combination of these conditions under such circumstances that personal injury might have resulted (4).

1.6 Near Miss: is an incident where no injury or illness occurs. Therefore, an incident can be either an accident or a near-miss (5).

1.7 Dangerous occurrence: An unplanned, uncontrolled event, which has the potential to cause death or serious injury but did not this time. It must be reported to the national enforcing authority even though there is no reportable injury this time, as it could have done so in slightly different circumstances.

These typically include unintentional collapse of structures, explosions and failure of lifting equipment.

1.8 Harm: Physical injury or damage to the health of people, or damage to property or the environment (6).

1.9 Hazardous situation: Circumstance in which people, property or the environment are exposed to one or more hazards.

1.10 Welfare: It concerns the provision of facilities for workplace comfort and includes eating, washing, changing, toilets and living/sleeping accommodation and first aid facilities. It is the facilities employers providing insurance to the on-going health of workers.

1.11 Work related ill-health: It concerns harm to a worker's health caused by their work. This would include both physical and psychological harm.

1.12 Health: It is a state of well-being. It concerns an absence of disease, physiological and psychological harm. It concerns fatigue, stress; noise induced hearing loss or illness resulting from exposure to hazardous substances and materials (7).

1.13 Safety: "Freedom from risk which is not tolerable" (8)

"Safety means the absence of accidents or unacceptable risk. Hence, the accident is a manifestation of RISK, which is likely to cause damage to persons in the workplace from such things as equipment, materials and working at height" (7).

Differences between risks to Safety and risks to Health:

Risks to safety	Risks to health
Slips, trips and falls	Exposure to hazardous chemicals e.g.H_2S
Falls from height	Exposure to asbestos
Struck by vehicle	Exposure to pathogens
Contact with electricity	Repetitive strain injuries (WRULDs)
Contact with moving parts of machinery	Stress
Violence	Noise induced hearing loss

Table 1.1: Difference between risks to Safety and risks to Health.

1.14 Incident: is referred to as a work-related event(s) in which an injury or ill health (regardless of severity) or fatality occurred, or could have occurred (5).

1.15 Accident prevention: It is the technique of anticipating and controlling events so that accidents are avoided and the consequent damaging results do not occur. This technique covers a very wide field, dealing, as it does, with the attitudes and the unsafe conditions in the workplace, thus ensuring the correct control systems in operation (11).

2. The reasons for accident prevention:

The reasons or the benefits of providing and maintaining good standards of health and safety are the following:

2.1 Moral: The employer needs to provide a reasonable standard of care to reduce pain and suffering to the individual, their family and friends.

2.2 Economic: Accidents cost a great deal of money in direct and indirect costs. A study by the HSE in the UK concluded that health and safety failures cost 8.5% of contract value.

2.3 Social and Legal:

2.3.1 Social: Society's expectations of businesses to have good standards of health and safety have evolved and increased. In economies with a high level of economic development, the expectancy is generally far higher than in societies which are usually less economically developed because people are looking for work and will accept very poor working conditions. However as the society develops, the expectations grow.

Society is also concerned with risks or threats from hazards which impact on it and could provoke a large public response due to the event causing widespread damage or the occurrence of multiple fatalities in a single event.

2.3.2 Legal: Furthermore, in most countries, there are specific legal requirements on the employer (both civil and criminal) to provide and maintain a safe place of work, safe plant and equipment, safe systems of work, competent workers and high standards of training and supervision.

3. Bird's Accident Triangle:

A detailed research done in Frank Bird broadened the hypothesis by acquiring property damage and compared the circumstance to an iceberg, with the vast majority of the accidents (near misses) being covered up.

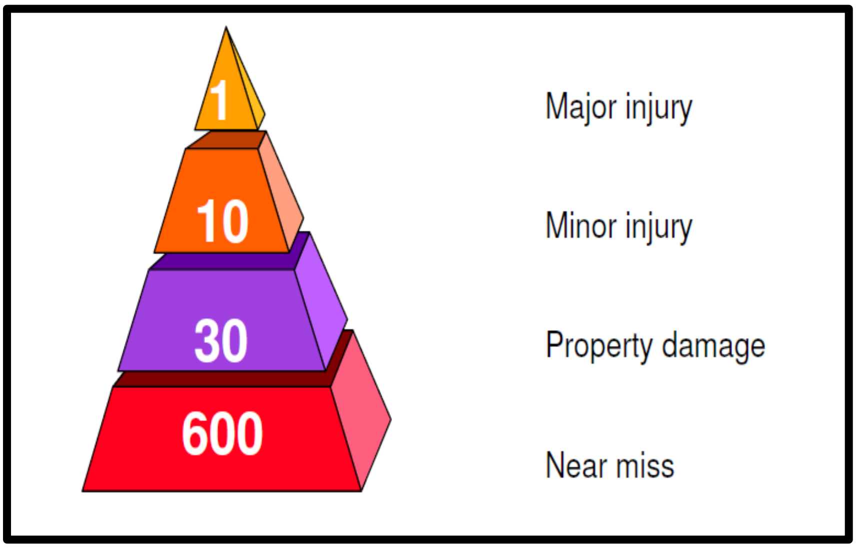

Figure 1.1: Bird's Accident Triangle (12)

4. Fire hazard:

4.1 The Fire Triangle:

Before a fire can start, three components have to be present in sufficient quantities. These form a structure known as the fire triangle. If one of these elements is removed, the fire will go out.

Figure 1.2: Fire triangle (12)

4.1.1 Heat:

Heat acts as the source of ignition and anything that gives off heat can start a fire. (Note that the source of ignition is not necessarily a flame, a spark or fire itself, but the heat they give off.

4.1.2 Fuel:

The fuel for a fire does not have to be a recognized fuel in the sense of petrol or gas. It may be any combustible material. Most substances are combustible under the right circumstances although those circumstances vary for different materials, and because the means of extinguishing the fire may vary. We shall consider the types of fuel in a little more detail later when looking at the way in which fires are normally classified.

4.1.3 Oxygen:

The oxygen essential for combustion is usually supplied from the surrounding air. However, the naturally present oxygen may be enhanced by the presence of other sources of oxygen such as compressed air, the pure oxygen in gas cylinders used for welding, or by the combustion of peroxides, nitrates, and similar chemicals. Note that as the oxygen in an enclosed space is used up by the fire, so the fire will go out.

4.2 General definitions:

4.2.1 Flammable: Any liquid with a flashpoint of between 21 and 55°C. Example is diesel (12).

4.2.2 Highly flammable: Any liquid that has a flash point of less than 21°C. Example is petrol (12).

4.2.3 Extremely flammable: Gaseous substances that are easily ignited when in contact with air. Example is acetylene (12).

4.2.4 Flash Point temperature: The minimum liquid temperature at which there is sufficient flammable vapour that when mixed with air is capable of temporary ignition under prescribed circumstances (13).

4.2.5 Fire Point temperature: The minimum liquid temperature at which there is sufficient flammable vapour that when mixed with air is capable of ignition and continuous burning under prescribed circumstances (13).

4.2.6 Flammable limits: also called explosive limits, and defined as: "The explosion limits vary with pressure and temperature. As a rule, the concentration range between explosion limits increases with increasing pressure and temperature (14).

They refer to the conditions under which a mixture of a flammable material and air will catch fire or explode. If the percentage of flammable material in the air is between the minimum and maximum limits, the presence of a flame or a source of ignition will likely lead to rapid combustion or explosion. A change in temperature or pressure may vary the flammable limits.

- **The lower flammable limit (LEL):** is the concentration below which a flame will not propagate (13).
- **The upper flammable limit (UEL):** is the concentration above which a flame will not propagate (13).

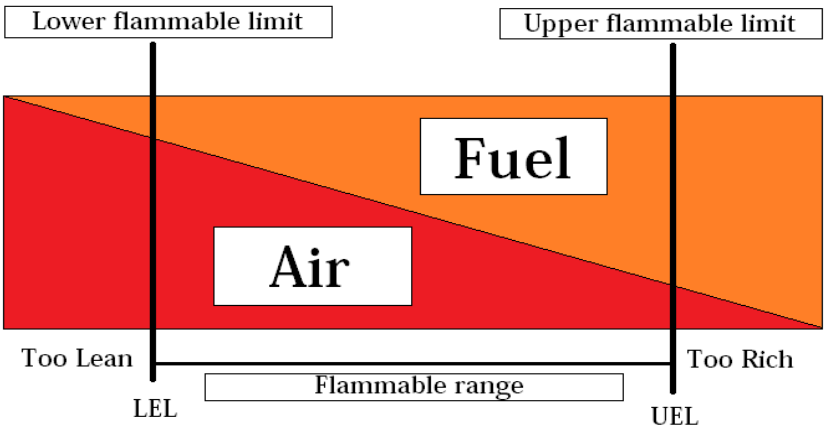

Figure 1.3: The lower and upper flammable limit (13)

4.3 Classification of fires:

Fires are classified into five categories according to the fuel type. The classification also serves as a basis for identifying the means of extinguishing different types of fire:

4.3.1 European Fire Classification System Fires:

- **Class A:** These are fires involving solid materials, normally of an organic nature, such as paper, wood, coal and natural fibres. These fires usually produce burning embers.
- **Class B:** These are fires involving flammable liquids or liquefied solids, such as petrol, oil, grease, fats and paint.
- **Class C:** These are fires involving gases or liquefied gases, such as methane, propane, and mains gas.
- **Class D:** These are fires where the fuel is a metal such as aluminium, sodium, potassium or magnesium.
- **Class F:** These are fires fuelled by cooking fats, such as of fat frying.
- **Fire Involving Electrical Risk:** It is imperative to first disconnect the power supply. The fire can then be dealt with according to the classification of the type of fire as indicated above. For fires involving live electrical equipment where the power supply cannot be isolated and there is a risk of electrical shock, the extinguisher agent must be non-conductive, such as CO2, vaporizing liquids and dry powder.

4.3.2 American Fuel Classification System:

- **Class A:** Ordinary combustibles Consists of ordinary combustibles such as wood, paper, fabric, and most kinds of rubbish.
- **Class B:** Flammable liquids and gases. These are fires whose fuel is flammable or combustible liquid or gas. The United States system designates all such fires "Class B".
- **Class C:** Electrical fires are fires involving potentially energized electrical equipment.
- **Class D:** Metals These fires consist of combustible metals such as magnesium, potassium, titanium, and magnesium.
- **Class K:** Cooking oils and fats (kitchen fires) Class K fires involve unsaturated cooking oils in well-insulated cooking appliances located in commercial kitchens.

4.4 Basic principles of heat transmission and fire spread:

Once a fire has started there are four methods by which it can spread; convection, conduction, radiation and direct burning.

4.4.1 Convection: Convection is the process whereby heat moves through a gas or liquid. When a gas or liquid, such as air or water, is heated, it expands and becomes less dense. As a result, it rises and cooler air or water is drawn in to replace it, creating a current.

Convection currents created in the air by fire are a major means of fire spread. They may carry burning materials through the air and into contact with other combustible materials and also, depending upon the intensity of the fire and the heat generated, create strong localised winds which may fan the flames and cause flare ups.

4.4.2 Conduction: Heat may be transmitted through certain materials, known as conductors, without those materials themselves actually burning. This is particularly the case with metals. Thus, the heat generated by a fire (or any other process producing heat) may be transferred to a separate location where it can act as a source of ignition).

This has important implications for many steel frame buildings which feature widespread use of metal within the structure of the building (for example, steel girders) and the services which run through it, such as pipes and various types of ducting.

4.4.3 Radiation: Radiation is the general term for the process by which energy is lost from a source without direct contact. Heat radiation refers to the process whereby the heat given off by hot objects passes through air and through certain types of transparent material such as glass. This radiant heat can in itself be sufficient to act as a source of ignition.

The intensity of radiant heat diminishes with the distance from its source. However, depending on the temperature of the source, heat transfer may take place over quite large distances.

4.4.4 Direct Burning: This occurs where heat is transferred directly by contact from one substance to another. Thus, if a piece of paper catches light then the heat (in the form of flames) can spread to the next piece of paper and then to the next until a whole area is on fire. Similarly, oil based paint on walls can spread fire, as can a pool or trail of flammable liquid.

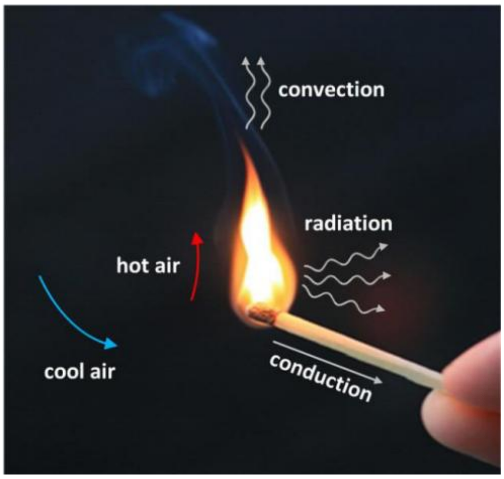

Figure 1.4: Basic mechanisms of heat transfer in a match flame (15)

4.5 Consequences of fire:

Losses due to fire have an enormous cost (both financial and human) to industry and the community and yet most fires are preventable. Disruption to business in the form of loss of production, loss of plant and, sometimes, injury and loss of life can often be crippling. Even a minor fire involves disruption and a reduction in output which benefits no one (except the insurance company requesting higher premiums). Over 70% of businesses which have suffered a major fire either do not re-open or fail within three years of the loss.

Effects on health	Effects on safety
• Death by asphyxiation.	• Structural failure leading to crush injuries.
• Toxic poisoning.	• Electrocution where the heat melts the insulation on live wiring and the worker comes into contact.
• Burns (internal and external).	• Trips, slips and falls during the evacuation, especially when there is panic.

Table 1.2: Effects of fire on humans.

5. Explosion hazard:

5.1 Definition:

It can be defined as following:

"An explosion is the rapid transformation of a material system giving rise to a strong emission of gas, accompanied by a significant emission of heat" (15).

"A rapid temperature and pressure rise resulting in an audible spherically propagating pressure wave" (16).

5.2 Types of explosion:

Deflagration and detonation are the two main subtypes of an explosion as a phenomenon.

5.2.1 Deflagration: "Explosion propagating at subsonic velocity" (17).

5.2.2 Detonation: "Explosion propagating at supersonic velocity and characterized by a shock wave" (17).

5.3 Explosion origins:

Two types of explosion correspond to released energy of chemical origin:

- The explosion of an ATEX.
- The explosion that results from thermal runaway.

Two types of explosion correspond to a released energy of physical origin:

- The rupture of a pressurized container by a gas.
- A brutal vaporization of an overheated liquid.

5.4 Explosive atmosphere:

"A mixture with air, under atmospheric conditions, of flammable substances in the form of gas, vapour, mist or dust in which, after ignition, combustion spreads throughout the unconsumed mixture" (19).

The mixture must be neither too poor nor too rich in fuel so it needs to be in its explosive range.

LEL < concentration of the flammable substance in the mixture < UEL

5.4.1 Classification of hazardous areas:

Gases, Vapours	Dust	Definitions
0	20	A place in which an explosive atmosphere is continually present.
1	21	A place in which an explosive atmosphere is likely to occur in normal operation occasionally.
2	22	A place in which an explosive atmosphere is not likely to occur in normal operation, but if it does only occur for short periods.

Table 1.3: Classification of hazardous areas.

5.4.1.1 Gases and vapours:

- Zone 0: place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is present continuously or for long periods or frequently.
- Zone 1: place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is likely to occur in normal operation occasionally.
- Zone 2: place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

5.4.1.2 Dust:

- Zone 20: place in which an explosive atmosphere in the form of a cloud of combustible dust in air is present continuously, or for long periods or frequently.
- Zone 21: area in which an explosive atmosphere in the form of a cloud of combustible dust in air is likely to occur, occasionally, in normal operation.

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

5.5 Thermal runaway:

This phenomenon corresponds to the loss of control of a chemical substance or a reaction medium temperature placed within an enclosure or a closed system. This change in temperature is due to the presence of exothermic phenomena, chemical or physical transformations, whose calorific power is not eliminated by a cooling system or is greater than the quantity of heat evacuated to the outside.

The reaction medium can lose control of temperature in the following cases:

1. Due to the exothermic chemical reactions (main or secondary, desired or not).
2. When it is composed of substances which are brought to a temperature higher than their decomposition temperature.
3. When it is composed of substances whose decomposition is autocatalytic.
4. When it is the seat of a gas-producing reaction.

5.6 BLEVE:

5.6.1 Definition and description:

The BLEVE is an acronym for Boiling Liquid Expanding Vapour Explosion and this term was invented in 1957 by three researchers from the Factory Mutual: James Smith, William Marsch and Wilbur Walls, following the rupture of a phenol tank that was superheated. The BLEVE can be defined as a major container failure in two or more pieces, at a moment in time when the contained liquid is at a temperature well above its boiling point at normal atmospheric pressure. The BLEVE is also defined as the explosive release of expanding vapour and boiling liquid when a container holding a pressure liquefied gas fails catastrophically.

A BLEVE happens when a reservoir containing a liquid (most of the time a pressure liquefied gas) is submitted to an aggression that results in the reservoir rupture. The rupture of the reservoir can be thermal due to wall thinning and/or fissures induced by an increase of the reservoir wall temperature and internal pressure, or mechanical due to an impact. When the reservoir opens due to rupture, the vapour expands and the liquid becomes superheated, triggering the liquid boiling. In addition, a blast wave is generated, and the loss of containment of the reservoir can lead to fragment projections.

The reservoir rupture is not always leading to the formation of a fireball. But if the liquid is flammable, the fluid released, mixed with air can be ignited by a heat source and can form a fireball. If the ignition is delayed, it can also lead to a flash fire or a vapour cloud explosion (VCE). If the liquid is not flammable but toxic, the released content disperses in the atmosphere.

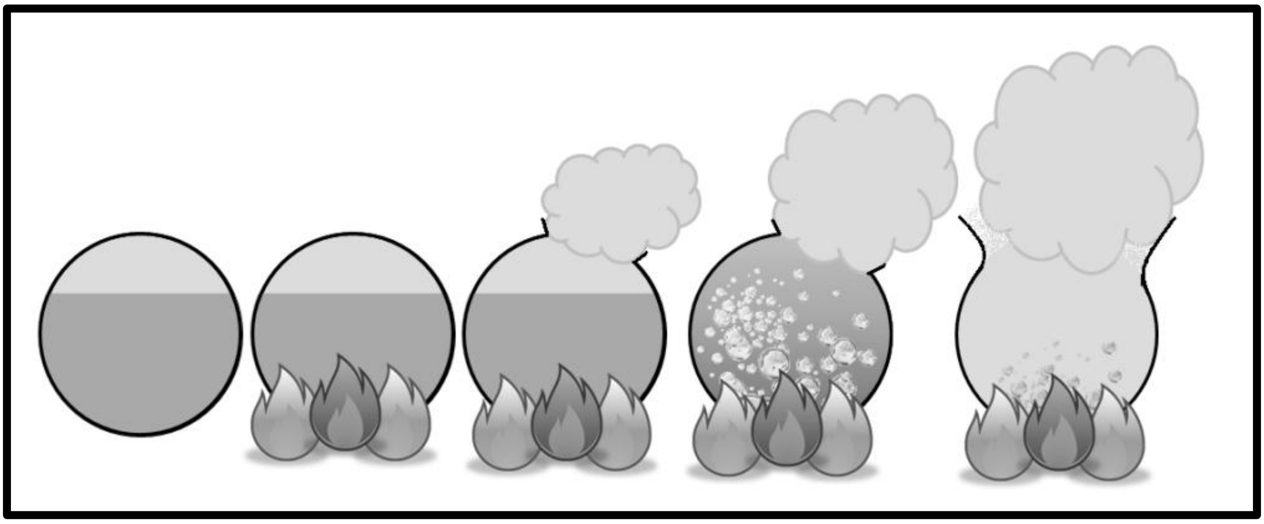

Fig 1.5: Schematic of BLEVE phenomenon (29)

5.6.2 BLEVE hazards:

BLEVE phenomenon has three major consequences:

- The formation and evolution of a fireball.
- The generation and propagation of a blast wave.
- The fragment projection.

5.7 Boil-over:

Most of the hydrocarbon atmospheric reservoirs contain a water layer due to condensation effects, drilling and transport or from the natural composition of the oil. If by accident, a fire starts at the fuel surface, the flame progressively heats the fuel and consequently the water layer until the water starts to boil and expels the fuel from the reservoir. Different names are given to the fuel ejection, as sketched in Fig 1.6; a Slopover is a discontinuous frothing over of the fuel on one side of the tank and a Frothover is a continuous and low-intensity frothing of the burning material. Nevertheless, the most dangerous fuel ejection is the Boilover that induces violent fuel ejections, flame enlargement and possible formation of fireballs.

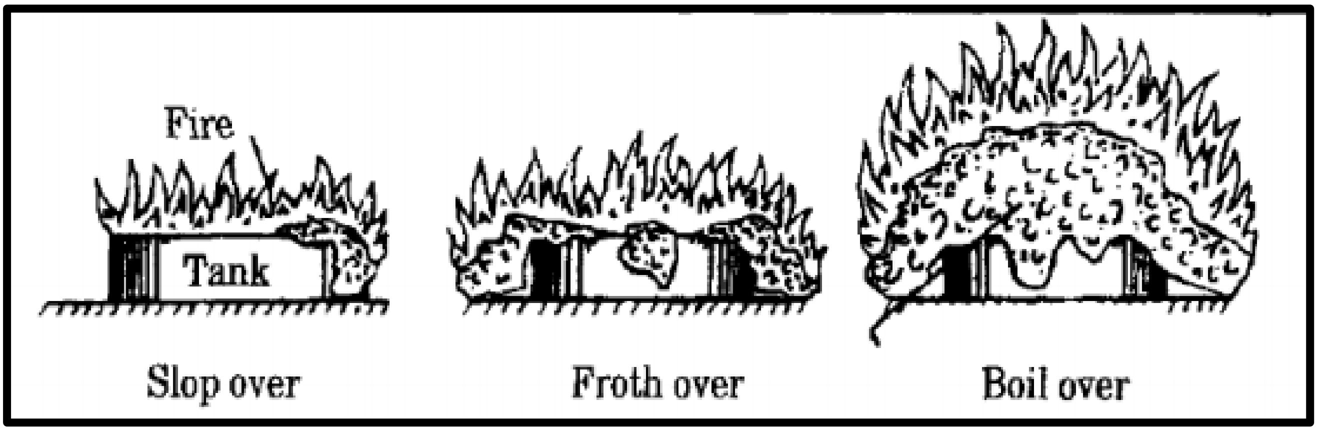

Figure 1.6: Different types of fuel ejection from pool fire burning (29)

5.7.1 Basic principle:

The Boil-over phenomenon is defined as a violent ejection of fuel due to the vaporization of a water sub-layer, resulting in an enormous fire enlargement and formation of fireball and ground fire, as schematized in the Fig 1.7 :

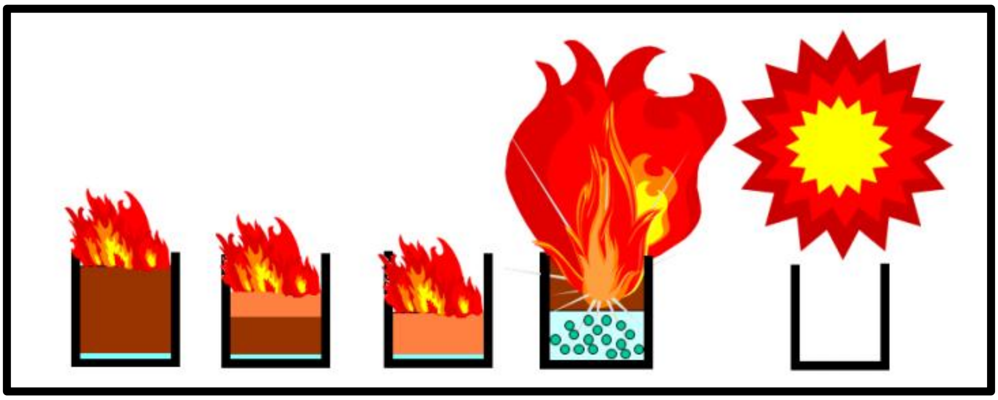

Figure 1.7: Schematic of BOILOVER phenomenon (29)

A Boil-over appears with the burning of oil viscous enough to enable formation of froth, the presence of a water sub-layer, and the apparition of a zone of nearly constant temperature inside the fuel. This so-called hot-zone has an expansion rate higher than the burning rate of the hydrocarbon free surface and therefore enhances the heat propagation downwards the water layer, decreases the time of Boil-over apparition, and increases the intensity of consequences which mainly consist in flame enlargement and radiation increase. If the fuel nature or the configuration of the reservoir does not lead to the formation of a hot-zone, the temperature gradient at the fuel-water interface is decreased and a larger part of the fuel is burnt before water vaporization.

Consequently, lower intensity of consequences (i.e. flame enlargement and radiation increase) is observed. But even if the consequences of a thin-layer Boil-over (Boil-over without hot-zone) are of lower intensity, the impact in terms of flame enlargement and radiation is also important.

The Boil-over phenomenon can be divided in three different periods, from the ignition of the fuel surface to the end of the fuel burning after Boil-over:

1. Quasi-steady period: This period starts after the ignition of the fuel surface and a small induction period where the flame propagates along the whole fuel surface. The pool fire is burning in a regular way, with very few influence of the water sub-layer. The flame is stable and the fire properties like the burning rate or the flame size are constant with time. During this period, the fuel layer in combustion progressively heats the water sub-layer.
2. Premonitory period: Once the water layer temperature is getting close to the boiling point, water bubbles develop at the fuel - water interface. They escape from the interface, pass through the fuel layer, and erupt from the fuel surface into the flame zone as oil-water dissolution droplets. The combustion of these oil-water bubbles emits a crackling sound.
3. Boil-over period: When the water vaporization is strong enough to push the fuel layer, the Boil-over starts, and the burning fuel is sprayed out of the tank and the flame height increases significantly and quickly. The flame increase and the violent water vaporization also emit noise, with stronger amplitude than the micro-explosion noise.

6. Toxic release hazards:

A toxic release is an uncontrolled or illegal acute release of any toxic substance, this can happen wilfully or accidently which is in this case more dangerous and must be taken in consideration in order to avoid its negative effects and mitigate the consequences.

6.1 General definitions:

6.1.1 Toxic substances: The toxicity of a substance is its capacity to cause injury once inside the body. The main modes of entry into the body by chemicals in industry are inhalation, ingestion and absorption through the skin. Gases, vapours, mists, dusts, fumes and aerosols can be inhaled and they can also affect the skin, eyes and mucous membranes. Ingestion is rare although possible because of poor personal hygiene, subconscious hand-to-mouth contact, or accidents.

6.1.2 Toxicity: "means how much of the substance is required to cause harm" (20).

6.1.3 Dose: "means how much of the toxic substance enters the body" (20).

In general, the greater the amount of a substance that enters a body, the greater is the effect on it. This connection between amount and effect is called the dose-response relationship.

6.1.4 Duration: "is the length of time the body is exposed" (20).

The longer a body is exposed to a chemical, the more likely it is to be affected by it. Chemical exposure which continues over a long period can be particularly hazardous because some chemicals can accumulate in the body or because the health damage does not have a chance to be repaired.

6.1.5 Reaction and interaction: other substances the body is exposed to at the same time.

6.1.6 Sensitivity: "how your body reacts to the substance compared to other people" (20).

6.1.7 Exposure limits: Exposure limits are established by Health and Safety authorities to control exposure to hazardous substances. Exposure limits usually represent the maximum amount (concentration) of a chemical which can be present in the air without presenting a health hazard. However, exposure limits may not always be completely protective, for the following reasons:

1. Although exposure limits are usually based on the best available information, this information, particularly for chronic (long-term) health effects, may be incomplete.
2. Exposure limits are set to protect most workers. However, there may be some workers who will be affected by a chemical at levels below these limits.
3. Exposure limits do not take into account chemical interactions. When two or more chemicals in the workplace have the same health effects, industrial hygienists use a mathematical formula to adjust the exposure limits for those substances in that workplace. This formula applies to chemicals that have additive effects.
4. Limiting the chemical concentration in air may not prevent excessive exposure through skin contact or ingestion.

6.2 Routes of exposure:

"This defines how the substance enters the body" (20).

6.2.1 Inhalation: The most common type of exposure occurs when you breathe a substance into the lungs. Some chemicals are irritants and cause nose or throat irritation.

They may also cause discomfort, coughing, or chest pain when they are inhaled and come into contact with the bronchi (chemical bronchitis). Other chemicals may be inhaled without causing such warning symptoms, but they still can be dangerous.

6.2.2 Absorption: The skin is a protective barrier that helps keep foreign chemicals out of the body. However, some chemicals can easily pass through the skin and enter the bloodstream. If the skin is cut or cracked, chemicals can penetrate through the skin more easily. In addition, some caustic substances, like strong acids and alkalis, can chemically burn the skin. Others can irritate the skin. Many chemicals, particularly organic solvents, dissolve the oils in the skin, leaving it dry, cracked, and susceptible to infection and absorption of other chemicals.

6.2.3 Ingestion: The least common source of exposure in the workplace is swallowing chemicals. Chemicals can be ingested if they are left on hands, clothing or beard, or accidentally contaminate food, drinks or cigarettes. Chemicals present in the workplace as dust, for example, metal dusts such as lead or cadmium, are easily ingested.

6.3 Types of toxic chemicals:

6.3.1 Irritant chemicals: Primary irritants cause inflammation. Inflammation is one of the body's defence mechanisms. It is the reaction of a tissue to harm which is insufficient to kill the tissue and is typified by constriction of the small vessels in the affected area, dilation of the blood vessels, increased permeability of the vessel walls, and migration of the white blood and other defensive cells to the invading harmful chemical.

The aim is to concentrate water and protein in the affected area to 'dilute' the effect and wash away the chemical. Production of new cells is speeded up and contaminated surface cells are shed.

6.3.2 Sensitizers: Generally, sensitizers may not on first contact result in any ill effects, although cellular changes can be induced and the body's immune system affected. Subsequent exposures to the same, or related, chemicals may bring about violent allergic responses: the person has become sensitized. Generally, there is no mathematical relationship between the degree of exposure and the extent of the response.

6.3.3 Asphyxia products: Asphyxia products interfere with the body's oxygen uptake mechanisms. Air normally contains 21%oxygen. Oxygen deficiency in inhaled air, e.g. due to the presence of nitrogen, argon, or carbon dioxide in a confined space, depending on the concentration and duration, may affect the body and ultimately cause death from simple anoxia.

Levels below 19.5% oxygen can have detrimental effects if the body is already under stress, e.g. at high altitudes. Exposures below 18% should not be permitted under any circumstance.

6.3.4 Anesthetics and narcotics: Anaesthetics and narcotics, e.g. hydrocarbons and certain derivatives such as the various chlorinated solvents or ether, exert a depressant action on the central nervous system.

6.3.5 Systemic poisons: Systemic poisons attack organs other than the initial site of contact. The critical organs are the kidneys, liver, blood and bone marrow.

6.3.6 Respiratory fibroses: The hazard of particulate matter is influenced by the toxicity, size, and morphology of the particle. The critical size of dust (and aerosol) particles is 0.5 to 7 µm, since these can become deposited in the respiratory bronchioles and alveoli. If dust particles of specific chemicals, e.g. silica or the various grades of asbestos, are not cleared from the lungs then, over a period, scar tissue (collagen) may build up; this reduces the elasticity of the lungs and impairs breathing. The characteristic disease is classified as pneumoconiosis. Common examples are silicosis, asbestosis, coal pneumoconiosis and talc pneumoconiosis.

6.3.7 Carcinogens: Cancer is a disorder of the body's control of the growth of cells. The disease may be genetic or influenced by life style or exposure to certain chemicals, termed carcinogens.

6.4 What are the differences between acute and chronic effects?

6.4.1 Acute:

- Occurs immediately or soon after exposure (short latency).
- Often involves a high exposure (large dose over a short period).
- Can be minor or severe. For example, a small amount of ammonia can cause throat or eye irritation; higher concentrations can cause serious or even fatal lung damage.
- Relationship between chemical exposure and symptoms is generally, although not always, obvious.
- Knowledge often based on human exposure.

6.4.2 Chronic:

- Occurs over time or long after exposure (long latency).
- Often involves low exposures (small and repetitive doses) over a long period.
- Often involve inflammation and scarring of organs, such as the lung or kidney. Chronic effects are still unknown for many chemicals. For example, most chemicals have not been tested in experimental animals for cancer or reproductive effects.
- It may be difficult to establish the relationship between chemical exposure and illness because of the long time delay or latency period.
- Knowledge often based on animal studies.

6.5 The different forms of toxic materials:

6.5.1 Solid: A solid is a material that retains its form, like stone. Solids are generally not hazardous since they are not likely to be absorbed into the body, unless present as small particles such as dust, fumes, fibres, and nanoparticles.

6.5.2 Liquid: A liquid is a material that flows freely, like water. Many hazardous substances are in liquid form at normal temperatures. Some liquids can damage the skin. Some pass through the skin and enter the body, and may or may not cause skin damage. Liquids may also evaporate, producing vapours or gases which can be inhaled.

6.5.3 Gas: A gas is a substance composed of unconnected molecules, such that it has low density and no shape of its own, like air. Gases mix easily with air (air itself is a mixture of nitrogen, oxygen, and other substances). Some gases, like carbon monoxide, are highly toxic. Others, like nitrogen, are not toxic but can displace the air in a confined space, causing suffocation due to lack of oxygen; these are called asphyxiate gases.

6.5.4 Vapour: A vapour is the gas form of a substance that can also exist as a liquid at normal pressure and temperature. Most organic solvents evaporate and produce vapours. Vapours can be inhaled into the lungs, and in some cases may irritate the eyes, skin, or respiratory tract. Some are flammable, explosive, and/or toxic. The terms vapour pressure and evaporation rate are used to indicate the tendency for different liquids to evaporate.

6.5.5 Dust: A dust consists of small solid particles in the air or on surfaces. Dusts may be created when solids are pulverized or ground. Dusts may be hazardous because they can be inhaled into the respiratory tract. Larger particles of dust are usually trapped in the nose where they can be expelled, but smaller particles (respirable dust) can reach and may damage the lungs. Some, like lead dust, may then enter the bloodstream through the lungs. Some dusts, such as grain dust, may explode when they reach high concentrations in the air.

6.5.6 Fume: A fume consists of very small, fine solid particles in the air which forms when solid chemicals (often metals or plastics) are heated to very high temperatures, evaporate to vapour, and combine with oxygen. The welding or brazing of metal, for example, produces metal fumes. Fumes are hazardous because they are easily inhaled, and have a large surface area in contact with body tissues. Some metal fumes can cause an illness called metal fume fever, consisting of fever, chills, and aches like the "flu." Inhalation of other metal fumes, such as lead, can cause poisoning without causing metal fume fever.

6.5.7 Fibre: A fibre is a solid particle whose length is at least three times its width. The degree of hazard is affected by the size of the fibre. Smaller fibres, such as asbestos, can reach the lungs and cause serious harm. Larger fibres may be trapped in the upper respiratory tract, and are expelled without reaching the lung.

6.5.8 Mist: A mist consists of liquid particles of various sizes which are produced by agitation or spraying of liquids. Mists can be hazardous when they are inhaled or sprayed on the skin. The spraying of pesticides and the machining of metals using metal working fluids are two situations where mists are commonly produced.

6.5.9 Nanoparticles: These extremely small particles, measuring 1 - 100 nanometers in diameter, are engineered for useful properties that differ from ordinary materials. Airborne nanoparticles are easily inhaled and absorbed into the bloodstream, nervous system, and other organs. Absorption through the skin is also possible. Because of their relatively large surface area, nanoparticles have a high hazard potential relative to their weight.

Conclusion:

At the end of this chapter we could clearly see the importance of accident prevention which provides a significant gain including money, reputation and avoiding legal prosecutions or loss of people's life, otherwise Neglect will result in several accidents, in most times catastrophic, which we have seen in detail during this chapter. Fire was one of the hazards presented in order to understand its physic-chemical properties including its spreading forms, composition and its severe effect on the company if occurs, we will see in the following chapters how to prevent the occurrence of fire and also how to mitigate the consequences if accidently happens.

Explosions are similar to fire but have a stronger effect and cause greater loss, they have so many forms depending on the causation event, and each type needs special technical control measures in order to avoid its happening. Finally in this chapter we understood the basics of toxic releases hazard and the effects of hazardous substances when get in contact with the human's body by different routes of exposure.

CHAPTER II

PROCESS HAZARDS PREVENTION

Chapter 2: Process hazards prevention

Introduction:

Hazard prevention is the technique of anticipating and controlling events so that accidents are avoided and the consequent damaging results do not occur. This technique covers a very wide field, dealing, as it does, with the design of the process and equipments, thus ensuring the correct control systems are in operation.

There are many hazards in process industries that can lead to loss of containment, fires or explosions resulting in an impact on health, safety, environment and plant assets. Process safety is best achieved by an intrinsic safety process design. However, when this is not practical or not possible, combined protective systems are required to mitigate the risk of hazards to an acceptable level. Protective systems may be implemented using different technologies such as mechanical, chemical, pneumatic, hydraulic, electric, electronic or programmable electronic. Those cover all residual risks identified and known as Safety Instrumented System (SIS).

1. Engineering design for process safety.

Engineering design for process safety is so significant so it must be an integral part of the life cycle of a facility. Identifying and addressing relevant process safety standards, codes, regulations, and laws over the life of a process are essential parts of committing to process safety. The primary objective is to ensure that process facilities remain in conformance with applicable standards, codes and regulations, and a company's internal standards and policies over the life of the facility.

The design solutions presented in this chapter are established and offered well proven approaches for mitigating the failure scenarios. However, a potential design solution is false protection and can contribute to hazards if it is not reliably engineered and maintained. The design should also take into account the need for periodic inspection and proof testing.

In this chapter we will assume that material of construction should be specified and selected to minimize corrosion, because external visual inspection would be difficult and interior visual inspection would be expensive and would increase downtime. The primary methods of preventing corrosion under wet insulation are preventing the entry of water into the system and protecting the surface of the piping or equipment.

Since no insulation system can be presumed to be waterproof, protective coatings are extremely important in preventing corrosion. Methods to reduce corrosion under insulation are:

- Avoid direct contact between dissimilar metals by coating the parts with insulating coatings or petrolatum tape to minimize galvanic corrosion.
- Avoid primary reliance on mastic seals and caulking as a weather barrier, both of which tend to dry with age and exposure to elevated temperatures.
- Design weather-proofing jacketing such that natural runoff will occur.
- Ensure inspection ports which are designed for water-tight construction are available to allow for corrosion inspection of the substrate.
- Prime and paint carbon steel lines prior to insulation and sealing.

It is further assumed that the facility has adequate safe work practices, which encompass hot work permits, confined space entry, ignition control, lockout / tag out, etc.

1.1 Equipment design:

In this part of the chapter we will try to determine the most significant design considerations for some of the process equipments including vessels and reactors.

1.1.1 Vessels: The process conditions of a vessel will influence all activities that contribute to the safe operation of the vessel. Therefore, the following conditions must be taken in consideration:

- During the design phase, special attention is required to define vessel design parameters properly. Codes and standard practices are available to address design pressures and temperatures thermal stress, and external loads such as wind, snow, and earthquake.
- Rapid cyclic heating of vessels is not desirable since this may cause local cracking of material. Minimum design metal temperatures dictate impact test requirements for materials in cold service.
- Faulty fabrication, for example, poor welding, improper heat treatment, dimensions outside tolerances allowed, or improper assembly, may cause problems to develop in pressure vessels.

- Internal components such as baffles, agitators, and trays should be installed in such a manner that liquid and vapours are not trapped, which might prevent them from being drained or vented from the vessel.

1.1.2 Reactors: Some of the considerations which must be taken in the design phase are:

- For reactors fabricated of metal (not glass-lined), it is recommended that a minimum design pressure of 50 psig be specified, even if the operating pressure is atmospheric.
- Reactors should be provided with overpressure relief protection.
- a malfunction detector could be installed
- Heat removal systems should be designed with all anticipated abnormal operating conditions taken into account.

1.2 Safeguard design:

Safeguard design involves two very important concepts:

- The safeguard being installed will work under existing process conditions.
- The safeguard does not create new hazards.

In the first case, it is important that safeguards are installed so that they can be tested and maintained. Facilities may have a false sense of trust, particularly management, believing that everything is safe because there are many safeguards.

In the second case, a poorly planned safeguard can create hazards. An example is a Safety Instrumented System (SIS) installed to stop the flow to a process vessel to prevent overfilling. When the SIS actuates an isolation valve, the pump providing feed to the vessel could deadhead, resulting in seal failure and loss of containment. To avoid this situation, the SIS should have activated shutdown of the feed pump or an automatic spillback (recycle) could be provided on the pump to satisfy minimum flow requirements.

1.3 Safety design to prevent toxic releases:

Approaches to the design of inherently safer processes and plants have been grouped into four major strategies:

1- Minimize and Reduce quantities of hazardous substances.
2- Substitute Replace a material with a less hazardous substance.

3- Moderate Use less hazardous conditions, a less hazardous form of a material, or facilities that minimize the impact of a release of hazardous material or energy.
4- Simplify Design facilities which eliminate unnecessary complexity and make operating errors less likely and which are forgiving of errors that are made.

These four strategies form a protocol by which the risks associated with loss of containment of hazardous materials or energy can be significantly reduced and in some cases eliminated. The elimination of risk due to loss of containment is very difficult, if not impossible to achieve using other risk reduction measures, i.e., active or passive safeguards. These measures, while effective if installed and maintained properly, generally reduce the likelihood of release and sometimes will mitigate the consequences of a release. However, they cannot reduce the risk to zero. However, while they are highly effective techniques, it is usually not possible to eliminate all process related risks since the properties that make a material hazardous are often the same properties that make it useful.

1.4 Asset management:

1.4.1 Consideration of integrity standards:

Whenever process equipment is designed or specified, it is essential that all of the intended activities are considered (e.g. not only must a pump be fit-for-purpose, but it supplies at the required pressure and flow rate. It must be also suitable for the substance that it is transporting, be able to be cleaned and isolated (chemically, electrically and mechanically) for maintenance, safely removed and reinstated). When specifying equipment, consideration should be given to design standards, such as EN standards, or process safety standards, such as pipe pressure ratings or welding standards. This means that expert advice may be needed to ensure that the correct decisions are made at the design stage.

If assets are not maintained correctly, this can result in defects and failures that can have serious health and safety implications. For example:

- Damaged, wearing or defective equipment can fail and cause leaks;
- Equipment can fail, which can affect the performance of the process plant, e.g. failure of a hot oil system could cause the process to fail; loss of a cooling system could result in a runaway reaction;
- Process plant will become ineffective and production will suffer;
- Safety systems, such as fire suppression, may fail to operate correctly when required.

1.4.2 Selection of equipment for the operating environment:

Some operating environments are such that use of the incorrect equipment can cause serious safety implications. For example, in a potentially flammable atmosphere where vapours or dusts can result in fire or explosion, the selection of the correct ATEX approved equipment is essential.

In other circumstances, the atmosphere may damage the equipment. For example, equipment used outside should be correctly rated for water resistance and in an atmosphere where there could be corrosive chemicals present, or even salty atmospheres, then any exposed metalwork could become corroded unless treated.

1.4.3 Asset integrity throughout the life cycle:

The life-cycle phases of the asset integrity management system are defined as follows:

Phase 1 – Design: The objective is to design for safety and integrity throughout the life cycle of the process. This will require actions such as:

- Safety studies;
- Maintenance and inspection strategies;
- Design, maintenance, inspection and operation philosophies;
- Design review by verifier.

Phase 2 - Procurement, construction, installation and testing (Pre-commissioning): The objective is to build in accordance with the design and with quality assurance to ensure that the build is completed correctly. Key actions include:

- Developing purchasing and quality plans;
- Obtaining inspection and test records;
- Document completion and handover.

Phase 3 – Commissioning: The objectives include functional testing to demonstrate that the design standards were achieved and that the process performs as intended. Key actions include:

- Commissioning and functional testing against design standards;
- Sign-off of tests by commissioning engineers;
- Verification by an external competent person.

Phase 4 – Operations: The objective here is to operate the plant within design intent. Key deliverables include:

- Ongoing risk assessment;
- Maintenance and inspection;
- Monitoring of control measures;
- Verification.

Phase 5 – Modifications: The objective is to ensure that modifications are carried out in a planned, properly-documented and risk-assessed manner, including identifying additional hazards and potential effects on operating and maintenance procedures, written schemes of examinations, as well as additional measures/actions are taken to ensure risks remain as low as is reasonably practicable. Key deliverables here hinge on the use of an appropriate management of change process (covered elsewhere in this element).

Phase 6 – Decommissioning: This would entail the removal of the installation from operation. Key deliverables here would include:

- Safety studies;
- Development of decommissioning strategies;
- Development of a decommissioning plan.

1.5 Safety design for BLEVE prevention:

The first recommendation would be to use the different models that can give a first idea of the rupture conditions and consequences of a BLEVE, for a given reservoir configuration.

Secondly, the blast wave shows a directivity effect, created by the cylindrical shape of the reservoir. Therefore, the orientation of the reservoir has to be chosen in order to have the facilities that need to be protected located preferably on the ends of the reservoir where the overpressure is smaller than on the sides where the overpressure is larger.

Finally, even if the cloud created by the fluid ejection does not ignite, it can be ignited after the rupture if a spark or another kind of ignition source is present. Therefore, limiting the presence of potential ignition source close to the reservoirs in the design and the installation phase can allow avoiding the generation of a vapour cloud explosion.

1.6 Safety design for BOILOVER prevention:

The reservoir configuration can increase the Boil-over apparition time, leaving more time for the emergency response. To increase the Boil-over apparition time, it is interesting to:

- Increase the lip height (decreasing the burning rate).
- Increase the fuel thickness.
- Decrease the wall conduction (by increasing the size of the reservoir or by using less conducting materials).
- Avoid placing some metal structure inside the reservoir (like the thermocouple rake that is heating the fuel).

Concerning the reduction of the Boil-over consequences, increasing the Boil-over apparition time consequently decreases the fuel quantity available for the flame enlargement.

2. Safety Instrumented System (SIS).

Safety instrumented systems (SISs) have been used for many years to perform safety instrumented functions (SIFs) in the process industries. In other words safety instrumented systems perform a critical role in providing safer and more reliable process operations. So if instrumentation is to be effectively used for SIFs, it is essential that this instrumentation achieves certain minimum standards and performance levels.

2.1 Terms and Definitions:

2.1.1 Safety Instrumented System (SIS):

"The Safety Instrumented System (SIS) includes all devices necessary to carry out each SIF from sensor(s) and logic solver to final element(s)" (21)

"A SIS may include software" (21)

"A SIS may include human action as part of a SIF" (21)

So a Safety Instrumented System is a system that provides an independent and predetermined emergency shutdown path in case a process runs out of control and poses a real risk for persons and environment (explosion, fire…).

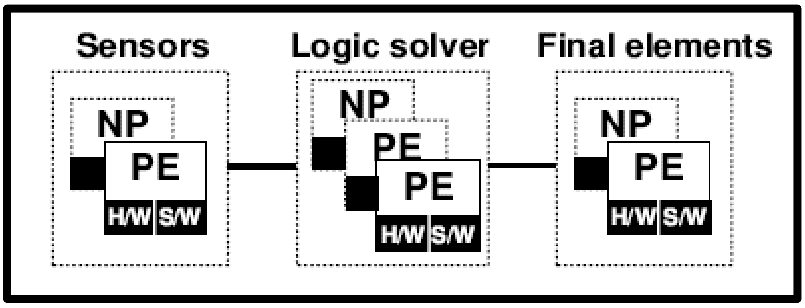

Figure 2.1: Structure of safety instrumented system (21)

2.1.2 Safety Instrumented System components:

1-Sensor: Is a device which delivers, from a physical quantity, another quantity, often electrical (voltage, current, resistance), used for the measurement or the command. This physical quantity can be the temperature, the pressure, the level, the flow rate, the concentration of a gas.

2-Processing unit (logic solver): The "processing" function can be more or less complex. It can be reduced to acquiring a quantity measured by a sensor and indicating it. She can also consist in activating the control of one or more actuators on the basis of a combinatorial function of the information delivered by different sensors. Processing units can be classified into two categories according to their technology:

- Wired technologies, based on elementary logic components (relays), linked together electrically (or pneumatically).
- Programmed technologies, based on data acquisition or alarm units, programmable logic controllers, digital control systems, industrial computers or electronic cards with microprocessors.

3- Actuators: An actuator can be (valve, motor, servo-motor, etc.) transforming a signal (electrical or pneumatic) into a physical phenomenon which makes it possible to control the starting of a pump, the closing or opening of a valve, etc. driving energy, we say pneumatic, hydraulic or electric actuator.

Finally, the processing unit is connected to the sensors and to the actuators by transmission means. These can be electric cables, telephone lines, radio waves (transmission by walkie-talkie, etc.), or pipes (pneumatic or hydraulic transmission). The sensors, the controller and the actuators are safety equipment. Safety equipment is an element of a SIS that performs a safety sub-function. Examples:

- A sensor fulfils the "detect gas" sub-function,
- A motorized valve fulfils “stops a leak” sub-function.

Associated with the processing, all these sub-functions allow the realization of the "control a leak" safety instrumented function

All components of a SIS are selected, designed, installed, maintained and tested to achieve the specified risk reduction for each SIF. The SIS can fail to provide risk reduction due to failure of components or systematic failures resulting from human errors of commission.

To minimize SIS failures:

- Selected SIS components are reliable and suitable for the service and environment in which they are operated, and
- A management system is implemented to verify and assure that systematic failures are minimized across the SIS lifecycle.

2.1.3 Safety Instrumented Functions (SIF): There are two definitions:

Safety Instrumented Functions (SIF) are protective functions implemented in a Safety Instrumented System (SIS). A typical SIS is comprised of multiple SIFs; typically, each SIF has process sensors that measure a process deviation, a logic solver that executes the functional logic, and final control elements (e.g. valves, pumps) that bring the process to a safe state (22).

A SIF is designed to achieve a required SIL which is determined in relationship with the other protection layers participating to the reduction of the same risk (21).

2.1.4 Basic Process Control System (BPCS):

System which responds to input signals from the process, its associated equipment, other programmable systems and/or operators and generates output signals causing the process and its associated equipment to operate in the desired manner but which does not perform any SIF. In other words; a BPCS includes all of the devices necessary to ensure that the process operates in the desired manner (21).

2.1.5 Safety integrity:

It is the ability of the SIS to perform the required SIF as and when required. Safety integrity comprises hardware safety integrity and systematic safety integrity (21).

2.1.6 Safety integrity level (SIL):

Discrete level (one out of four) allocated to the SIF for specifying the safety integrity requirements to be achieved by the SIS (21).

Note: SI L 4 is related to the highest level of safety integrity; SIL 1 is related to the lowest.

2.1.7 Safety integrity requirements:

"Requirements which shall be satisfied by a SIS to claim a given SIL for a SIF implemented by this SIS" (21).

2.1.8 Safety requirements specification (SRS):

"Specification containing the functional requirements for the SIFs and their associated safety integrity levels".

2.1.9 Functional safety: It can be defined as following:
"Functional safety is part of overall safety that depends on the proper functioning of a system or equipment in response to its inputs" (23).

"Part of the overall safety relating to the process and the BPCS which depends on the correct functioning of the SIS and other protection layers" (21).

So the purpose of functional safety is to control unacceptable risks that could lead to dangerous accidents. It covers systems implementing protection solutions applied in several fields: mechanical, electrical, electronic, programmable electronics, hydraulics...

2.2 Standards relating to Safety Instrumented Systems:

2.2.1 IEC 61508 standard:

In 1984, IEC Technical Committee 65 began a task of defining a new international standard for safety. This standard IEC 61508 is the only multi-sectoral standard dealing with the whole problem of systems electrical, electronic and programmable E / E / EP; related to safety, it deals with both hardware and software. It is also the only technical standard that provides keys, which you only need to comply with achieving a goal. This standard lets the user to carry out his risk analysis and suggests ways to reduce this risk. It does not concern simple systems, for which the failure mode of each element is clearly defined and for which the System behaviour can be fully determined in the event of a failure. By example, a system comprising limit switches and electromechanical relays connected to a circuit breaker can be designed without having recourse to IEC 61508. The IEC 61508 standard is based on two concepts that are fundamental to its application: the life cycle in safety and safety integrity levels.

It comprises 7 parts:

- 61508-1: General requirements.
- 61508-2: Requirements specific to E / E / PE systems.
- 61508-3: Requirements relating to the software.
- 61508-4: Definitions and abbreviations.
- 61508-5: Examples of methods to determine the level of security integrity.
- 61508-6: Guides for the application of parts 2 and 3 of the standard.
- 61508-7: Overview of techniques and measures.

The IEC 61508 standard is the basis for other sectoral standards (e.g.: machines, processes continuous, rail, nuclear) or products (e.g.: variable speed drives). It therefore influences the development of E / E / PE systems and products concerned with safety across all sectors.

Figure 2.2: IEC 61508 standard and its girls' standards by sector of activity

2.2.2 IEC 61511 standard:

The IEC 61511 sector standard concerns safety instrumented systems for the process industry sector. This standard presents an approach to activities linked to the safety life cycle, to meet these minimum standards. This approach was adopted in order to develop a rational and coherent technical policy. Most of cases, the best safety is achieved by a safety process design intrinsic, whenever possible, combined, if necessary, with other systems of protection, based on different technologies (chemical, mechanical, hydraulic, pneumatic, electric, electronic, programmable electronics) and which cover all residual risks identified. It consists of three parts:

1. IEC 61511-1: Framework, definitions, system, hardware and software.
2. IEC 61511-2: Guidelines for the application of IEC 61511-1.
3. IEC 61511-3: Guidance for determining the required levels of safety integrity.

This standard makes it possible to define requirements relating to specifications, design, installation, operation and maintenance of a SIS, in order to have all confidence in its ability to bring the process to a safe state. IEC 61511 restricts the scope to systems for SIL 1 to 3 (SIL 4 applications cannot be processed by a SIS alone). The applications that require the use of a safety integrity level SIL 4 is rare in the process industry. These applications should be avoided because of the difficulty in achieving and maintaining such high levels of performance while throughout the safety life cycle.

2.2.2.1Utilisation of IEC 61511 in system design:

Compliance with the IEC 61511 standard series will help assure reliable and effective implementation of SIS to achieve risk reduction objectives, thereby improving process safety. Users in the process industry should use this standard series to develop their internal procedures, work processes, and management systems which provide a framework for managing people, processes, and systems to improve overall safety and operational performance.

2.2.3 IEC 62061 standard:

IEC 62061 is based on the same concepts as those of IEC 61508. It is intended for the use by machine designers and manufacturers of electronic control systems relating to machine safety. It concerns the specification of prescriptions and makes recommendations for the design, integration and validation of these systems.

2.2.4 IEC 61513 standard:

IEC 61513 [IEC61513 01] concerns the nuclear power plant safety sector. It presents the requirements relating to the control systems used for performing the safety functions of nuclear power plants. The design of the control can be achieved using a combination of components traditional wired to computer components. Compliance with IEC 61513 facilitates compatibility with the requirements of IEC 61508 as interpreted in the nuclear industry.

2.2.5 The EN 50126 standard:

The EN 50126 [EN50126 99] standard is mainly concerned with applications railways. It allows specifying the main concepts of dependability .systems such as: reliability, availability and security.... This standard is constituted of two daughter standards. EN 50128 [EN50128 01] is intended for the software part of railway protection systems. EN 50129 [EN50129 98] concerns systems electronic security for signalling [SAL 07].

2.3 SIS safety life-cycle:

Necessary activities involved in the implementation of SIF occurring during a period of time that starts at the concept phase of a project and finishes when all of the SIF are no longer available for use (21).

SIS safety life-cycle according to IEC 61511-1:

1- Hazard and Risk Analysis (H&RA): To determine the hazards and hazardous events of the process and associated equipment, the sequence of events leading to the hazardous event, the process risks associated with the hazardous event, the requirements for risk reduction and the safety functions required achieving the necessary risk reduction.

2- Allocation of safety functions to protection layers: To determine the required SIFs and the associated safety integrity requirements for each SIF.

3- SIS safety requirements specification: To specify the requirements for each SIS, in terms of the required SIF and their associated safety integrity, in order to achieve the required functional safety.

4- SIS design and engineering: To design one or multiple SIS to meet the requirements for SIF and their associated safety integrity.

5- SIS application program development: To define the requirements for the development of the application program.

6- Factory acceptance test (FAT): To test the devices of the SIS to ensure that the requirements defined in the SRS are met.

7- SIS installation and commissioning: To install the SIS according to the specifications and drawings; and then commission the SIS so that it is ready for final system validation.

8- SIS validation: To validate, through inspection and testing, that the installed and commissioned SIS and its associated SIF(s) achieve the requirements as stated in the SRS.

9- SIS operation and maintenance: To ensure that the required SIL of each SIF is maintained during operation and maintenance. Moreover, that the SIS is operated and maintained in a way that sustains the required safety integrity.

10- SIS modification: To make corrections, enhancements or adaptations to the SIS, ensuring that the required SIL is achieved and maintained despite of any changes made to the SIS.

11- Decommissioning: prior to decommissioning any SIS from active service, a proper review is conducted and required authorization is obtained, also we have to ensure that the required SIF(s) remain operational during decommissioning activities.

12- SIS verification: To test and evaluate the outputs of a given phase to ensure correctness and consistency with respect to the products and standards provided as input to that phase.

13- SIS functional safety assessment FSA: investigation, based on evidence, to judge the functional safety achieved by one or more SIS and/or other protection layers.

14- Safety lifecycle structure and planning: To establish how the lifecycle steps are accomplished.

2.4 Properties of a SIS:

A number of properties characterize safety instrumented systems:

- Safety instrumented systems require an external energy source to fulfil their safety function.
- Several sensors or actuators can be linked to a single processing unit.
- All combinations of sensors, processing units and actuators that are required to perform safety functions are considered as part of safety instrumented systems.
- The sensors, the processing unit, the final elements are safety equipments and perform safety sub-functions. All of the sub-functions perform the safety function.

2.4.1 The main characteristics of a Safety Instrumented System (SIS):

The good SIS takes a new approach to help reducing risks and use the intelligence embedded in the sensors and logic solvers to increase safety. The following are the most important characteristics of a SIS in order to reach best level of functional safety:

1- Risk Reduction: The ideal SIS begins with field devices. Smart field devices:

- Proactively communicate maintenance alerts from intelligent sensors.
- Support advanced diagnostic capabilities for sensors and logic solvers for both self-test and detection of abnormal situations in the surrounding process.

2- Easier Regulatory Compliance: The ideal SIS is designed in accordance with IEC 61508 and is certified by a recognized certification agency.

3- Increased Availability: An ideal SIS increases the availability of an operating process. It:

- Increases system availability through redundancy as required.
- Reduces operator response time with advanced alarm management.
- Manages bypasses during start up sequences.

4- Reduced Project Capital: With pressure on power plants to increase their return on capital, the ideal SIS reduces the engineering and installation effort by providing:

- Simplified safety logic development and testing with powerful certified algorithms.
- A flexible architecture for centralized or decentralized deployment.
- Ability to fully test safety logic before deployment.
- Integrated Basic Process Control System (BPCS) and SIS data without mapping or handshaking logic while keeping these functions separate per IEC 61511.
- Common engineering tools for the BPCS and SIS.

5- Reduced Operations and Maintenance Costs: Like capital budgets, operating and maintenance budgets are under constant pressure. The ideal SIS reduces operations and maintenance costs by:

- Providing a common engineering and operator interface for both BPCS and SIS
- Synchronizing time and collecting events between BPCS and SIS
- Performing continuous diagnostics of sensors and logic solvers

It’s important to consider ongoing support when multiple suppliers are involved. When one supplier has the full range of products and services for the BPCS and SIS, there is only one place to go for the answers and support needed.

Conclusion:

As shown in this chapter, the design for process safety is a vital step that must be not only taken in consideration but also be included in the engineering phase of any process or equipment. Because the design of the equipment defines its property to cause damage resulting at the end in an accident which is in most of the times a catastrophic one. Dimensions, shape and thickness are all important factors which define the fragility or the strength of the equipment and also the severity of the accident if occurs such as the diameter of an explosion.

Our research showed that in case of failure of the safety design, SIS can be used as a second preventive guard to provide a high level of functional safety. We summarised the components of a SIS and its basic principles of functioning, also the main characteristics to build an ideal SIS taking into account the design, maintenance time and, the most important thing for a company which wants to invest, money.

CHAPTER III

PROCESS FIRE SAFETY

Chapter 3: Process fire safety

Introduction:

Fire and rescue units are an important subject for the protection of the critical infrastructure. A primary goal of rescue units is to extinguish fire and to act in case of any emergency in order to protect life and property. While this basic goal may seem straightforward to a civilian, the tactics used by the rescue department to accomplish this goal may vary considerably. Achieving fire safety in any company or building requires a combination of suitable materials such as extinguishers, first aids and good establishment of emergency procedures. We will also explain the necessity of fire drills to be conducted regularly in order to check the effectiveness of the fire safety equipments and procedures. Finally we will show the different techniques used to avoid toxic releases and how to deal with such accidents.

1. Fire extinguishing main principle:

If one or more of the fire triangle elements of the fire is removed, the fire will be extinguished. This can be done by:

1.1 Cooling the fire: To eliminate the heat, regularly by utilizing water to diminish the temperature to underneath fire point.

1.2 Starving the fire of fuel: Restricting the fuel supply by separating the progression of combustible fluids, limiting waste by good housekeeping and limiting amounts of powers put away on location and so forth.

1.3 Smothering the fire: By limiting its oxygen supply.

1.4 Interfering with the chemical reaction: By intruding on the chain of combustion with for instance Halon extinguishers.

2. Principles of fire prevention (CHESS):

- **C**ontrol of ignition sources.
- **H**ousekeeping.
- **E**limination/minimisation of fuels.
- **S**torage in a good and organised way.
- **S**afe systems of work.

3. Design features to prevent electrically generated sparks:

3.1 Flameproof equipment:

This is completely enclosed equipment intended to withstand any explosion inside the equipment/apparatus, so keeping any interior gas from dropping out of the equipment/apparatus and igniting the encompassing flammable environment.

3.2 Intrinsically safe equipment:

Equipment where the electrical energy is decreased to a level so low as being unequipped for giving sufficient energy to turn into a ignition (heat) source.

Measures available to minimise the risk of fire from electrical equipments could be

- Correct choice of equipment to guarantee it is appropriate for the climate;
- Pre-utilize visual investigation by the client;
- Establishing the right fuse rating;
- Ensuring circuits and sockets are not over-burden;
- Disconnecting or detaching equipment when not being used;
- Checking all vents are clear and unobstructed;
- Uncoiling extension links;
- Protection of cables from mechanical damage by careful routing or using armoured cable.
- Regular inspection, testing and maintenance.

4. Structural measures designed to prevent smoke and fire spread:

There are so many structural measures that could be used including the following:

- Compartmentation by use of fire resisting materials such as concrete, brick etc;
- Fire doors;
- Fire Stopping;
- Smoke Vents;
- Fire dampers;
- Sprinkler systems.

4.1 Compartmentation:

Any place conceivable enormous spaces in buildings should be divided up into smaller separate compartments by fire resistant walls which ought to be conveyed up to the ceiling or rooftop.

Public structure laws and codes of training will require building originators to compartmentalize all structures. A compartment is a piece of a building that is separated from all different parts by walls and floors, and is intended to contain a fire for a predefined time. This fire compartmentation will be evaluated to oppose the spread of fire and smoke for a specific period (regularly 30 minutes). All components of the compartment will be rated to a similar standard.

Compartmentation concerns partitioning a structure into separate fire compartments to:

- Restrict fire development and the spread of fire.
- Enclose explicit fire hazards.
- Provide safe shelters and means of escape.
- Assist fire-fighting operations.

4.2 Fire doors:

The term fire door refers to a smoke and fire resisting door. Fire entryways are needed to go about as a barrier n of smoke and fire since they structure part of the fire compartment. Fire entryway respectability is kept up as the entryway leaf is planned not to twist in the casing under the impacts of fire. Auxiliary restriction is given clamping action of intumescent seals.

Each part ought to be shielded from fire in bordering zones by fireproof entryways which have imperviousness to fire of 30 minutes and close naturally in case of a fire. (If they are not wedged open). This will hold back the fire and smoke to enable occupants to leave the building safely.

Fire doors ought to be fitted with effective self-closing devices and named Fire Door Keep Shut '. Self-shutting doors might be held open with automatic door release mechanisms linked to the fire alarm system or enacted by free smoke detectors on either side of the entryway. The delivery component ought to work on power failure, on fire alarm activation or operation of one of the independent smoke detectors.

4.3 Fire stopping:

Roof and floor voids should be away from trash and secured to keep the spread of fire starting with one compartment then onto the next. Where a cavity happens over or under a fireproof wall it ought to separate by a fire-resistant partition. Holes around services , for example pipes, links, and so forth going through a fire resistant wall ought to be 'fire stopped' with a material, for example mortar, filler, and so forth of a similar imperviousness to fire as the divider.

4.4 Smoke Vents:

These are fitted into the top of structures and work when exposed to the hot convection gases. This means that all heat and smoke is currently exhausted to atmosphere.

4.5 Fire dampers:

Ventilation and heating conduits must be fitted with fire dampers where they go through compartment walls and floors.

4.6 Sprinkler systems:

These limit the spread of fire and smoke by working just in the region where the fire is found.

5. Fire refuges:

These are required where the fire risk assessment shows that it is impossible that individuals will have the option to clear securely to an appropriate assembly point. It is a structure (control room on a chemical plant) or some portion of a structure (concrete stairs) that is intended resist smoke and flame for up to 2 hours.

It is a region of a structure intended for occupation by individuals during a fire or other crisis, when evacuation may not be safe or conceivable. Inhabitants will remain there until rescued by fire fighters. Typical examples of where we might find a refuge will include where:

- People who can't get to a safe escape route.
- Anyone helping someone else who is kept from getting away.
- People with a handicap may prevent them escaping.
- Immobile patients are in a hospital.
- The old, debilitated or infirm or immobile.

6. Fire resistance:

Combustible materials, when present in a structure as enormous nonstop territories, for example, for coating dividers and ceiling, promptly touch off and add to spread of fire over their surfaces. This can speak to a danger to life in structures, especially where dividers of emergency exit courses and stairways are fixed with materials of this nature.

Materials are tested by insurance bodies and fire research foundations. The motivation behind the tests is to characterize materials as indicated by the propensity for fire to spread over their surfaces. Similarly as with all state administered test strategies, care must be taken when applying test results to genuine applications.

Levels of fire resistance can be as following:

- 30 minutes;
- One hour;
- Two hours.

6.1 Behaviour of common building materials when in a fire:

6.1.1 Steel: Spreads fire by conduction and requires treatment. It loses 2/3 quality at 6000°C and starts to distort or sag since it expands when hot and changes properties when cooled.

6.1.2 Concrete: Dehydrates, crumbles and collapses. At the point when heated above 3000°C steel fortifying bars start to twist and cause spalling (blistering and breaking away of concrete surface). In the event that steel support is heated, at that point it arrives at a basic temperature 5500°C loses half of strength. It also loses structural integrity on cooling however doesn't typically fall out of nowhere.

6.1.3 Brick and block: Gives fundamental part of non-combustible and heat proof component and can ensure different areas e.g. Load bearing columns, staircases and shafts. Load bearing brick work has good fire resistance.

6.1.4 Timber (Wood): Fire resistance primarily relies upon:

- Thickness and cross sectional region
- Type – hardwoods are superior to softwoods
- Sacrificial lumber
- Treatment.

6.1.5 Building boards and slabs: Fire resistance and surface spread of fire attributes are good characteristics of board materials. On the off chance that exhibition characteristics are low, at that point requires treatment. Lime put together mortar with respect to inner walls whenever upheld by lathing or extended metal has great fire resistance.

6.1.6 Glass: Non-combustible yet for the most part offers little resistance from fire. So standard glass is a frail point in compartment because of breakdown and will permit transmitted heat to go through it. Notwithstanding, there is fireproof coating that can last 1.5 hours. This can be as wired glass or overlaid glass which includes 3 to 5 layers with interlayers of intumescent material which responds at 1200°C to form opaque shield and can also prevent radiated heat.

The important features which can affect the fire resistance of a wall are the following:

- Thickness.
- Applied rendering or plastering.
- Whether load bearing or not.
- Presence of perforations (weaken brick).

7. Fire detection and alarms:

This can be either accomplished by individuals in the zone or via automatic detection. By automatic fire detection systems are the exact opposite thing fitted to a structure. During the development stage substantial dependence is put upon the carefulness of site workers and fire watch methodology. Small domestic style indicators could be used in touchy zones yet these will just give limited warning. Fuel oil and gas tanks might be fitted autonomously with detectors as a result of their inborn danger should a fire start.

There isn't anything to state that a manual alarm system, for example, a bell or shouting can't be utilized as long as everybody comprehends the system. It is basic that the alarm is audible in all pieces of the premises.

Warning might be manual or automatic, for example, gongs, chimes, and so forth appropriate for little single storey structures with generally safe.

Break glass points- audible sign all through the structure with sign on a focal control board. These have the burden in that they depend on individuals to recognize the fire and sound the alarms.

There is no cover out of hours. Programmed system give consistent recognition and alert sounding and can likewise call the fire brigade , demonstrate definitely where the fire is; and trigger extinguishers.

7.1 Alarms:

7.1.1 Manual Emergency warning systems:

- Shouting ‘Fire!’
- Break glass points
- Public Announcement systems
- Whistles
- Bells
- Klaxons/sirens

7.1.2 Automatic fire alarm systems:

An automatic fire alarm system comprises of fire indicators and manual call points situated in zones all through a structure. These are wired to control and demonstrating equipment which shows the origin of the alarm call, and initiates audible alert sounders. A dependable power supply is required, including an emergency supply.

Fire detectors are intended to recognize at least one of the three qualities of a fire: smoke, heat or flame. No single kind of detectors is the most suitable for all applications and the last decision needs to rely upon singular circumstances.

7.2 Detectors:

Detectors might be either fixed temperature, or rate-of-rise detectors which possibly work if the temperature rise is quick. Point detectors ensure a little area around the detectors while line detectors will provide protection to any area relating to the line covered by the detector.

7.2.1 Heat detectors: These operate using a variety of physical principles:

- Melting of solids, e.g. fusible links.
- Expansion of metals, e.g. bimetallic strips.
- Expansion of liquids or gases, e.g. pneumatic or hydraulic detectors.
- Changes in electrical properties of materials.

7.2.2 Smoke detectors: It is important to differentiate between the visible and invisible smoke generated by combustion processes when selecting the detector.

7.2.3 Ionisation detectors: Work on the principle that the small invisible particles produced early in a fire will interfere with the movement of ionised air inside a chamber irradiated by a radio-active source.

7.2.4 Optical detectors: Rely on the obscuration or the scattering of light by smoking particles. They consist of a light source producing a focused beam which is detected by a photocell. When the beam is affected by smoke an alarm is given.

7.2.5 Flame detectors:

- Infra-red detectors respond to infra-red radiation which has the low flicker frequency characteristic of a diffusion flame typical of fires.
- Ultra-violet detectors detect the UV radiation emitted from flames. They are liable to be activated by sources such as lightning and ultra-violet lamps.

The degree or modernity of the fire warning will differ from site to site. For example on a little outside site, or those including little buildings and structures, ‘word of mouth’ could be sufficient. While on bigger outdoors locales, or those including structures a lot with a predetermined number of rooms, to such an extent that a yell of 'fire' probably won't be heard or could be misunderstood, a klaxon, whistle, gong or little independent restrictive alarm unit likely could be required. On locales for complex multi-storey structures, all things considered, a wired-in system of call point sounders will be needed to give a powerful fire warning system that meets the relevant national standard.

8. Emergency Evacuation Plan (Fire Plan):

Every working environment should have an emergency plan. The arrangement should remember the action to be made by staff for the occasion of fire, the evacuation procedure and the arrangements for calling the fire brigade.

For small locales this could appear as a basic fire activity notice posted in positions where staff can understand it and become familiar with it.

High-fire-hazard or bigger locales will require more detailed plans, which assess the discoveries of the danger evaluation, for example, the staff significantly at risk and their location.

For enormous building locales, notices giving clear and compact instruction of the daily practice to be continued in the event of fire ought to be prominently displayed.

The notice should include the method of raising an alarm in the case of fire and the location of an assembly point to which staff escaping from the workplace should report.

8.1 Fire Drills:

Practice Fire Drills should occur to guarantee that the employees know about what to do in case of a fire and for the safety clearing of the premises. They can likewise appear any imperfections in the evacuation strategies so they should be as genuine as could be expected under the circumstances.

Check that the caution can be heard in all pieces of the premises.

- Test the effectiveness of the evacuation procedures both generally and in relation to specific requirements (such as the need to ensure the safety of disabled employees & visitors).
- Familiarise employees (particularly those new to the undertaking) with the alarms, evacuation procedures, escape routes and assembly points so that, in the case of a real fire they would know what actions to take.
- Providing an opportunity for fire wardens and others with specific capacities to practice their assigned jobs.

There may also be a legal requirement to provide instruction to employees on the action to be taken in emergency situations.

Role Calls are to be taken at the assembly points to guarantee that the evacuation is finished.

Provision for disabled may have to be provided and this can be in the form of providing places of safety as refuges to await rescue. Other precautions could involve consultation with fire brigade, perceptible alarms, provision of special escape equipment, appointment of Fire Wardens to help evacuate and details of locations of disabled workers.

Personal Emergency Evacuation Plans (PEEPs) are prescribed for those individuals expecting help to leave the structure. PEEPs explain the method of escape to be used in each area of the building on a case-by-case basis, and when agreed are kept by the relevant parties.

8.2 Benefits arising from regular fire drills:

- Satisfying the legal requirement.
- To give guidance to employees on move to be made in case of such an emergency.
- Checking that the alarm can be heard by everybody inside the work environment.
- Testing the adequacy of the evacuation procedure (particularly for disabled employees and guests).
- Familiarising new employees with the alarms, procedure escape routes and assembly points.
- Providing an open door for fire wardens (and others) to practice their assigned jobs.

8.3 Contents of training programme for employees on fire:

- Means of raising alarm/sound of alarm.
- Contact the emergency services.
- Fire evacuation routes/Fire evacuation signs.
- Who are and the role of fire marshals.
- Assembly points/Places of safety/role call.
- When not to tackle a fire.
- Types of fire extinguishers to be used to maintain escape.
- Prevention of spread of fire/fire doors/close windows.
- Not to use lifts.
- Evacuation in orderly manner/no running.
- Prevention of return/Disabled evacuation procedure.

9. Means of escape:

Means of escape is a constant shielded course from close by the work environment to a position of relative security.

While considering the appropriateness of a means of escape we ought to consider:

- The number of workers who will utilize it.
- Any individuals with unique necessities.
- The imperviousness to fire of the structure.

- The position and number of escape routes (preferably two).
- The presence of substance which are promptly ignitable.

The main requirements of a safe means of escape will be:

- Ideally at least two escape routes in different directions.
- The provision of means for detecting the fire and raising the alarm which should be clearly heard throughout the building.
- Fire resistant walls, floors and ceilings along the route.
- Adequate size relative to numbers of persons.
- An acceptable travel distance to the nearest available exit.
- Clearly marked/direction arrows.
- Emergency lighting is provided where necessary.
- Escape routes free from obstructions and clearly marked.
- Escape routes have suitable fire integrity.
- Escape routes of sufficient width and fire protected and kept clear of obstructions.
- All fire doors to open easily, self-close and open outwards. All fire doors closed to prevent spreading of smoke in the event of a fire.
- Fixed stairs to upper floors.
- FAFFE is located along routes as required.
- Procedures for the evacuation of those with a physical impairment.
- There is a designated, appropriate assembly point.
- Practice the evacuation at regular intervals.
- Provision of adequate, competent fire marshalls regular fire drills Requirements to ensure the safe evacuation of persons from a building in the event of a fire.

9.1 Travel Distances:

Travel distance is estimated by method of the briefest course to a position of safety.

The separation ought to be estimated from all pieces of the premises to the closest spot of sensible safety, which is:

- An ensured stairways enclosure (storey exit).
- A separate fire compartment where there is a last exit to a position of absolute safety.
- The closest accessible final exit.

Each escape route should be autonomous of one another and organized so that individuals can move away from a fire to get away. Escape ways ought to consistently prompt a position of safety. This should be wide enough for the quantity of inhabitants and ought not regularly decrease in width.

Typical Maximum Travel Distances for construction sites:

- Maximum Travel Distance (meters) only 1 exit - 9 Meters
- Maximum Travel Distance (meters) 2 or more exits – 18 Meters

In many cases there will not be an alternative at the beginning of the route. For example, there may be only one exit from a room to a corridor, from which point escape is possible in two directions.

9.2 Stairs:

Stairways should be of sufficient width for the number of people who are likely to use them in an emergency and should not normally be less than 1 metre wide.

9.3 Escape Doors:

Doors on escape routes should open in the direction of travel where:

- More than 50 people have to use the door.
- The door is at or near the foot of a stairway.
- The door serves a high risk fire area.
- The door is on an exit route from a building used for public assembly.

People escaping should be able to open any door on an escape route easily and immediately. Outward opening doors which have to be fastened whilst people are in the building should be fitted with a single form of release mechanism, such as a push bar or pad.

9.4 Emergency Lighting:

All escape routes, including outer ones, must have adequate lighting for individuals to securely evacuate. It should clearly indicate the entire escape route and provide illumination of fire alarm call points and fire-fighting equipment. It can be battery powered or supplied from a central emergency power source. Emergency lighting should be positioned:

- Near each intersection of corridors. (near means within 2 metres horizontally)
- At each exit door.
- Near each change of direction (except on a stairway).

- Near each stairway so each flight receives direct light.
- Near any other change of floor level.
- Outside each final exit.
- Near to each fire alarm call point.
- Near to fire-fighting equipment.
- To illuminate exit and fire safety signs.
- On escalators.
- In toilets and lobbies in excess of 8m2;
- Covered car parks.

Each emergency lighting system should be subject to a regular test and maintenance regime.

9.5 Directional Escape Signs (Safety Condition signs):

Emergency escape routes and final exit doors should be indicated by suitably located signs. Signs should conform to the requirements of country specific standards which often require a pictogram. If the route to be taken is not obvious the signs may incorporate a directional arrow.

On staircases and ramps the arrow should leave no doubt as to whether the route is up or down. Signage can also be supplemented by words such as ‘Fire Exit’.

Where possible signs should be placed above doors and openings to which they relate, not less than 2 metres above floor level.

Assembly Points should be provided and clearly marked and all staff made aware of their correct assembly point and the importance of going to it.

10. First Aid Fire Fighting Equipment (FAFFE):

- Fire Hose Reels
- Fire Extinguishers
- Dry Sand/Powdered Graphite - Class D Fires
- Fire Blankets

10.1 Hose Reels:

Hose reels are usually a coil of 25mm internal diameter flexible hose attached to a metal former permanently connected to the mains water supply. They should be situated close to room exits or close to staircases arrivals and if in cupboards clearly marked. Wherever possible sufficient hose reels should be given so that no part of the structure is far of 6 meters from the nozzle of the hose reel when it is completely expanded

The advantages of hose reels are that fairly cheap to install and maintain, there is constant supply of water and the personnel using the hose reel are not too close to the fire. Where they form part of the building design they should be programmed to be installed and commissioned as soon as possible during the construction phase.

The disadvantages are that they are only suitable for class A fires and also due to the volume of water can cause damage to equipment. The hoses could be poorly located which may cause inadequate coverage of the area required. Also the hose may be passed through fire doors preventing them closing. Another possible hazard is of people tripping over the hose.

10.2 Portable extinguishers:

10.2.1 Extinguishers types:

Water (Colour code – Red): Water extinguishers should just be utilized on class A fires. Water works by cooling the burning material to underneath its ignition temperature consequently, eliminating the heat part of the fire triangle, and the fire goes out. Water is the most well-known type of extinguishing media and can be utilised on most of fires including solid materials.

NOTE: Never use water on electrical or flammable liquid fires. Water is a conductor that can lead to short circuits and the risk of shock. Flammable liquids will float on water and continue to burn or vaporise to form an explosive cloud.

Foam Extinguishers (Colour Code – Cream): Foam extinguishers contain water and a chemical which produces foam. The foam gives a "blanket effect which smothers the fire, in this way isolating the fuel from the air supplying. It additionally has a cooling impact, these extinguishers are best when dealing Class 'B' fires, for example combustible liquids.

Dry Powder Extinguisher (Colour Code – Blue): The powder has a smothering effect and chemically interacts and excludes oxygen. Designed for Class A, B and C fires however may just subdue Class A fire for a brief timeframe. Powders provide extinction faster than foam, yet there is a more serious danger of re-ignition and this should consistently be borne in mind. Whenever utilised inside, a powder extinguisher can cause problems for the operator due to the inhalation powder and obscuration of vision.

Carbon Dioxide (CO2) Extinguishers (Colour Code – Black): Smothers with inert gas blanket and excludes oxygen. This type is in effect a high pressure gas cylinder containing liquefied CO2 and fitted with a nozzle. It is safe to use on electrical fires (it causes little damage to expensive electrical equipment) and on burning liquids. It should be used with great care because asphyxiation can occur in a confined space, also the discharge tube and nozzle should never be held in the hand during operation, as icing occurs which can be very harmful to the skin.

Cooking Oil Fires (Colour Code – Canary Yellow): New style foam extinguishers have been designed to specifically deal with Class F fires. This type of foam extinguisher congeals on top of the oil and excludes the oxygen.

10.2.2 Sitting of fire extinguishers:

The following points should be considered when sitting fire extinguishers:

- On escape route;
- Nearby identified fuels;
- At a suitable height;
- Same position on different floors;
- Readily available: maximum 30 meters;
- Maintenance requirements;
- Training requirements;
- Protected against damage and weather.

10.2.3 Inspection and Maintenance of fire extinguishers:

Arrangements for the inspection and maintenance of fire extinguishers in the workplace include:

- Daily checks (Fire Warden) to ensure extinguisher is in proper place has not been discharged, lost pressure or been damaged.
- Weekly inspection (Fire warden) of safety clips, indicating device, corrosion, external damage.
- Six monthly serviced by a competent person to manufacturer's instructions and the date recorded on the extinguisher.
- Five yearly extended service administration by a competent individual including full discharge.
- Twenty year complete update or substitution

10.3 Metal Fires:

Sand effectively smothers small solid fuel or flammable liquid fires and excludes oxygen, it must be kept dry. Class D Metal Fires are a specialist type of fire and they cannot be extinguished by use of any of the traditional fire extinguishers. Metal fires can be extinguished by smothering them with dry sand. However, the sand must be totally dry or an explosion may happen. Special extinguishers specifically designed for metal fires are produced; the extinguishing agents used may be graphite, talc or salt. These extinguishers fundamentally work by the smothering principle.

10.4 Fire blankets:

A fire blanket is a highly flame-resistant blanket that can be used to extinguish a small fire or to wrap around a person in case of a fire. Fire blankets are made from 2 layers of woven glass fibre fabric and an inner layer of fire retardant film. They work by cutting off the oxygen supply to the fire.

10.5 Training:

The Organisation should, where necessary:

- Take measures for fire-fighting in the premises.
- Nominate skilful people to implement those measures.
- Arrange any fundamental contacts with external emergency services.
- Training of 'fire-fighting teams'' might be desirable in certain circumstances, yet care must be taken not to put workers at risk.
- Provide formal training.

10.6 Hazards to which Fire and Rescue Services can be exposed:

- Exposure to fire, heat smoke, fumes or toxic gasses.
- Falls from height.
- Collapse of structures.
- Being struck by falling objects.
- Contact with electricity.
- Explosion of such things as gas cylinders.
- Exposure to chemicals, radiation or biohazards such as discarded syringes.
- The need to move or handle equipment in restricted spaces.
- Struck by passing traffic.
- Attacked by members of the public or animals.
- Stress from the work itself.

11. First aid:

The right reaction to a harmed individual once an accident has happened is of crucial importance as it can mean the avoidance of additional injury, ill-health or even death. It is a case of welfare provision. The main purposes of a first aid:

- Preserve life and minimising the consequence of any serious injury;
- Treatment of minor injuries that do not require further medical attention.

It is feasible for associations to concur shared arrangements in joint areas, for example, in building constructions, however this must be clearly expressed in the contract documentation, otherwise it is expected that every business is giving their own cover.

To match an employer's first aid provision to their needs they must conduct a first aid risk assessment. The criteria to consider are:

- Distribution and nature of workforce;
- Numbers of employees;
- Nature of work (hazards & associated risks);
- Location(s);
- Shift patterns.

It is an obligation that all the employees within the company shall be informed of the nature and the location of the first aiders, the first aid facilities and equipments.

11.1 First aid kit content:

There is no standard list of items, but we recommend the following list as a minimum typical content for up to 10 employees:

- A leaflet giving general guidance on first aid;
- Four individually wrapped triangular bandages;
- 20 individually wrapped adhesive dressings;
- Six safety pins;
- Six sterile unmedicated wound dressings;
- Two large unmedicated wound dressings;
- Two sterile eye pads;
- One pair of disposable gloves,
- Alcohol;
- Betadine;
- Scissor (Made of titanium);
- Oxygenated water;
- Serum for eyes.

First Aid Boxes should be:

- Empty of any medicines or tablets;
- Checked regularly;
- Restocked after use;
- Near a hand wash basin;
- Properly identified (safety condition sign).

11.2 First aider:

This concerns any employee who has successfully completed first aid training at the Red Crescent organisation or at the civil protection which allows him to intervene in case of any accident in the workplace, their number and distribution should only be decided by the employer after the results of a suitable risk assessment of the working area.

11.3 First aid room:

It should have:

- A Couch or a bed for injured people;
- Easy clean surfaces in order to keep it clean all the time;
- A good access and clear of any obstacles;
- Hand washing facilities.

11.4 Priorities of First Aid:

11.4.1 Prevent: in order to avoid any additional loss of life or injury to the first aider, victim or the public, for example it is not recommended to approach an electrocution victim until the power has been isolated.

11.4.2 Preserve: The life and well-being of the victim by dealing with the airway, Breathing and circulation or any by treating any other injuries in different body parts.

11.4.3 Promote: this concerns to keep the victim comfortable and reassure until emergency help arrives.

12. Toxic releases prevention:

The company must think carefully about the appropriate prevention techniques in order to avoid the occurrence of any accidents related to toxic releases, especially in the event of fire which is considered as a significant cause of toxic releases in different industries, and this may include the following points:

- Safety education which provides people with knowledge and training in skills, informing, motivating and persuading them about the potential effectiveness of preventive measures. It is concerned with raising awareness of toxic releases problems and influencing priorities for action in case of occurrence. Without these activities, prevention strategies such as regulation and legislation will have little impact.
- Risk communication and alerts about chemical risks: An immediate and widespread alert is needed when large population groups and the environment are at risk of accidental exposure, for example as a result of chemical spills, fires, explosions and other such incidents. In such cases, messages should quickly provide clear instructions about what to do. The messages have to be defined quickly, but carefully, so that they are truthful but do not give rise to panic.
- Packaging should be suitable for transport, storage and use and be adequately labelled. Many countries have regulations to ensure that dangerous goods are in good quality packaging that is constructed and closed so as to prevent any leakage that might occur under normal conditions of transport, and require packaging to be tested to ensure that it conforms to specifications.
- Engineering controls are a method for preventing poisoning in an occupational setting. Several measures are available to control, minimize or eliminate exposure. They include automation of a process to eliminate the need for workers to be exposed; replacing highly toxic chemicals with less toxic ones; use of ventilation systems to control the amount of hazardous chemicals in the air. Engineering controls also include routine maintenance of equipment to ensure it is in good condition.
- Personal protective equipment such as respirators, gloves, aprons, boots, and overalls, can provide a measure of protection in situations where engineering controls may not be feasible or fail and especially in case of emergency.
- Pre-employment medical examinations determine a person’s physical ability to do the job, and identify any medical conditions which may be worsened by exposure to particular chemicals, or make the person more susceptible.

After the occurrence of such accident and the situation is controlled, the following information should be collected by the safety team and specialists in the investigation:

- Name and quantity of the hazardous substance(s) released;
- Cause and circumstances of the release;
- Number of victims and their classification (employees, responders, students or the general public);
- Number and types of injuries;
- Medical outcome;
- Any decontamination procedures or evacuation activities.

This collected data will benefit the emergency preparedness activities, such as planning for future responses and training personnel by using case studies.

Conclusion:

At the end of this chapter we can clearly see the importance of fire safety in any company which requires not only a variety of fire fighting equipments including extinguishers, fire hoses, alarms, detectors and others, but also a well trained fire fighting team to be present on site. This includes simple employees who can have simple trainings on how to use materials in order to extinguish fire, or on using first aid kit in case of any injuries, and of course on how to evacuate in case of emergency.

All of this can be united and organised by plans and procedures in order to be well prepared for any unexpected event including fire, explosions or toxic releases on site, and finally the need of practicing the drills by simulations in order not only to test the effectiveness of the fire fighting equipments but also to get used to emergency evacuation and reduce its time as low as is reasonably practicable.

CHAPTER IV

PROCESS SAFETY MANAGEMENT

Chapter 4: Process safety management

Introduction:

Wherever people seek to make a living or achieve specified goals, organisations arise. They cannot function by allowing their members to do whatever they think needs to be done, they have to be organised by creating of a management system in order to control the process and its operations. The formal structure takes place as duties are assigned, procedures adopted. So rules, and regulations are circulated and the production processes are begun. In process safety terms this is expressed in the setting of goals of commitment to safety and the demonstration to individuals that deviations are not acceptable. In this chapter we will see how this can be achieved by establishing different management systems such as permit to works and contractors management in order to avoid any conflicts and misunderstandings which can lead to serious incidents affecting the process, people's life and the company's reputation. A good management system will allow the company to reach the following benefits:

- Provides a systematic way to manage process safety activities in the organisation.
- Process safety becomes an integral part of the organisation's value system (safety culture).
- Reduction of hazards, risks and accidents.
- Reach a high productivity level and job satisfaction.
- Increase the company's reputation affecting directly its incomes in terms of money.

1. Contractor management:

A 'contractor'' is an individual or an association that is paid to offer assistance to a customer without them being straightforwardly employed. The scale of contractor use within the process industries is critical, with numerous organisations using contractors to convey the following types of service:

- Provide additional manpower and labour, such as during high production or busy maintenance periods.
- Provide professional skills, such as during construction and closure activities. This may include contracting a designer until providing welders, electricians and pipe fitters to install plants and equipment. Diving services, transfer ships and catering companies can also often act as contractors for large organizations.

1.1 Contractor selection:

It is important to choose contractors carefully and appoint them according to their capabilities and not for convenience. If the client does not take sufficient care in selecting the appropriate contractor, he may be held responsible for the contractor's actions. The contractor should have the ability to safely deliver the project and should have extensive experience in the process industry to ensure that the contractor understands the potential impact of his work on the site, especially any operating plant or process.

The following criteria can be used to assess the suitability of a contractor:

a. Have experience in the type of work required, as well as experience working in the processing industry (for example, the hazards of the processing industry may be very different from the construction site);
b. Have received training and experience in specific environmental safety requirements, for example, offshore requirements may include specific offshore survival training, etc.;
c. Applicability of the organization's health and safety policy;
d. Applicability and quality of risk assessment; examples can be requested for assessment;
e. Applicability and level of detail provided in the method description;
f. Accident history and statistical data, including emergency and danger reports;
g. Law enforcement history and prosecution;
h. Detailed information on how to monitor health and safety performance on site, including site inspections;
i. Qualifications of workers in the entire organization, including workers' abilities or site cards, and health and safety qualifications of managers and health and safety consultants;
j. Membership of professional bodies or industry associations;
k. Selection and management procedures of subcontractors;
l. Insurance coverage and details;
m. Arrangements for contact with customers;
n. References from previous customers.

1.2 Periodic review of contractor safety performance:

It is important to maintain a close working relationship with the contractor and make the contractor satisfied and satisfied with their safety performance. This will require regular reviews of the contractor's activities, which may include:

- Conduct on-site inspections to check compliance with method descriptions and risk assessments;
- Conduct safety inspections to monitor general standards including housekeeping;
- Attend regular meetings with contractors to discuss any issues and view accident data.

1.3 Contractor induction and obligations to provide information on site risks:

Although information about the hazards on the site may have been provided during the bidding phase, it is crucial that all relevant information must be communicated to the individual workers. This is usually done by using site induction. On-site induction is training and awareness training for all contractors working on-site, including the following information:

- Sign in/out procedures;
- Emergency procedures (fire, first aid, gas release, etc);
- Site rules, such as transport safety, smoking, work at height rules, etc;
- Specific site hazards, e.g. flammable atmospheres, chemicals, asbestos;
- PPE requirements;
- Permit-to-work requirements;
- Accident reporting procedures;
- Near-miss and hazard reporting;
- Company drink and drugs policy, etc.

The client is best able to advise the contractor on the unique hazards and risks that may arise from on-site work. This information should be provided during the bidding phase to ensure that all parties are aware of the hazards of the site and any possible impact on the work. For instance, if the work was to be carried out on a vessel that had previously been in service, the customer not only needs to provide detailed information about the working environment (for example, any flammable atmosphere or any work at height, etc) but also details of previous use of the vessel, and any information about past content (such as safety data sheets).

1.4 Contractor ownership and site supervision/representation:

When contractors are used on site, they may be affected by activities carried out by site staff. Therefore, they should be included in the process risk assessment and safe working system. There should be a clearly identified person in charge who is responsible for the approval and daily management of contractors to ensure that they are well managed and supported. Each contractor should know who their client contacts are, as it will be the person responsible for answering any questions relating to the job.

1.5 Auditing contractor performance:

Contractors in any workplace need to be assessed to ensure that they are capable of doing this work and supervised to ensure that they are working in accordance with agreed health and safety standards. This is even more important in the process industry, because if the control is not correct, the risk is greater.

The preliminary assessment should be carried out according to the method description provided. Inspections may include audits to ensure that the standards comply with legal requirements and follow recognized guidelines, such as those issued by HSE.

During work, the contractor’s work practices should be monitored to ensure that they comply with the conditions stated in the method statement. This includes monitoring the standards described during the bidding phase to ensure actual compliance with the promised measures on site. Although the decision to deviate from the agreed procedure should be regarded as the contractor’s responsibility, it may endanger the contractor’s company and the client’s workers, so maintaining appropriate standards remains a shared responsibility.

After the work is completed, the client and the contractor shall meet to review the work standards and work methods, including accident history and other contractor performance indicators.

1.6 Contractor handover to client:

Finally, once the work is completed, any factories, buildings or equipment installed need to be handed over to the customer. If there is an installation, the level of information that needs to be handed over upon completion may be regulated by law; however, the information that may be required may include:

- Operation and maintenance manuals;
- Pipe work and instrumentation diagrams;
- Updated layout plans, including location of services;
- Design specifications;
- As-built drawings.

The contractor may also need to return any plants and equipment after get off work, by cancelling any work permits opened for the work.

1.7 Housing/siting of contractors:

In 2005, a typical aspect of the explosion and fire at BP's refinery in Texas City was that, despite the tragic, 15 contract workers working in or near the trailer between were killed. The refinery had a total of 180 workers. Also injured, 66 people were seriously injured so that they did not have time to work. Among the serious injuries, only 14 were BP employees. The rest are contractor employees from 13 different companies. Of the 114 workers who received first aid, 35 were BP employees; 79 were contract employees from 14 different contracting companies. It was also determined that none of the contract workers in the area surrounding ISOM were necessary for the start of the department (Baker Group Report).

The Texas City incident proved that "temporary" residences (such as contractor's trailers and cabins) have become permanent residences and have not been used in any form of process hazard analysis of the entire site during the management of the change process or the main work period.

In order to address the potential safety and health hazards of new buildings introduced, such as temporary mobile office trailers used for unit turnover, process operators should evaluate all newly installed structures under the management of the change procedures and include them in the overall process hazards analysis (PHA).

Temporary residences for workers (permanent employees or contractors) should be based on restricted areas in areas where explosions may occur, and all occupied trailers should be located outside vulnerable areas, even if this means moving them out of the facility.

It may be pointed out that after the incident, a large number of Texas workers were moved to permanent buildings away from the refinery.

2. Permit to work (PTW):

"The work permit system is a formal, documented procedure that is part of the safe work system. It is usually used for high-risk work and records measures to reduce risk, such as isolation. It is used to ensure that the correct precautions are taken and to inform everyone who needs to understand the Works" (24).

So the PTW is part of the safety and health management system. PTW is a formal authorization system used in an organization to control selected work activities to ensure safe execution on site. It is a means of hazardous communication between factory occupants; PTW authorized persons and PTW users. A permit-to-work can be used for some frequent activities but commonly for high-risk activities, such as:

- Hot work;
- Work on complex plant that requires isolation (chemical, electrical or mechanical);
- Confined space entry;
- Work on high-voltage electrical systems;

The permit is only part of the safe working system and is used in conjunction with method descriptions, task analysis or risk assessment. The permit issuer requires a detailed understanding of the factory where the work is to be performed, while the worker uses task analysis to communicate the required hazards and control measures to the issuer.

2.1 Key features of permit-to-work:

We can mention the following:

- Scope of work - this specifies what work is to be carried out, the location and the equipment to be worked on;
- Duration of the work - this includes the date and time that the permit is valid to and from;
- Identification of hazards-a detailed description of known hazards identified through risk assessment and site knowledge; any specific risk assessment can be referred to;

- Isolations - any isolations needed (such as electrical, mechanical or chemical lines) are detailed and the location of the isolation recorded; This should follow a formal lock out, tag out (LOTO) process that physically prevents the re-energisation of the system; Any additional controls, such as PPE, are also detailed;
- Links to other permits - if there are other permits related to the activities, these are also referenced here; For example, there may be a confined space permit for parts of the activities;
- Emergency controls - any additional emergency controls are detailed;
- Specific controls - any additional controls, such as gas testing requirements and PPE needed, are recorded here;
- License acceptance and cancellation-In this section, the license is given to the worker by the issuer before the start of work; both parties sign to confirm their understanding of the content and agree to work under the license conditions; after the work is completed, Return and cancel the license; these parts are as follows:
    - Issue: The permit is signed by the issuer to confirm that the isolations are in place and that the responsibility for the area is being handed to the accepter;
    - Receipt: The permit is signed by the person(s) doing the work to confirm that they understand and abide by the conditions;
    - Clearance/return to service: The permit is signed by the worker to state that the work is complete and the area can be returned to service, or that work is not yet complete and needs to be continued. This hands the area back to the operator;
    - Cancellation: The operator signs to confirm that they agree to put the equipment back into use and cancel the isolation.

Sometimes permits are issued in triplicate, one is displayed on the job site, one is provided to workers, and the final master copy is kept in the permit office. It is important that the person issuing the permit has a full knowledge of the area and does not issue another work permit in the area where conflicts may occur. It should also be remembered that a license is only a document-if the license is not properly issued and is not respected as necessary, then it will not provide protection from damage.

2.2 Interfaces with adjacent plant:

The permit issuer must consider the potential impact of the project on neighbouring plants or equipment, or the possibility that other plants may affect the safe operation of the permit, which is important. Similarly, if the equipment has watch and backup equipment, control measures must be taken to ensure that these equipment cannot work at the same time. Usually, this is achieved by ensuring that all permits are issued from a central issuing agency or location and are clearly displayed so that any conflicts can be identified-in simple terms, issuing permits for high-temperature work nearby is dangerous for disassembly And replacement of equipment containing flammable materials.

2.3 Interfaces with contractors:

The process of granting a work permit is designed to protect both the contractor and the worker-both the contractor and the worker should obtain the permit under appropriate circumstances, although the contractor may also need to take other measures, such as participating in a contractor’s briefing or demonstrating ability. The license should always be issued by the organization, not by the contractor itself.

2.4 Types of permit:

There are several different types of work permits in use. Each company will determine which PTW to use as needed to ensure process safety and protect all workers from process hazards.

- **Isolation permit/general permit-to-work**: It contains detailed information on general work activities, such as activities that require locking and isolation of electrical, mechanical or chemical services. It is often referred to simply as a "work permit" and may form the basis of other people's writing.
- **Hot work permit:** These warnings are issued when the work piece may produce sparks or hot surfaces, so there is a risk of fire. Specific control measures may include clearing combustible areas, monitoring fires, controlling flammable vapours, and using screens and fire blankets
- **Cold work:** Some work can generate a risk of ignition without being classically considered ‘hot work’; for want of a better term, this is known as ‘cold work’. For example, drilling, cutting metal, use of metal equipment, etc can generate sparks and

small localised heat sources, but would not fall under the definition of hot work as there is no flame or glowing surface.

- **Electrical:** Work on high voltage (HV) electrical systems are usually controlled by a special work permit, as this can be only issued by authorized personnel with appropriate qualifications. Those who accept the HV license must also be competent, and controls may include specific complex disconnection, isolation and lockout requirements.
- **Confined space:** Work in confined spaces is usually carried out under permit with other requirements are specified, including methods to ensure an inhalable atmosphere, any gas monitoring requirements, emergency and rescue procedures, etc.

2.5 Typical circumstances when a permit is not required:

If the activity is not in the on-site processing plant, does not require isolation or disconnection, and does not fall under the definition of other permit activities (i.e., non-hot work or confined space), it will usually not be carried out under a work permit. Instead, another safe working system will be used.

Generally, as long as the activities of inspectors, surveyors, engineers, and visitors are approved in advance, and their activities do not interfere with plant or equipment and they are not carrying potential ignition sources.

Work performed in designated maintenance (for example, workshops) and building areas usually does not require a permit.

3. Shift handover:

Shift handover is a term used to describe the transfer of information between the off-duty shift and the upcoming new shift. Recent researches have emphasized that communication errors or misunderstandings between shifts are one of the causes of loss of life, property damage, and serious injury, production loss and adverse environmental impact. Currently, there is no single document that defines good practices or recommends how to evaluate or improve current practices, but the purpose is to characterize the type and quality of shift handover activities by applying the following instructions and influence the improvement of current practices:

- Review of organisational policy and procedures;
- Review of selection and development of key staff;
- Identification of critical incidents;
- Gaining ideas for continuous improvement;
- Examining shift handover (and crew change offshore);
- Questioning and observing key post holders.

Transferring from one shift to another requires the delivery of many types of safety-critical information, such as the problems of the previous shift, safety incidents, and any ongoing permit work pending approval. Therefore, it is vital to give proper importance to shifting.

In view of the fact that effective communication during handover is very important, operators should make this activity a top priority. Shift handovers should be included in safety-critical topics that are regularly monitored and audited by management. They should determine its importance in policies and procedures, assign responsibilities and set minimum standards. A description of how to make an effective handover should be provided so that individuals can evaluate and improve their practices. High-risk transfers that require special attention should be marked. During shifts and in all other work activities, the importance of effective communication skills indicates that this attribute should be one of the selection criteria for key positions. In addition, if necessary, existing employees should be provided with opportunities to develop their communication skills.

One reason for miscommunication when the shift is the key information needed to incoming staff have not been analyzed or recorded. Analyzing information needs and providing reliable methods to capture this information, such as structured logs or computer-generated displays, facilitate accurate communication. Take factory maintenance after shifts as an example. This is a high-risk activity, because unless newcomers are given an accurate “picture” of their work progress, they may take measures based on incomplete or incorrect understanding. .

Shift handovers are particularly important, and there are potentially high risks in bridging the huge gap in understanding, including:

- After prolonged absences (for example, changing staff);
- Between experienced and inexperienced employees;
- During the maintenance of the factory, it will be carried out in two shifts;

- When safety-critical systems are unable to operate or have been overtaken, such as when isolating sprinkler systems for maintenance.

In order to maximize efficiency, a face-to-face personal handover should be conducted and relevant information (such as a computer screen) should be provided. All personnel entering and exiting should participate in a two-way dialogue in order to ask questions, explain and clarify. It is important for individuals to understand the company's transfer standards, expectations for transfers, and which transfers are high-risk or potentially problematic.

The personnel performing the shift transfer must have the appropriate level of technical and professional knowledge and must be able to communicate effectively. This may mean that communication training is required to improve the skill level of workers.

3.1 Shift handover requirements:

Shift handover should be:

- Considered a high priority: it may be necessary, for instance, to bring the incoming shift in a bit earlier to ensure that there is time for the discussions;
- Carried out face-to-face between those involved (usually between the shift leaders);
- Carried out using accurate written and verbal communication: the handovers are usually supported by documentation to record the discussions (e.g. handover log);
- Based on analysis of the information needs of the incoming staff: there are some activities that would be essential to communicate to the incoming teams, e.g. if the sprinkler system was not working or if critical spares were due to site;
- Given as much time as necessary to allow for questioning and explanation.

3.2 Typical information shared at shift handover:

As we have seen earlier, it is crucial to provide the appropriate importance to the handover. In some cases, it may be necessary to actually prove a change in the status of the plant or process to ensure a clear understanding of any problems or limitations caused by the work in progress.

During shift handover the main issues communicated at shift handover may include:

- Operational status of the plant;
- Any emergency situations or incidents that have occurred;
- Any safety issues, particularly safety systems that are not operating/are isolated;

- Details of maintenance activities, especially any ongoing works that will continue into the next shift;
- Maintenance activities planned for the incoming shift;
- Permit-to-work details, especially those still open;
- Operational issues for the incoming shift (e.g. production plans);
- Planned receipt of hazardous material deliveries for the incoming shift;
- Any drills or exercises planned;
- Physical demonstration of plant state.

4. Safe start-up and shut-down:

During shutdown and start-up operations, processing plants are most vulnerable. Certain "safe" controls may be inactive or closed to allow deviations from normal operation or to quickly restore the plant to normal operation. It is true that serious industrial accidents may occur. The near collapse of the Three Mile Island nuclear reactor on March 28, 1979 is a good example.

Having a competent and well-trained operator, responding to alarms in a controlled manner is essential for safe and productive operations. Unplanned downtime should be reduced, process safety should be improved, and operator efficiency should be improved and better production of process performance.

4.1 Types of start-up and shut-down:

4.1.1 Planned: This is a normal operation, where start-up or shutdown will be performed in a predetermined sequence so that the equipment reaches operating conditions and shuts down safely.

Planned shut-down is sometimes referred to as a "turnaround closure." It is applicable when the factory is closed for regular maintenance and replacement. This shutdown usually takes several months (usually several months) in advance, because it is related to product supply and plant demand assessment (for example: catalysts that have expired need to be replaced, fouling in critical process areas, pumps, etc.) The service life of equipment parts such as compressors, valves and filters.

The shutdown operation will include a risk assessment of various shutdown activities and include internal personnel and contract workers to ensure that all risks are clearly stated and communicated. This closure will take advantage of the knowledge and experience of the process and the various interactions that may occur in a controlled manner.

4.1.2 Unplanned: This is a place that is shut down unexpectedly, for example due to equipment failure (usually due to negligent maintenance), power failure, operator error or similar accidents. Unplanned shut-down may be partial or complete closures. In any case, this is a dangerous period because there is no "plan" for such incidents, and close attention needs to be paid to the details of the shutdown to ensure plant safety.

4.1.3 Emergency: This is a special type of unplanned shutdown that occurs when a dangerous situation occurs and measures (manual or automatic) are taken to shut down the plant. This is most likely the result of a possible breach of the safe operating range. It may be signalled by local alarms, operator monitoring or external operating conditions (such as inclement weather). When an operator is required to take action, the importance of human factors will be critical, because the operator needs to make decisions and take actions without having to have complete information and experience. The design of emergency hardware and safety critical components should result in a controlled shutdown.

A shutdown inspection must be performed immediately to obtain information about the plant and process conditions, and to understand the cause of the emergency, to inform future operations and guide the start-up after the remedial work is completed.

4.1.4 Staged: This is the time to complete the start-up or shutdown in stages. For example, some parts of a large plant (such as a catalytic cracking unit) may not be able to shut down safely and quickly, and it may take several days to shut down. Generally speaking, the meaning of the start-up phase is to implement the process step by step according to operational and safety requirements (for example, as required). Before filling the container with volatiles, inerting the container with N_2 to ensure that there will be no interaction between air and hydrocarbons, resulting in fire or explosion**.**

4.1.5 Delayed: Delayed closing always refers to a problematic situation, such as a valve leak, but an assessment is required to control the situation until an appropriate full/partial closing can be handled. Therefore, if a leaking valve is found in the first two weeks of the planned closure, it can be assessed and decided to monitor it and take local control measures until it can be resolved as part of the planned closure.

4.2 Pre-start-up safety review:

There are various stages prior to the start-up of a process:

- Ensure that the factory is ready. This may be a highly participatory process in itself, as it requires inspection and testing of all physical and operational elements of the process before charging and starting the plant;
- Generally, this involves the pre-start phase, during which a detailed inspection will be carried out to ensure that the piping works, valves and other structural elements are correctly installed on appropriate standards (design compliance);
- Ensure that the mechanical, electrical and instrument installations are correct;
- Making sure equipment is 'run in' to ensure it operates as expected and to standard;

Pipelines, vessels, reactors, etc have been properly flushed, cleaned and dried as appropriate. The pre-start-up safety review is based on a process hazard analysis (PHA) whose purpose is to identify design and other changes, including changes to maintenance and operating procedures. This should also include checking that the appropriate standards have been complied with, especially for any safety critical elements.

4.3 Plant shut-down important considerations:

- All staff to be trained in the shut-down procedures;
- Residual product contained in pipe work and vessels (both storage and reactors). It may be impossible to know precisely at what point a certain reaction has reached;
- Residual temperature or pressure that needs to be neutralized;
- Inerting and flushing of process components;
- The management of change (MOC) implications (shut-down is a change and organisational elements may be compromised if the MOC does not include these, including such matters as authorisation, consultation and co-ordination, e.g. as between process engineers, operators, maintenance);
- Standard operating procedure (SOP) for isolation and quarantine of plant - small openings being plugged and larger pipe work being blinded, etc;
- Thorough checking and verification that the plant is in a safe state, supported by relevant standard operating procedures (SOPs) including PTWs;

- Where normal safety controls are compromised or turned off, e.g. venting, alarms, water supplies, SOPs and alternative controls must be in place;
- Management of the SIS to ensure adverse signals interactions have been predicted and controlled (normal operation set up does not apply to shut-down; the SIS may need to be overridden, e.g. valve closing when low flow is detected, which in shut-down would affect the emptying of the plant). This includes oversight and focus on control rooms that should be fully staffed when shut-down/start-up takes place;
- Communication through and with all stakeholders. Principally, these will be the operators and supervisors, the design team (who know how the whole process works and be aware of change history) and the maintenance team.

5. Maintenance strategies:

Perform inspection and visual maintenance as much as possible without affecting the safe operation of the equipment, for example: without removing covers and guards. If isolation is required, it should be included in the design phase. By including a lockable electrical isolator and drain valve to achieve "dual prevention and discharge" isolation.

Maintaining equipment on a preventive basis is much more effective, rather than wearing equipment to the point of failure, so effective asset integrity management program are essential for any plant.

Maintenance records will need to be carefully kept, some of which are required locally, but some are required by law, such as pressure systems, Legionella control and statutory records for lifting equipment. Records can be paper or electronic, but they must be traceable.

5.1 Risk-based maintenance and inspection strategies:

There are three main types of maintenance and inspection strategies available:

- **Breakdown maintenance:** This is highly reactive and requires operators to repair or replace factories and equipment that fail during use. This is not a preventive measure. The only sign of an operator's problem is equipment failure.

- **Condition monitoring:** In this maintenance strategy, the operator looks at indicators that may indicate that the equipment is not operating as expected or will not operate as expected, which will identify symptoms of deterioration before the equipment actually fails. For example, the noise level of the motor can be monitored to determine whether the bearings are worn, thermography (thermal imaging cameras) can be used to detect hot spots on equipment, which can indicate areas that may be overheated.
- **Planned preventive maintenance**: This is a true active maintenance system, through which inspections and inspections can be carried out before failures occur to minimize the impact on the factory. A true planned preventive maintenance system includes regular inspections, planned maintenance activities, non-destructive testing, and measures to correct any defects found.

5.2 Risk-based calibration of instrumentation:

Instrument calibration is an indispensable activity in the process industry, and there are many good reasons to calibrate instruments, but the consequences of neglecting to maintain calibration may lead to:

- Failure to meet the quality system;
- Safety risks for employees and customers;
- Poor product quality and loss of reputation;
- Failure to comply with legislation, causing the loss of the licence to operate;
- Unexpected downtime;
- Economic losses.

The measurement accuracy of the instrument drifts with time, and it is usually difficult to eliminate this drift. The drift of modern instruments is usually smaller than that of older instruments, but environmental conditions, extreme temperatures, changing seasons, and humidity can cause the instruments to be stressed, and instruments that are used frequently or in critical processes tend to wear out more quickly.

The most common procedure for users is to check the instrument regularly to see if the instrument has drifted and makes adjustments as needed, but if the operator does not have an appropriate policy to ensure that the instrument is routinely calibrated, and the instrument drifts, it cannot perform the measurement with assured accuracy.

The calibration of the instrument is very important, because the instrument is responsible for ensuring that the factory is operating within its safe operating range and monitoring the process flow, temperature, and pressure. Maintenance procedures must be established to ensure that meter sensors and transmitters are calibrated with appropriate audit records.

For example, hydrocarbon leak detectors (usually gas detectors) must be maintained and calibrated to ensure that any threats to the process and worker safety are detected in a timely manner, and neutralized or mitigated.

Other instruments are used to ensure that workers can enter confined spaces and work safely (oxygen and gas detectors), while voltage detectors can ensure that electricians can work safely on isolated and locked equipment.

Nowadays, risk-based thinking has been applied to the calibration of instruments, essentially calculating the company's legal, human and financial costs if the calibration procedure fails.

6. Management of change (MOC):

Management of Change is a process to evaluate and properly manage any modifications to the design, control, operations or staff of a covered process.

It is a process intended to:

- Assure no unintended hazards are introduced;
- Assure risks are properly evaluated & minimized;
- Keep current.

The 1974 Flixborough disaster in the United Kingdom highlighted the need for effective management of the change process. Without proper consideration of the design requirements, the piping works were modified by the staff to allow maintenance of the leaking container, and they did not have the required capabilities. The result was a pipeline that could not withstand the pressure and ruptured, causing a release and explosion, killing 28 people.

An effective management of change (MOC) process is the cornerstone of process safety. It is a formally documented system designed to identify required modifications. All changes to the process plant and process design should be properly recorded to ensure that process knowledge is retained:

- MOC documents should clearly record all proposed changes and keep them as official records;
- Any process documents, such as process and instrument diagrams, operation manuals, etc. should be updated accordingly;
- The MOC file should be saved with the design specification for future reference.

All employees should be trained on MOC requirements, necessary MOC conditions and the process of obtaining MOC approval. Personnel in the approval process should receive additional training to ensure their ability.

6.1 Requirement for hazard and risk analysis:

The MOC process requires hazard identification and risk assessment to ensure that all changes are fully understood before any changes are implemented to ensure that no new hazards are introduced and existing risks are not unintentionally increased. It should include permanent and temporary modified procedures, and will include hardware and software changes. In order to capture all proposed changes, the process must be implemented steadily and usually by ensuring that senior managers advocate for the process within the organization, and ensuring that the process is seen as a driver rather than an obstacle to engineering changes and removal of any negative attitudes.

The MOC process should review the proposed modification to the existing operating parameters and design criteria. As well as the installation of new plant and equipment, the MOC process should be used to evaluate and record any planned changes to safety critical devices, replacement of equipment with non-identical alternatives, changes to alarms or other operating parameters, especially those that are outside the ‘safe operating envelope’. In some circumstances, changes to key workers (e.g. changing staffing levels) should be considered as requiring MOC.

This means that the following documentation may be required to support the MOC application:

- Original process design criteria;
- Existing process drawings;
- Detail of proposed changes, including mechanical and electrical equipment specifications;
- Details of trip and alarms planned;
- Risk assessments or HAZOP (Hazard operability).

6.2 Management of change requirements:

The MOC application must be:

- Clearly defined and communicated to those in the approval process;
- Submitted in advance of the change by the person proposing the modification to all relevant stakeholders (e.g. engineering, health and safety, production department, research and development, operational staff, maintenance workers, etc);
- Tracked and managed as different stakeholders review and approve or make comments;
- Given final approval by a suitably responsible person(s). Formal approval should be granted by senior management for the most significant changes (such as removal of safety critical devices).

6.3 Consultation:

When consulting and informing those affected by the changes, the following needs to be considered:

- Effective change management should be the result of collective decision-making and effective consultation rather than the decision of one individual;
- Those affected should be consulted through the process and any changes should be communicated to those affected, including operational staff and maintenance workers.

Conclusion:

In a process Industry, the previous elements of Process Safety Management system mentioned in this chapter are important to be implemented in order to achieve process control through hazard identification, risk analysis and assessment, risk mitigation, hazard management control and emergency action plan.

This chapter has highlighted the most important management system elements which are linked and related to each other in order to construct a strong and a reliable management system. We also clarified the importance and the application guidelines for each of them so it becomes easy for employers to have a good organisational system within their company. The application of process safety management identifies process hazards to be understood and controlled so that process related injuries and incidents can be prevented.

Finally we can have as a conclusion that process safety management is a vital key for any company in order to prevent process hazards especially those which can be caused by organisational problems such us conflicts, misunderstandings or bad handover.

General conclusion:

The process sector has made significant progress in terms of process safety. Companies in the sector have become able to understand how process incidents manifest, and shifted to the proactive management of process hazards in order to prevent the occurrence of these incidents. This development in controlling process hazards has been the result of enhancements in the process design and advancements in science and engineering fields.

In this work, the most common issues related to the process safety were reviewed. The safety department within the company must ensure the coordination of the prevention of major risks through rigorous monitoring of regulations, process safety in collaboration with operators, staff awareness and training in safety and the organisation of the intervention in the event of major accidents.

The recommendations made in this thesis are intended to improve process safety within companies and ensure that all workers arrive home to their friends and family safe each day. The aim is to integrate occupational health and process safety improvements while supporting innovation and fostering productivity in the sector. We propose in this general conclusion to summarize the main recommendations presented in this thesis:

- Employers must develop a written action plan to achieve the employee participation required by the process safety management (PSM). Employers must negotiate with employees and their representatives on the conduct and development of process hazard analysis.
- The employer must establish and implement written procedures to maintain the ongoing integrity of process equipment Employees involved in maintaining the ongoing integrity of process equipment must be trained in an overview of that process and its hazards and trained in the procedures applicable to the employees’ job tasks.
- Employers must develop and implement written operating procedures consistent with process safety information to provide clear guidance to safely perform activities involved in each covered process.
- The training must emphasise the specific safety and health hazards of the process, emergency operations including shutdowns, and other safe work practices applicable to employees' tasks. The employer can prove in writing that the employee has the required knowledge and skills.

- The contract employer must ensure that contract employees are trained in the work practices necessary to perform their job safely and that they are instructed in the known potential fire, explosion, or toxic release hazards related to.
- It's essential that employers conduct pre-start safety reviews for new and changed facilities. Before introducing highly hazardous chemicals into the process, the pre-start safety inspection must confirm the Safety, operating, maintenance, and emergency procedures are in place and are adequate also the Training of each employee involved in operating a process has been completed.
- Written procedures to manage changes to process chemicals, technology, equipment, and procedures, and change to facilities that affect a covered process, must be established and implemented considerations are addressed prior to any change such as the technical basis for the proposed change, Impact of the change on employee safety and health.
- Even with the best plan, if an accident occurs, emergency pre-planning and training must enable employees to know and be able to take appropriate measures. Therefore, an emergency action plan for the entire plant must be developed and implemented.
- Finally, top management of companies in the sector are compelled to take further steps to integrate process safety management into decision making by considering the input from process risk analysis along with the financial and operational input when making decisions, and boost their commitment toward proper and robust PSM.

Beyond the implementation of these recommendations is the need to open communication about emerging health and safety issues and potential solutions. The identified recommendations and control measures must be taken into account by vulnerability studies which identify these hazards, assess them and give rise to action plans that will be monitored and managed over time and they must be periodically re-examined in order to identify the possible non-conformities and eliminate them as much as possible. This is not the endpoint of our research to improve process safety; in fact there is a lot to do. Health and safety is not a static issue, it's constantly changing as workplaces and technologies evolve and only in partnership can we continue to improve process safety outcomes.

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